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Kañch

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Quarterly Journal of **The All India Glass Manufacturers' Federation**

Bi-lingual

Special Feature

AIGMF since 1944

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Kanch

Quarterly Journal of **THE ALL INDIA GLASS MANUFACTURERS' FEDERATION**

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Contents

From President's Desk

From the book 'Welcome to the Glass Age', the Jan-March issue of Kanch carried articles on: Creating a United Nations International Year of Glass; Glass History and the Arrival of the Glass Age; and Glasses for Healthcare.

The current issue carries articles on Affordable and Clean Energy provided by Glass; Glass in Information and Communication Technologies (ICT) and Photonics; and Reflections on Reflection: Glass in Architecture.

July-September issue will carry articles on Sustainable Glass Production with Carbon Reduction; Sustainable Glass in a Circular Economy; and Social, Cultural and Environmental Sustainability within the International Art Glass Movement.

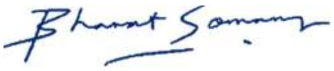
Finally, the Oct-Dec issue will carry articles on Museums and Society; Glass beyond Glass; Education! Education! Education! ; and Gender Equality and Diversity in the Glass World.

In addition to these specialized chapters, special events in different cities are planned by the AIGMF to celebrate the International Year of Glass in India along with coverage of news on IYoG from the activities world over.

Centered around IYoG, we are happy to announce our annual contest for Youth: 1st Poem / Essay writing Contest on 'Green as Glass' or काँच और पर्यावरण. Online entries are invited from the age group between 7-24 from educational institutes and youth across India at info@aigmf.com with winners to be announced on the International Youth Day on Aug 12. Apart from 1st, 2nd and 3rd cash prizes, top 250 entries will get a specially designed 2022 Calendar Glass Bottle made out of the recycled glass.

We also invite ideas from stakeholders on the additional activities that could be planned during the year.

The last Executive Committee meeting was held virtually on April 30. With the fading of the Pandemic, we are planning to re-start physical meetings with AGM/Ex Com on Sept 3 at Delhi. And later Dec 10, the Executive Committee Meeting at Guwahati and related IYoG events. All Members are invited to participate ■



(Bharat Somany)
President AIGMF
and Vice - President, HNG & Inds. Ltd.

5th AIGMF Glass Awards

Supported by:

In recognition of the tremendous contribution to Indian Glass Industry, The All India Glass Manufacturers' Federation (AIGMF) announces C K Somany Award for Innovation & Technology and Balkrishna Gupta Award for Exports.

C K Somany Award for Innovation and Technology will be given to an individual who has made significant contributions to the glass industry in the field or fields of manufacturing, product development, environmental factors, business performance/growth, research and development and/or science/technology.

Balkrishna Gupta Award for Exports will be given to an individual/firm by considering following factors: who have contributed towards identification or growth of new potential markets/volume of exports/reaching no. of countries or any other area showcasing valuable contribution in Glass Exports.

Winners

Year	CK Somany Award for Innovation and Technology	Balkrishna Gupta Award for Exports
2021	Mr. Udit Kapoor, Kapoor Glass India Pvt. Ltd.	M/s Borosil Renewables Ltd.
2020	Dr. Mukul Chandra Paul, CSIR-CGCRI	M/s La Opala RG Ltd.
2019	Mr. B L Kheruka, Gujarat Borosil Ltd. *(Now, Borosil Ltd.)*	M/s Firozabad Glass Shell Industries
2018	Mr. S K Jhunjhunwala, La Opala RG Ltd.	M/s Piramal Glass Pvt. Ltd. *(Now, PGP Glass Pvt. Ltd.)*

Referral applications can also be submitted by Regional Associations: U.P. Glass Manufacturers' Syndicate (UPGMS)- Firozabad; South India Glass Manufacturers' Association (SIGMA)- Hyderabad; Western India Glass Manufacturers' Association (WIGMA)-Mumbai; Northern India Glass Manufacturers' Association (NIGMA)-Bahadurgarh, Haryana and Eastern India Glass Manufacturers' Association (EIGMA)- Kolkata, who may give recommendation for giving an award to a likely individual.

AIGMF may consult Banaras Hindu University (BHU-Ceramic Glass Division), CGCRI (Central Glass and Ceramic Research Institute), CCPS (Confederation of Construction Products and Services) and FOSG (Federation of Safety Glass), for identifying suitable candidates for the award.

5th Awards in these categories would be given during the Annual General Meeting in Aug/Sept 2022.

The jury for the awards comprise of:

- Dr. K. Annapurna, Chief Scientist, Glass Division, CSIR-Central Glass & Ceramic Research Institute (CSIR-CGCRI)
- Mr. Dave Fordham, Publisher, Glass Worldwide, London (UK)
- Mr. Sanjay Somany, Former President AIGMF and CMD HNG Industries Ltd.
- Mr. P K Kheruka, Former President AIGMF and Chairman Borosil Ltd.
- Mr. Vinit Kapur, Secretary AIGMF

Applications are invited at info@aigmf.com from within India from all those connected with the glass industry who may submit a brief write-up/CV in support of their candidature latest by July 25, 2022.

Note: *The Glass Worldwide, Kanch and Glass News have the exclusive rights of announcing the winners; including winning interviews in print and on websites i.e. www.glassworldwide.co.uk / www.aigmf.com that could be followed by other magazines and websites*■

GLASS News

GERRESHEIMER BOOSTS GLOBAL PRODUCTION CAPABILITIES WITH NEW STATE OF THE ART FACILITIES IN INDIA

Gerresheimer has significantly ramped up its glass production capacities in India. Its glass production received a new state-of-the-art and sustainable furnace technology.

By adding capacities in India, Gerresheimer intends to ensure consistent supply for critical pharma and healthcare facilities supporting increased packaging demand and public health. Gerresheimer already operates production facilities, including Triveni and Neutral Glass, which the company acquired in 2012.

The four highly specialized Indian plants belong to the Gerresheimer Group's worldwide production network. The plants are equipped with high technology manufacturing process for production of pharmaceutical primary packaging made of moulded and tubular glass.

Gerresheimer has installed the latest Type I Borosilicate melting furnace for flint and amber glass production using cross-fired oxygen technology and an increased portion of electric heating to melt the new Barium free type I glass formulation. This new state of the art furnace is equipped with newest production machines also having most sensitive inspection equipment following the Gerresheimer moulded glass production standards. *"With this technology, we will substantially enhance our product quality and address additional market segments"*, said Mr. Stefan Rieder, Global Senior Vice President Commercial Moulded Glass.

Gerresheimer ensures full conformity of its products and follows the European pharmacopoeia, the United States pharmacopeia and meets YBB requirements for China and FDA registration with a Drug Master File as the standard. The production operations are carried out in sanitized rooms. Gerresheimer applies the rules of Good Manufacturing Practice (GMP) and is classified in accordance with ISO standards.

Gerresheimer is a leading global partner to the pharma and healthcare industry. With specialty products made of glass, the company contributes to health and well-being. Gerresheimer is represented worldwide and produces with around 10,000 employees wherever its customers and markets are. With plants in Europe, North and South America and Asia, Gerresheimer generates sales of around €1.4 billion. Its wide range of products includes pharmaceutical packaging and products for the simple and safe administration of medicines: Insulin pens, inhalers, micropumps, prefillable syringes, injection vials, ampoules, bottles and containers for liquid and solid medications with closure and safety systems as well as packaging for the cosmetics industry.

EIUG WELCOMES DAVE DALTON AS CHAIR OF THE UMBRELLA ORGANISATION

With over 40 years of experience in the glass industry, Mr. Dave Dalton has taken over from Mr. Richard Leese of the Mineral Products Association and will be supported by British Glass Federation Manager Ms. Jenni Richards as co-chair during the two-year term.

The change in chair comes at a challenging time for energy intensive industries with unprecedented energy costs and a crucial six months that will determine whether some energy intensive companies can continue to manufacture in the UK or export production abroad. Many energy intensive sectors and subsectors have already relocated, but those products are still imported into the UK for use.

Mr. Dalton comments: *"Energy intensive industries like the glass sector need competitively priced, reliable and sustainable energy supplies in order to keep processes running. At present, this is simply not the case and the cost to our industries could be very high. Government needs to act quickly and decisively, and we are here as a group to hold them to account."*

"Over the next two years as EIUG Chair, I hope we can work with Government to ensure a long-term energy strategy that will enable and incentivise energy intensive sectors to decarbonise and remain internationally competitive so that we can continue to manufacture in the UK, contributing to UK GDP and supporting jobs and communities across the industrial heartlands."

The Energy Intensive Users Group (EIUG) is an umbrella organisation that represents the interests of energy intensive industrial (EII) consumers. Its objective is to achieve fair and competitive energy prices for British industry.

The EIUG represents EIIs including manufacturers of steel, chemicals, fertilizers, paper, **glass**, cement, lime, ceramics, and industrial gases. EIUG members produce materials which are essential inputs to UK manufacturing supply chains, including materials that support climate solutions in the energy, transport, construction, agriculture, and household sectors. They add an annual contribution of £29bn GVA to the UK economy and support 210,000 jobs directly and 800,000 jobs indirectly around the country.

These foundation industries are both energy and trade intensive remaining located & continuing to invest in the UK and competing globally requires secure, internationally competitive energy supplies and freedom to export without tariff barriers. However, inward investment, growth and competitiveness have been hampered for years by UK energy costs higher than those of international competitors. In some cases, investment, economic activity & jobs have relocated abroad, leading to a subsequent increase in imports.

EIUG Contact: Director - Energy Intensive Users' Group director@eiug.org.uk

GLASS SAFEST PACKAGING FOR FOOD NEW RESEARCH SAYS

International research, published in the journal Critical Reviews in Food Science and Nutrition found that nearly 3000 chemicals can potentially leak from packaging into food, making human exposure to these chemicals highly probable. Most of these chemicals (65%) were unknown in that they have not been recorded in any regulatory or industry list to date. Of the almost 3000 chemicals detected that can potentially leak into food, more than two thirds were identified in plastics.

By contrast, glass & ceramic are by far the safest food contact materials, which is in line with the low chemical complexity of these materials.

"The study shows that glass is safest among the packaging materials as it has virtually no detected chemicals and therefore is the safest for human health," says Ms. Adeline Farrelly, Secretary General of FEVE the EU federation of container glass producers.

The study states that 2881 Food Contact Chemicals (FCCs) have been detected, in a total of six Food Contact Material (FCMs) groups. More than two thirds of the FCCs (1975) were identified in Plastic FCMs, followed by paper & board (887), Other FCMs (760), and multi-materials (614). The fewest FCCs were detected in metal (251) and glass & ceramic (47).

"This research shows the potential risks linked to migration of chemical substances into the food chain and by consequence into the environment", says Ms. Adeline Farrelly. *"There is a considerable knowledge gap to fill on food contact legislation. But also, Life Cycle Assessment methodologies on packaging must and should take into*

AIGMF delegation met Additional DGFT Mr. Anil Agarwal to discuss RoDTEP scheme and presented International Year of Glass calendar bottle at Udyog Bhawan, New Delhi on June 3.

account chemicals including hazardous chemicals used in food contact packaging materials that can potentially also leak into the environment".

FEVE is the Federation of European manufacturers of glass containers. Its members produce over 20 million tonnes of glass per year. The association has some 60 corporate members belonging to approximately 20 independent groups. Manufacturing plants are located across 23 European States and include global blue chip and major companies working for the world's biggest consumer brands. The Container Glass sector in Europe, makes a significant contribution to the EU Economy and supports essential sectors. More than 125,000 people work in the glass packaging value chain across Europe. It guarantees resilient local supply chains, with a proximity of service to its suppliers and clients. Every year €610 million is invested in upgrading plants for better energy efficiency and reduced CO_2 emissions (a significant 10% of the operational and maintenance costs). The sector exports around €1.2 billion (empty bottles and jars) and if we take account of items almost always or often packed in glass, glass is an enabler of extra EU exports of around €250 billion (data 2019).

For more information, contact: Mr. Michael Delle Selve - E-MAIL m.delleselve@feve.org

GLASSTEC ONLINE PRESENTATION

An exclusive Digital Sneak Peak presentation for the upcoming glasstec 2022 was organised by Messe Dusseldorf and MDI on June 2 for the Indian audience.

The presentation provided the exclusive insights on what one can expect at glasstec, with its diverse supporting programme etc., for the main show slated to be held from Sept 20-23, 2022 at Dusseldorf in Germany.

The interactive session provided the opportunity for participants to know about arrangements made especially after the Covid, Schengen visa, general queries, etc.

For more information, please email to messeduesseldorf@md-india.com

SAINT-GOBAIN PRODUCES ZERO-CARBON FLAT GLASS

Saint-Gobain mobilised a network of partners with the reuse of 100% cullet from end-of-life glass sourced from renovation or demolition sites and from production offcuts. The group's industrial and research teams succeeded in adjusting all of the furnace's technical parameters to this dual challenge of operating with 100% recycled material and 100% biogas, while ensuring the right optical quality of the glass.

Saint-Gobain said that the achievement is a clear demonstration of its commitment to reach carbon neutrality by 2050. It complements the group's investment announced last year to build the world's first carbon-neutral plasterboard plant in Norway.

This feat was achieved by using 100% recycled glass (cullet) and 100% green energy, produced from biogas and decarbonised electricity. It was implemented for one week in Saint-Gobain's flat glass manufacturing plant in Aniche, Northern France.

COCA-COLA WIDENS ITS REACH, CUTS COSTS WITH GLASS BOTTLES

Beverage maker Coca-Cola India Pvt. Ltd is promoting returnable glass bottles once again, after years of focusing on disposable plastic bottles. The change helps the company reach out to more users, and reduce packaging costs, a top company executive said.

"In 2021, we could predict that inflation is going to be one of the major challenges in the coming year and glass bottle is the least impacted packaging in inflation. It also gives us an affordability play in large parts of India," said Mr. Sanket Ray, President for India and South-West Asia, Coca-Cola.

The bottles rolled out last year at a ₹10 price point (200 ml) in select states are available across the company's top-selling brands such as Coca-Cola, Thums Up, and Sprite. In some markets, glass bottles now make up 30% of beverage sales. Overall, they account for a little less than 10% of the company's business.

Coca-Cola's move comes at a time when inflation is eating into household budgets, raising the prices of everything from soaps to fuel. As a result, shoppers are reaching out for more affordable packs or moving to cheaper brands.

The maker of Sprite and Coca-Cola carbonated beverages said it has lowered price points of such glass bottles from ₹12-14 to ₹10 in seven states in India to drive its affordability agenda.

"We have started expanding the distribution, inputting more glass, and also putting marketing behind it," Mr. Ray said. The company is seeing "really strong momentum" in sales of such bottles, largely led by demand emerging from small towns and rural areas.

"Our expectation was that inflation will be between 3% and 5%—this has increased to some extent now. Inflation is going to be part of strategy; if we want to expand in India we have to focus on affordability as a solution. For that, we have to invest in glass bottles," he added.

India isn't the only market where Coca-Cola is trying glass bottles to counter inflation—a recent report by Reuters said Coca-Cola is expanding the distribution of its cheaper returnable glass bottles in several emerging markets.

ये है दुनिया का सबसे लम्बा कांच का पुल, 'White Dragon'

वियतनाम का बाख लांग पैदल यात्री पुल जिसका नाम ''सफेद ड्रैगन'' (White Dragon) है- ये 632 मीटर (2,073

फीट) लम्बा है और एक विशाल जंगल से 150 मीटर (492 फीट) ऊपर है।

पुल का फर्श फ्रेंच- निर्मित टेम्पर्ड ग्लास से बना है, जिससे यह एक बार में 450 लोगों तक का वजन सहने के लिए पर्याप्त मजबूत है। कांच के फर्श का मतलब यह भी है कि पर्यटक डरावनी सैर करते हुए अद्‌भुत दृश्यों का लुत्फ उठा सकते हैं।

पुल के संचालक के एक प्रतिनिधि होआंग मान ड्यू ने कहा 'पुल पर खड़े होने पर, यात्री प्रकृति की सुंदरता की प्रशंसा करने में सक्षम होंगे।

बाख लांग वियतनाम का तीसरा कांच का पुल है, स्थानीय बुई वान थाच ने कहा कि उन्हें उम्मीद है यह अधिक पर्यटकों को इस क्षेत्र में आने के लिए प्रोत्साहित करेगा।

कंपनी का कहना है कि यह दुनिया का सबसे लम्बा कांच के नीचे का पुल है, जो चीन के ग्वांगडोंग में 526 मीटर की संरचना को पार कर गया है। वियतनामी पर्यटन प्रमुख दो साल के कोविड शटडाउन के बाद पर्यटकों को वापस लुभाने की कोशिश कर रहे हैं, जो लगभग सभी विदेशी यात्रियों को बाहर रखते हैं।

(News Source: AIGMF Research Team / World Wide Web)

Membership of the Federation

Members of the Federation are classified into two categories; manufacturers of primary glass articles are enrolled as **Ordinary Members** of the Federation and suppliers to the glass industry viz., suppliers of machinery, raw materials, consultants and others connected with the glass industry are enrolled as **Affiliate Members**.

Foreign Companies supplying machinery etc., to the glass industry are also enrolled as **Affiliate Members**.

Membership forms can be downloaded from www.aigmf.com/membership.php

Members of the Federation are enrolled on the recommendation of Zonal Associations viz.:

- Eastern India Glass Manufacturers' Association (EIGMA)
- Northern India Glass Manufacturers' Association (NIGMA)
- South India Glass Manufacturers' Association (SIGMA)
- Uttar Pradesh Glass Manufacturers' Syndicate (UPGMS)
- Western India Glass Manufacturers' Association (WIGMA)

ADMISSION FEE / ANNUAL SUBSCRIPTION

Ordinary Members:

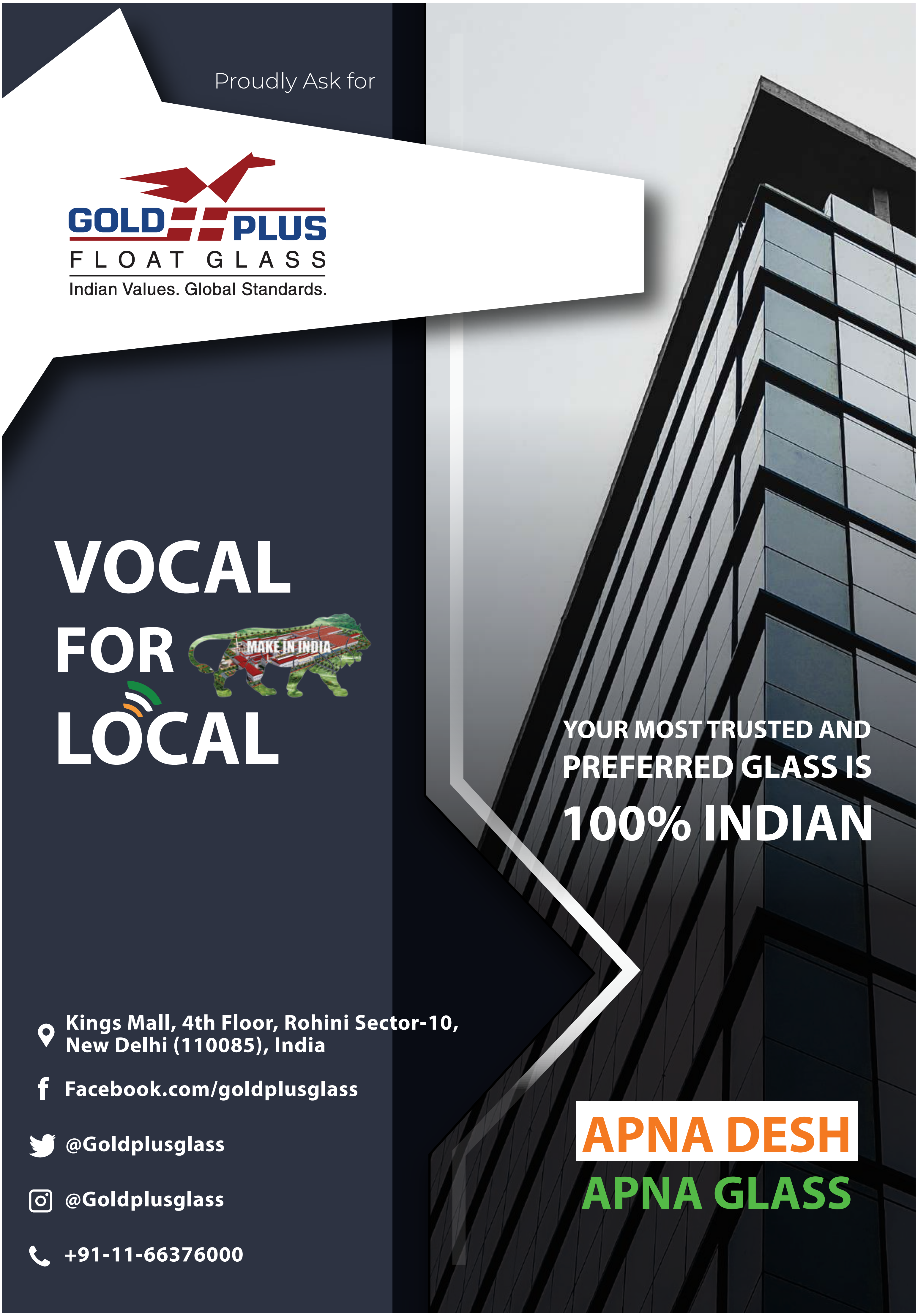
- Admission fee ₹ 5,000/-
- Annual subscription: Single Unit: ₹ 30,000 + GST as applicable
- More than one Unit: ₹ 1,20,000 + GST as applicable
- Applicants for enrollment for a period of five years may pay a consolidated amount of ₹ 1,40,000 for a single Unit and ₹ 5,50,000 for more than one Unit + GST as applicable

Affiliate Members:

- Admission fee ₹ 5,000/-
- Annual subscription: ₹ 12,000 + GST as applicable
- Applicants for enrollment for a period of five years may pay a consolidated amount of ₹ 55,000 (including admission fee) + GST as applicable

Affiliate Members from countries other than India:

- Admission fee US $ 200
- Annual subscription: US $ 500 + GST as applicable
- Applicants for enrollment for a period of five years may pay a consolidated amount of US $ 1,800 (including admission fee) + GST as applicable ■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Gold Plus was the first 100% Indian-owned float glass manufacturer.

On the Spot... Jimmy Tyagi

The first and only 100% Indian-owned float glass manufacturer, Gold Plus is currently in the throes of its largest capacity expansion to date. CEO Jimmy Tyagi exclusively updated *Glass Worldwide,* preferred international journal of the All India Glass Manufacturers' Federation, on the company's plans for construction of a greenfield plant to meet increasing demand for float and solar glass.

GW: Having traded glass since 1985 and processed automotive and architectural glass since 1996, Gold Plus has achieved remarkable growth in the wake of becoming the first wholly Indian-owned company to produce float glass in 2009. What position does the company currently hold in the India flat glass production business?
We are the second largest float glass producer in India in terms of installed capacity. Customer delight has always been our aim and our Chairman, Mr Subhash Tyagi, the visionary who laid the targets for the company, has been very clear about that. To meet our customers' expectations we have grown as a float glass manufacturer. There is enough growth potential in India and we target that growth.

GW: What are the current capabilities of your existing manufacturing facility at Roorkee, Uttarakhand in the north of India?
We have two float lines in Roorkee with a combined installed capacity of 1250tpd along with a mirror line. A new silver mirror line is under installation and will be upstream by March 2022 [at the time of this interview].

Our focus is to make sure that we provide a complete the range of products for our customers. We produce clear float glass, tinted glass, reflective glass, frosted glass and mirrors at Roorkee.

GW: What are the highlights of recent investments in Roorkee?
We commissioned Line 2 at Roorkee in January 2018 and after that Line 1 was rebuilt in 2019 where we increased the capacity from 460tpd to 550tpd and made improvements to the whole line, providing better fuel efficiency, product capability and life of the furnace.

As mentioned earlier, the new silver mirror line will be operational by March 2022.

GW: What was the motivation for the recently announced expansion programme in southern India?
This expansion is planned when considering the growth of float glass industry in India. Our Chairman is committed to making India self-reliant for float glass. He believes this investment will not only help us in serving our customers based in the south and west regions in efficient way but will also reduce dependency on imports.

The expansion will be at Belgaum, Karnataka. We have already started work at the site and will put up three lines consisting of two float lines and one solar glass line. Total installed capacity will be 1,900tpd (800tpd for each float and 300tpd for solar). The three lines will be operational over the next two years.

GW: How has the Covid-19 pandemic impacted the construction plans?
Covid has been really difficult for everyone in the country, but recently the restrictions have started easing. Now, the construction activities are progressing well at site. We make sure that we follow all the Covid protocols. It's important for everyone's safety.

GW: Having previously worked with internationally renowned companies such as Fives, Glaston, Grenzebach, ISRA, Lahti, LiSEC, Schiatti Angelo and others, who will be the main suppliers of technology to support the new investment?
We have signed contracts with CTIEC, Grenzebach and ISRA for this project. All are extremely reputable suppliers and we have had good experience with them in the past. ▸

Our idea is to adopt the best and latest technology available right now that can help us improve efficiencies in all aspects of the production process.

Artist's impression of the new plant that will occupy a 200-acre area in Belgaum, Karnataka.

GW: Why was the location of Belgaum, Karnataka chosen for the new plant?
Since we already have a presence in North India, we wanted our next location to provide us with good strategic coverage that would complement the existing location. Belgaum was chosen after a thorough study of various locations. This is a beautiful location, meets all our basic requirement and is strategically very well placed to cover the south and west market. Once this location is operational, it will help us in serving our customers in an even more efficient way.

GW: Will the new location provide opportunities for exporting produce?
The intent is to cater to the Indian market but being closer to port opens up the possibility of exports in the future.

GW: What products will be manufactured at the new plant?
Our product range will consist of clear glass, a tinted glass range, reflective glass and frosted glass. This will be the first facility in India to manufacture 15mm and 19mm thickness clear float glass. There is a plan to add a mirror line and an offline coater later at this facility.

GW: So customers have reacted positively to the announcement of the plant?
The response has been amazing, especially from our customers from southern and western parts of India. They are eagerly awaiting the plants to be operational. Gold Plus has always had a customer-centric approach and with this expansion we will be able to deliver goods even more efficiently all over India.

GW: How many people are employed by Gold Plus and will it be a challenge to recruit a workforce in Belgaum with the necessary expertise?
Over 1,400 people are part of the Gold Plus family at present. Over the years we have created a good infrastructure that has helped us nurture young talent. This has proven to be a good way to develop an experienced set of people. We are well prepared to recruit another 2,000 people required for the new facility.

GW: How is Gold Plus investing in the specialist flat glass processing facility in Kala Amb, Himachal Pradesh, catering to high value glasses such as toughened, laminated, insulating, ceramic printed, acoustic, bulletproof and automotive?
In the processing facility we are continuously making improvements to keep up with the latest technology. We have plans to upgrade our infrastructure there in 2022.

In recent years Gold Plus has invested significantly at the existing manufacturing facility in Roorkee.

GW: How would you summarise Gold Plus' growth strategy for the years to come?
We want to be a leading player in the flat glass manufacturing segments and will continue to expand in the float and solar segments in the coming years. Our focus will be to make sure we are able to serve the Indian market in best possible ways.

The Indian flat glass market will grow at a good pace and we would like to have a major share.

GW: With Gold Plus being a member of the All India Glass Manufacturers' Federation (AIGMF), how important is the federation's role in the furtherment of the Indian glass industry?
The AIGMF is the single biggest platform to bring together the glass Industry in India. They have been a great ambassador for the Indian glass industry at various levels. Their representation has definitely helped the industry in a lot of ways. All concerns and improvements required for the glass industry in India are always addressed efficiently by the AIGMF.

GW: With the next editions recently rescheduled for 14–16 September 2023, how useful are events such glasspro INDIA and glasspex INDIA?
These exhibitions provide very good platforms to interact with all vertical markets within the glass industry. We are looking forward to participating at such events when they take place again. ●

Further information:
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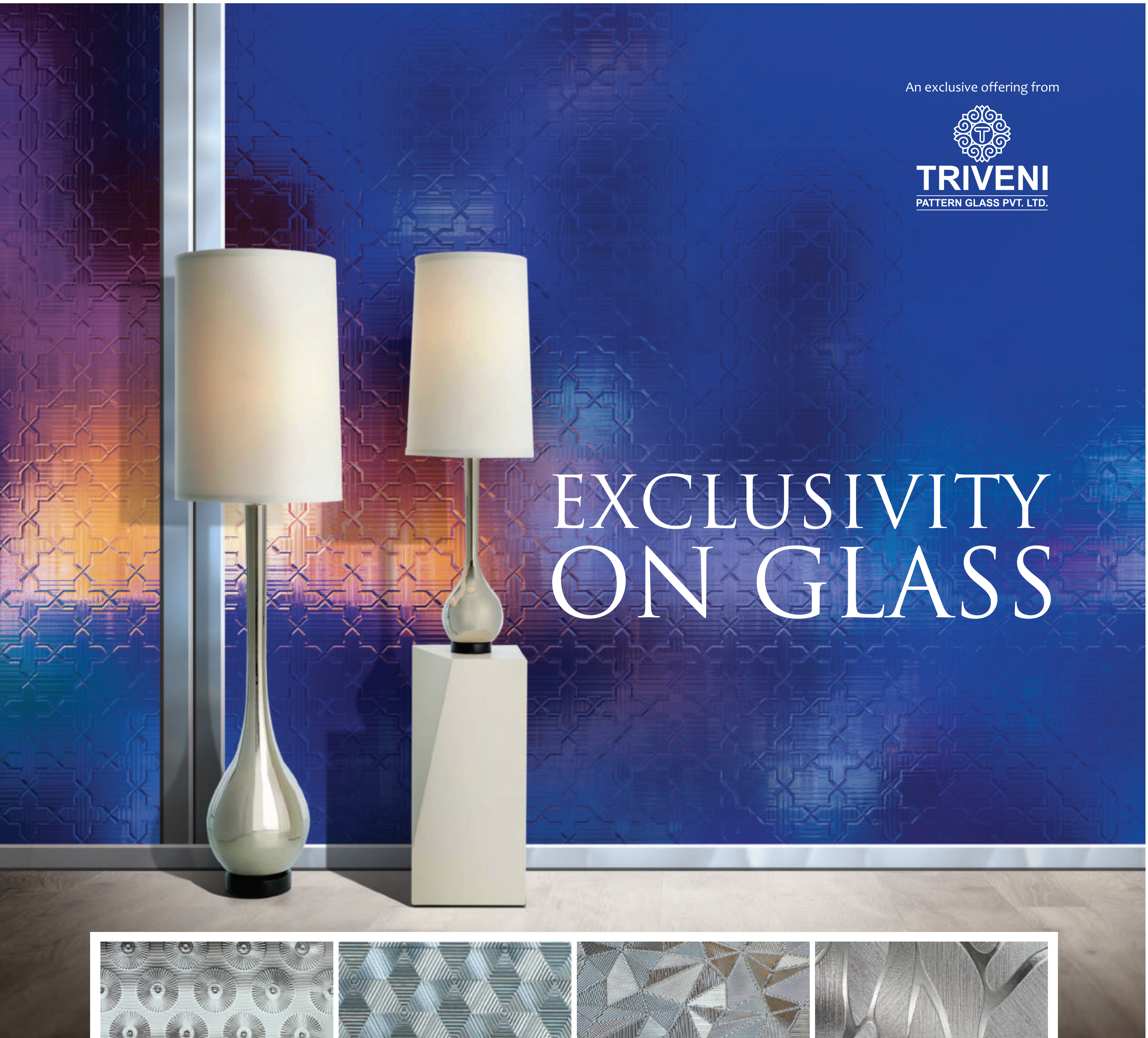
email: info@goldplusgroup.com
web: www.goldplusgroup.com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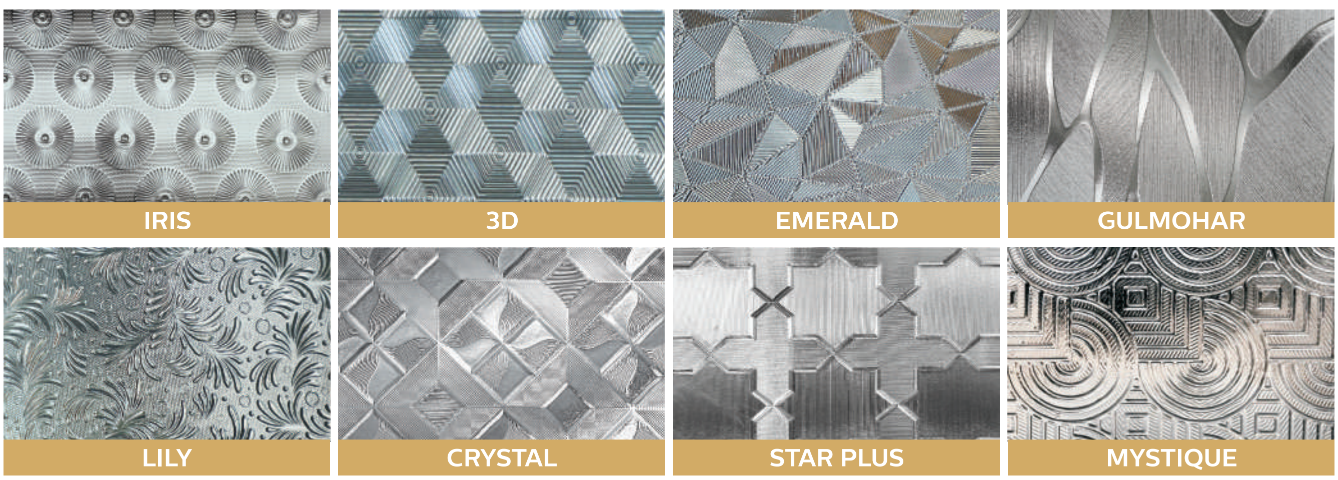
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Decarbonisation in the Float Glass Industry

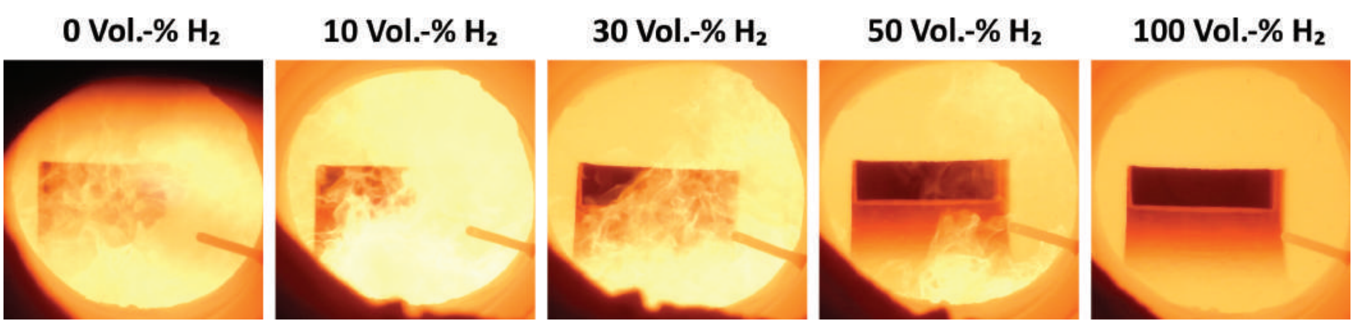
MELTING AND GLASS FURNACE OPERATION USING ALTERNATIVE ENERGY SYSTEMS

It is not just advancing climate change and the need to reach carbon neutrality by 2045 but also our current dependency on fossil fuel imports that make it clear there is no alternative to switching to renewable energies and new technologies. How can the energy-intensive float glass industry so far heavily dependent on natural gas become carbon neutral by 2045? The energy efficiency of glass production is already close to what is physically-technically feasible today. Carbon neutrality can only be achieved by shifting to new key technologies and sustainable raw materials to avoid process-related emissions.

According to current surveys by the Federal Association of the German Glass Industry (Bundesverband Glasindustrie e.V. – BV Glas), up to 7.4 million tons of glass are produced annually in Germany. The final energy consumption required for this stood at 19.1 TWh in 2020, of which 15.1 TWh were generated by means of fossil fuels, especially natural gas, and the remaining 4 TWh by electricity. Every year 3.9 million tons of CO_2 are emitted by systems subject to Emissions Trading, i.e. by glass melting and downstream combustion processes. An additional process-related million tons of CO_2 are generated by the thermal decomposition of the carbonate raw materials. The energy efficiency thus achieved is remarkable nonetheless: while some 100 years ago the production of one ton of glass still required 6,000 kWh, today less than 1,000 kWh suffice. While in former times approximately three tons of CO_2 were emitted per ton of glass, it is less than 500 kg today. There is not a lot more to be saved here, which is why carbon neutrality requires a consistent shift to new technologies and renewable energy. According to BV Glas, the glass industry currently covers some 75% of its total energy demand by natural gas.

In Europe float glass, for instance, is mostly produced in cross-fired regenerative furnaces where the batch is molten at constant process temperatures of around 1,650°Celsius over the complete life of the furnace, ideally at least 15 – 20 years.

Many of the major glass producers and associations are already conducting in-depth studies into sustainable transformation options, such as Saint-Gobain, for instance. This company is currently examining and will still be until 2025, how its production at the Herzogenrath site might become carbon neutral. They see the highest potential in using regeneratively produced, green hydrogen for glass manufacturing. Energy savings could still be achieved in processing as well as by energetically optimised energy use and supply at the site. The project is being modelled in cooperation with the city of Herzogenrath, neighbouring communities and numerous institutes like the "Gas- und Wärme-Institut Essen e. V." (Gas and Heat Institute), the "Institut für Technische Thermodynamik" (Institute for Technical Thermodynamics), the "Institut für Industrieofenbau und Wärmetechnik" (Department



[22-01_Flammenbilder], Flames with varying admixture degrees of hydrogen
Left to right: 0%, 10%, 30%, 50%, 100% (H_2, volumetric)
Photo: GWI Leicher, J., Islami, B., Giese, A., Görner K., Overath, J.: Climate-friendly process-heat generation by hydrogen in the glass industry: the "HyGlass" Project. 3rd Aachen Furnace Construction and Thermo-Process Colloquium, 2021

[22-01_Floatglasfertigung], Float glass production at Saint-Gobain, furnace control
Photo: Saint-Gobain

for Industrial Furnaces and Heat Engineering) as well as the "Institut für Stromerzeugung und -speicherung" (Institute for Power Generation and Storage) of RWTH Aachen. If the model test is successful, the site could be climate-neutral starting in 2030.

Another project that gives hope: last August the NSG Group Company Ltd (Pilkington Glass UK) reported the successful float glass production with the help of hydrogen as a fuel. The trial was run at Pilkington's furnace in St. Helens (nominal load of approx. 800 tons of glass per day) in two stages: in the first stage one part of the furnace was fired with 100% hydrogen, replacing 20% of the natural gas volume in total. In the second stage hydrogen was admixed to the natural gas in all burners of the furnace. Due to the limited hydrogen supply its total share was limited to 15% in this stage of the trial.

A permanent shift could only be realised based on a comprehensive network of hydrogen pipelines – otherwise the road transport would counteract the desired climate neutrality. Pilkington's initiative forms part of the "HyNet Industrial Fuel Switching-Project" to decarbonise industrial processes in the North-West of Great Britain.

KEY TECHNOLOGIES NOW BEING RESEARCHED

Existing manufacturing processes in the glass industry are already highly optimised to manufacture glass in a consistent quality and with low pollutant emissions. In view of the targets agreed in the Paris Climate Agreement and growing social pressure, the glass industry is doing in-depth research across its entire process chain. The option that seems obvious would be the 100% use of green power (also to avoid conversion losses), but for physical reasons not all types of glass can be molten electrically and electric furnaces are still limited in size. The furnaces usually operated in the float glass industry cannot be fully electrified at present. BV Glas estimates that it is more probable for furnaces of this size to focus on hybrid technologies that additionally rely on green hydrogen as a fuel.

There are two key technologies on the horizon that might replace the existing base by 2045:

- Fully electric melting furnaces that melt the batch by introducing electric energy via electrodes. The use of regenerative power alone does currently not suffice to fire bigger melting units.
- Hybrid furnaces also using hydrogen could get up to 80% of the energy required for melting electrically via electrodes and get the remaining energy by burning hydrogen. Questions regarding the supply, availability and economic viability of green hydrogen are still unanswered at the moment.

Roadmap: Which technology is expected when?
By 2025
100% operation of conventional melting furnaces
Late 2020s
Installation of first hybrid furnaces with hydrogen firing
From 2030
- Shift to hybrid furnaces with hydrogen firing
- Use of fully electric melting furnaces
By 2045
Complete replacement of natural gas-fired melting furnaces
(Source: BV Glas)

Despite all roadmaps the aforementioned key technologies are still under research, but the possible effects in case of a successful shift can already be calculated for the float glass industry as follows according to BV Glas:

- Decline in absolute CO_2 emissions by 75%.
- The share of process-related CO_2 emissions from the thermal decomposition of so far non-CO_2-neutral raw materials would remain unchanged. The possible use of CO_2-neutral raw materials must therefore become the

[22-01_Behälterglas], Production of glass bottles

Photo: BV Glas e.V.

subject of research. The potential savings achieved by using more cullet is very limited in the float glass industry in Germany. Contrary to widespread opinion, float glass cullet in Germany is recycled almost completely, but only 11% in float glass production. The greater part is reused in the container glass and glass wool industry. BV Glas is currently preparing a publication on this topic.

- The specific energy consumption decreases slightly but with an altered mix of regeneratively produced power and green hydrogen.
- Manufacturing costs will rise by 70% because energy costs are expected to triple compared to 2020 – the effects of the Ukraine crisis have not been factored into this estimate yet.

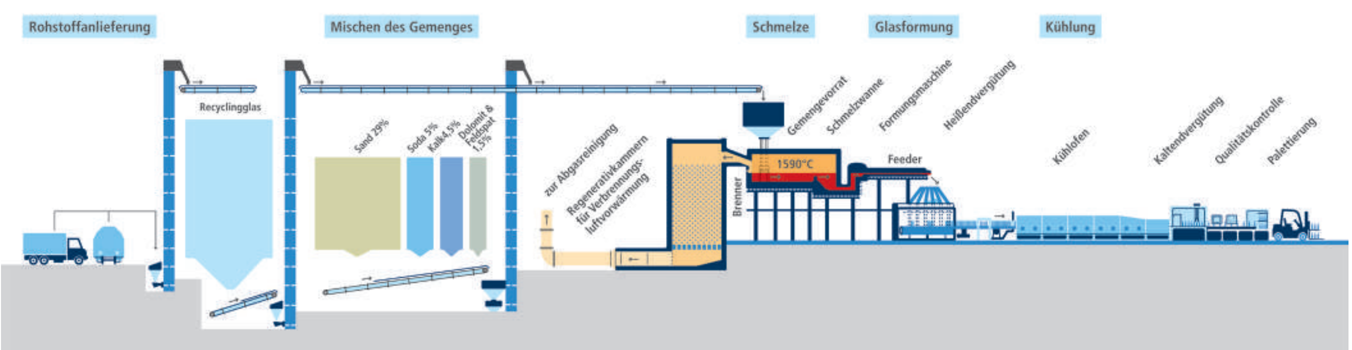
Long term the successful installation of a circular material economy that functions cradle to cradle would offer savings potentials – the buzzword here being buildings as "material banks".

IMPACT ON PRODUCTION PROCESSES AND PRODUCT QUALITY

As part of the "HyGlass" project the Federal Association of the Glass Industry (BV Glas) and the Gas and Heat Institute (Gas- und Wärme-Institut Essen e.V. – GWI) are studying the impact of using hydrogen as a fuel on the extremely sensitive process of glass production, product quality and pollutant emissions. This study includes both a view of all processes when increasing amounts of hydrogen are admixed to natural gas and the 100% use of green hydrogen along the entire glass production chain. (Process of industrial glass production. Graph: BV Glas)

The HyGlass Project here focuses on studying the impact of hydrogen on regenerative melting furnaces and the downstream combustion processes, for instance in the feeders used in the container glass industry. This makes sense since the European gas industry plans to directly feed a rising percentage of hydrogen into the natural gas grid in addition to building dedicated hydrogen infrastructures in future. Then the production plants in the glass industry will also be supplied with a mix containing significant amounts of hydrogen and therefore featuring combustion properties different to natural gas – producing an impact on product quality, pollutant emissions and possibly on the plant lifecycle.

The impact of all this is specifically



[22-01_BV Glas Illu Fertigung], Industrial glass production process

Graph: BV Glas e.V.

studied by HyGlass – especially in terms of combustion, which plays an important role in many process steps, in melting and in the so-called feeders which transport the molten glass and where it is homogenised for moulding. The melting process is the most energy-intensive part of glass production and the feeder is often decisive for high product quality. One anticipated difficulty here is that melting furnaces and feeders will differ substantially in technical terms and also in terms of size and energy needs.

While in the melting furnace burner systems with non-premixed flames and high air preheat temperatures or oxy-fuel burners are used, feeders use numerous small burners with premixed flames mounted to the side walls. Accordingly, the effects of higher hydrogen contents in natural gas need to be assessed differently. While with feeders, process control and possible flame flashbacks are especially relevant questions, the priority aspects for melting furnaces are efficiency, heat transmission and nitrogen oxide emissions (NO_x).

The necessary product quality is influenced both in the feeder and in the melting furnace. Initial results of the studies indicate that the effects of hydrogen on combustion are manageable but that previously fine-adjusted measuring and control technologies are required. The thermal nitrogen oxide emissions (NO_x) can rise with a higher hydrogen content, but the proven measures for NO_x reduction should continue working once adapted.

In the light of these studies it would make sense to bring these two key technologies – fully electric and hybrid melting furnaces with hydrogen – to market maturity as soon as possible – in cooperation with the plant and component manufacturers already operating in Germany and Europe whose expertise should be incorporated into a national strategy.

A global challenge is our consistent departure from fossil energies and the speedy installation of infrastructure for regenerative power along with the connection of glass industry sites to a hydrogen infrastructure yet to be created. Here political foresight and planning are also an imperative – also in view of the long investment cycles. To achieve full carbon neutrality plenty of research in sustainable raw materials is still needed in addition to this and the creation of a reliable circular economy ■

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Affordable and Clean Energy provided by Glass

Prof. Himanshu Jain

Prof. Peng Shou

INTRODUCTION

Glass plays a critical role in a broad range of energy technologies spanning energy generation, conservation and storage. In many cases, glass is the enabler of these technologies or a key component of devices. For example, in the energy generation sector photovoltaic (PV) and concentrated solar power applications cannot be realized without suitable glasses for protecting and packaging active devices. Glass is the most promising wasteform for containing and disposing high-level nuclear waste, thereby assuring that this mode of energy generation remains clean. In the form of foam, glass is a preferred choice over polymers for heat and sound insulation of buildings due to its low density, low thermal conductivity, incombustibility, adhesive compatibility, etc. In more advanced applications approaching commercialization, such as solid-state batteries for energy storage glass plays a more active role, performing specific functions within a device. In the following sections, we review six representative application areas exemplifying how glass is addressing one of the most pressing societal needs of today.

GLASS FOR PHOTOVOLTAIC TECHNOLOGY

As the world today sets carbon neutrality as the leading direction to go green and more than 120 countries have pledged to achieve this by the year 2050, the next 30 years represent a crucial window of opportunity. For this goal, we need to refocus on the energies we use as our power sources and develop new industries as the foundation on which to build the edifice of green development. To transform a fossil-based world to green energy, humankind will inevitably embrace cleaner and ever lower carbon energies. Ensuring energy supply and energy security, and enhancing the efficiency of energy production and consumption remain our basic tasks. It is evident that carbon neutrality will

Figure 1: World's largest integrated thin-film solar cell building demonstration project in Anhui, China

Source: China Triumph Engineering

Figure 2. Photovoltaic panel

Source: Pixabay

not be realized without renewable energies.

As an important constituent of renewable energies, photoelectric solar energy is becoming more important in the world's future energy system (Figure 1). According to China National Energy Administration, under the zero-carbon scenario by 2060, photoelectric power generation will reach 3414 billion kWh, amounting to roughly 30% of the world's power supply, thus constituting its main part.

Materials are key to propel the development of photovoltaic power generation. A silicon-based solar cell is usually composed of a cover glass, a film, some solar cell materials, special metal wires, a backplane glass, among others. The main body of the solar cell is sealed in the film between the cover and backplane glasses. In the field of thin-film solar cells, glass is the key substrate for film coating required by various cell types. Thus, glasses underpin the development of photoelectricity.

With the development of photovoltaic glass, silicon-based solar cells currently occupy a dominant position in photovoltaics, accounting for 93% of the global market in 2020 with a module conversion efficiency of roughly 25%. As photovoltaic glass becomes thinner and cell's conversion efficiency improves, the dual-glass module, tunneling-oxide passivating contact (TOPCon) heterojunction with intrinsic thin film solar cell (heterojunction technology, HJT) will define the development of the crystalline silicon solar cell.

The second-generation photovoltaic, thin-film solar cells offer a lower production cost, less pollution, stable performance and good low light performance. Compared with crystal silicon solar cells, they are a perfect choice for building-integrated photovoltaics (BIPV). Due to persistent silicon raw material shortages in the international market and an ever-quickening pace to cut carbon emissions, thin film solar cells represent a new trend that is gaining considerable attention in the photoelectric market (Figure 2 and Figure 3). At present, industrial thin-film solar cells, such as those based on cadmium telluride (CdTe) and copper indium gallium selenide (CIGS), have a module conversion efficiency around 20%. The progress in their efficiency enhancement has outpaced that for crystal silicon solar cells. Thanks to the application of thin film solar cells in the construction industry, BIPV has become a high-growth area around the world, especially in developing countries. As China steps up efforts to formulate its national standards of thin-film solar cells for BIPV, the importance of glass in photovoltaic application will be further highlighted.

GLASS FOR SOLAR-THERMAL TECHNOLOGY

The Sun with its effective blackbody temperature of 5762 K steadily emits radiant energy, of which about 1.8x1014 kW is intercepted by the Earth. This solar heat, captured directly or indirectly, provides the most abundant of all renewable sources of energy available for human use. Solar thermal utilization dates back to prehistoric times and it can be used extensively. Basically, photothermal conversion materials are used to convert solar radiation into thermal energy, which can then be used in industrial productions, agriculture, animal husbandry and other fields. As science and technology advanced, solar thermal utilization has expanded from low temperature applications ($<100°C$) to medium and high temperature applications ($\geq100°C$). New technologies such as solar thermal power generation (Figure 4), solar stills for water purification and distillation, integrated solar buildings and thermochemical hydrogen production have been developed in recent decades to provide clean energies of higher-grade.

The key technologies for solar thermal utilization are heat collection,

Figure 3. PV energy landscape in the desert

Source: Pixabay

transmission and storage, and new glasses play a critical role in all three. In heat collection, the core component is the concentrating reflector, composed mainly of ultra-clear glass (also known as low-iron glass). The concentrating reflector is normally composed of a 1 mm to 4 mm ultra-clear glass substrate coated with a reflective silver layer, protected with a layer of copper and several protective paints on the back. For a concentrating reflector, reflectance can increase by 1.5% for every 1% increase in glass transmittance. Thanks to continuous optimization of raw material formulation and furnace structural design as well as fine control of the melting process, ultra-thin and ultra-clean glass with high transmittance and high weather resistance can be produced, paving the way for high-quality heat collection and highly efficient thermoelectric conversion.

Additionally, in heat transmission, the inner metal tube coated with a medium-high temperature selective absorption coating is sealed in a borosilicate glass tube with good acid and water resistance and a well-matched coefficient of linear expansion to the metal phase, bringing in a medium-high temperature solar vacuum tube collector with an operating temperature up to 400°C —a temperature that ensures more stable and efficient transfer and utilization of solar heat. In heat storage, by adding transparent phase-change materials to the glass envelope, the newly developed glass curtain wall can utilize solar energy effectively and reduce energy consumption of buildings. It is critical to the development of ecological architecture and the realization of a carbon neutral strategy. Therefore, new glass materials remain the basic component to enable efficient utilization of solar heat.

Highly efficient use of solar heat is

Figure 4. 50MW Solar Thermal Power Plant in Qinghai, China

Source: China Triumph Engineering

an important aspect of solar energy utilization. Thanks to continuing R&D efforts, new glass materials are increasingly used in solar heat. Undoubtedly, the development of these new materials and technologies will bring new opportunities and challenges to the solar thermal industry, nurturing economy of scale, accelerating commercialization, and promoting the rapid development of global renewable energies and low-carbon economies.

DESERTEC is an international project at Noor Ouarzazate in Morocco to provide sustainable wealth for every human on earth. The DESERTEC Foundation aims to turn the biggest idea of the 21st century into reality: green Desert-Energy that advances the decarbonization of Europe, guarantees Africa clean prosperity and makes the Middle East independent of oil income. As bad as deserts are for food production, they are ideal for energy production. At no other place in the world does the sun shine as much and so many strong winds blow across their flat plains. French and German companies are interested and China has also joined the project. The new 200MW Noor II plant has the world's largest installed capacity as a parabolic trough concentrated solar power plant, while the 160MW installed capacity of Noor III is the largest amongst the world's concentrated solar power plants.

GLASS FOR WINDMILL TURBINES

Wind, nature's gift to mankind, is inexhaustible and readily available. When Charles F. Brush built the world's first wind turbine in 1887, a new chapter was opened in wind power generation history. In the early days, blades of wind turbines were made of cedar wood. The improvement of wind power generation required lighter, higher-performance and lower-cost turbine blades. With seminal developments in glass melting, fiber forming, glass formulation and other related technologies, glass fibers with high-strength and high-modulus could be manufactured. These new developments led wooden and metal blades of wind turbines to be replaced by glass fiber composites such as seen in Figure 5 and 6. High-performance glass fiber-reinforced polymer composites have excellent mechanical properties, processability and corrosion resistance. They can meet the needs of large-scale marine application of wind power and have become the material of choice for large-sized wind turbine blades.

At present, the world's total installed capacity of wind power is 743GW, accounting for 6% of global power generation. As the world strives to achieve carbon neutrality by 2050, shifting to sustainable sources of energy has garnered increasing attention from countries around the world. The world's energy pattern will also be reshaped, meaning the proportion of renewable energy such as wind in the total energy mix will only increase. To achieve "net zero" carbon dioxide emissions by 2050, the annual demand of 180GW of new wind power installed capacity and more than 30% of wind power generation in the total energy mix by 2050, will set off explosive growth of the wind power market. The demand of 10,000 to 15,000 tons of glass fiber for 1GW of wind power installed capacity will also prompt the glass fiber industry to innovate. The future is in the hands of materials. Thanks to the continuous R&D of high-strength, high-modulus glass fiber and the strong demand for super-sized wind turbine blades, the performance of wind turbines will reach unprecedented levels. This will prompt the wind industry to reach price parity sooner with traditional fossil energy, thus demonstrating directly the value of clean and environmentally-friendly energy. Wind power will make our sky bluer and cleaner, and make us healthier, happier and live better. Figure 5 shows an eolic park (wind farm) by the coast and Figure 6 a giant wind turbine.

GLASS FOR NUCLEAR WASTE DISPOSAL

More than 250,000 metric tons of high level radioactive wasteform (HLW) from nuclear power plants and weapons production facilities worldwide, are under storage in tanks such as seen in Figure 7. Even though a small fraction of total radioactive waste, it contains much of the radioactivity, posing great danger for society and a challenge to scientists and engineers. This wasteform is waiting to be converted into solids and then disposed of permanently in geological repositories. The solidified wasteform with radionuclides immobilized in a suitable matrix must remain stable against corrosion from groundwater for 1000 years, when the radioactivity would become comparable to acceptable ambient conditions. Three immobilization technologies, viz. cementation, bituminization and vitrification have been demonstrated to be commercially viable. Among them the highest degree of volume reduction and safety are demonstrated by vitrification although it is the most complex and expensive method. After considerable analysis of pros and cons of various choices, glass has

Figure 5. Wind Farm

Source: Pixabay

appeared as the material of choice, and vitrification of HLW is currently being practiced in Belgium, France, Germany, India, Japan, Russia, UK and the USA.

Glass is attractive to immobilize HLW waste through vitrification for the following reasons:

- Strong capability to immobilize reliably a wide range of elements including radionuclides.
- Relatively high loading of HLW thereby resulting in small volume to be disposed.
- High chemical durability if and when the wasteform comes in contact with natural waters.
- Desired properties have a high tolerance to radiation damage.
- Well established production technology that can be adapted from glass manufacturing.

Historically, borosilicate glasses were identified as potential hosts due to their high chemical durability, glass formability with HLW added as variety of oxides, and manufacturability. Subsequently, Russia focused also on sodium aluminophosphate glass as the HLW matrix. Overall, these glasses may contain more than 25 components. Such variations of composition, not to mention other test variables, have generated a plethora of data, making a comparison of relative performance very difficult. To overcome this challenge and establish a scientific basis for further developments, a six-component borosilicate glass known as the International Simple Glass (ISG) has been established by broad consensus to balance simplicity vs. similarity to waste glasses: $60.2SiO_2$-$16.0B_2O_3$-$12.6Na_2O$-$3.8Al_2O_3$-$5.7CaO$-$1.7ZrO_2$ (in mol%). Its basic properties and structure have been determined as a reference. In spite of considerable data generated on this and several other candidate glass compositions uncertainty remains about the assurance that overall a HLW package can maintain integrity over the lifetime of radioactivity under the highly interactive environment of radiation, temperature and groundwater. For example, new modes of corrosion of stainless steel have recently been identified at the interface with glass. Such enhancement of overall package degradation would require further

Figure 6. A stunning image of a wind turbine

Source: Pixabay

optimization of individual components including glass.

GLASS FOR PHOTOBIOREACTORS

Photosynthesis by microalgae offers: an attractive approach to production of biomass rich in lipids and carbohydrates that can be used as a biofuel; CO_2 bio-fixation to reduce greenhouse gases; and treatment of wastewater to reduce excessive discharge of nitrogen and phosphorus that cause eutrophication. A suitable microalga can also produce bioelectricity in microbial fuel cells, and hydrogen for use as a pollution-free fuel. For an efficient production of microalgae for any of these applications with low probability of contamination, photobioreactors such as seen in Figure 8 are required. These closed systems offer desired control of the algae production process. Ideally, a photobioreactor system should allow control of: light penetration and distribution within the culture medium; CO_2 loading level; mixing and gas transfer; management of oxygen generated as a byproduct of photosynthesis process; temperature; pH; supply of nutrients; and hydrodynamic residence time.

The material requirements for the containment of microalgae within a photobioreactor system are to: (a) be chemically stable so that it does not corrode in salt water and can be cleaned and disinfected with commercial chemicals; (b) have a smooth surface and regular shape for uniform flow of medium to prevent biofilm formation; and (c) exhibit high transparency to sunlight yet be stable against ultraviolet wavelengths. Thin borosilicate glass tubes are shown to meet these requirements particularly well. Although such glass-based bioreactor systems require higher investment compared to those made from polymers like polyethylene or polyvinylchloride, their superior performance, low maintenance cost, and long life (>50 years) also make them economical over time.

GLASS FOR ENERGY STORAGE TECHNOLOGIES

Often there is a mismatch in the timing of energy production and its consumption in the required form. To resolve this mismatch, the energy must be converted into a form that can be stored for a period and then converted back into a form that can be utilized. The process of energy conversion should be sufficiently fast with minimal loss. Typically, electrical or thermal energy needs to be stored. The former is stored by converting it into a mechanical, chemical or electrochemical form, while the latter is stored through a change in material temperature, such as latent heat of phase change, or as thermochemical heat of change of

Figure 7. Used nuclear fuel is stored above ground in massive airtight steel or concrete-and-steel dry canisters, or in steel-lined water-filled concrete pools
Source: https://www.energy-northwest.com/energyprojects/Columbia/Pages/Used-Fuel.aspx

a material's chemical structure. At present glass is not central to these applications in use today on large scale but is emerging as one of the most promising materials for future advancements. Examples for storing electrical energy include solid state batteries relying on electrochemical conversion and generating hydrogen relying on chemical conversion. In emerging batteries, glass is useful both as an ion conducting solid electrolyte and an electronic-ionic mixed conductor for electrodes. Hollow glass microspheres are proving to be a safe host for storing hydrogen that is produced by electrolysis of water. For storing thermal energy, the most widely used approach exploits phase change materials with large latent heat and then sensible heating of the melt of high specific heat. Here typical glass forming oxide melts are attractive over other salts due to their high characteristic energies and inertness towards metal containers.

SUMMARY

The optical transparency to sunlight, high resistance to attack by chemicals

Figure 8. A photobioreactor made by Varicon Aqua for microalgae production; tubes are made of borosilicate glass
Source: Courtesy of Akihiko Kanamoto, OP Bio Factory Co., Ltd, & Varicon Aqua

and damage by radiation, versatility to dissolve high concentrations of extraneous oxides, and capacity for economic fabrication in complex shapes make glass indispensable to the realization of various energy technologies. Already, it is widely used in harvesting solar and wind energies via photovoltaics, solar-thermal, photosynthesis and windmill technologies. It is the material of choice for environmentally safe disposal of high-level nuclear waste that results from nuclear energy production. Further improvement in the performance of glass in these existing applications is expected with further optimization of compositions. Recent advancements in R&D have demonstrated proof-of-concept for applications of glass also in energy storage technologies such as solid-state batteries, hydrogen as a green fuel, etc., thus indicating tremendous opportunities alongside the challenges for growth of glass to address the problems of the energy sector.

REFERENCES

1. Arinicheva, Y. *et al.* (2020): "Ceramics for electrochemical storage" (549-709), in O. Guillon (editor), *Advanced Ceramics for Energy Conversion and Storage*, Elsevier.
2. Brow, R. K. & Schmitt, M. L. (2009): "A survey of energy and environmental applications of glass", *Journal of the European Ceramic Society*, 29 (7): 1193-1201.
3. Deubener, J. & Helsch, G. (2021): "Glasses for Solar-energy Technologies", *Encyclopedia of Glass Science, Technology, History, and Culture*, 2: 1113-1123.
4. IAEA (2018): *Status and Trends in Spent Fuel and Radioactive Waste Management*, IAEA.
5. Konur, O. (editor) (2020): *Handbook of Algal Science, Technology and Medicine*, Academic Press.
6. Ojovan, M. I.; Lee, W. E. & Kalmykov, S. N. (2019): *An Introduction to Nuclear Waste Immobilisation*, Elsevier.
7. Schott (2017): "How using a PBR with high end glass components makes algae cultivation more economically viable": https://pbr-blog.schott.com/2017/12/21/economic-efficiency-of-algae-cultivation
8. The Africa – EU Partnership (n. d.): "DESERTEC – tapping the solar power potential of the Sahara": https://africa-eu-partnership.org/en/success-stories/desertec-tapping-solar-power-potential-sahara
9. Wind Energy and Electric Vehicle Magazine (2020): "Situation of wind energy in Spain and in the world": https://www.evwind.es/2020/07/15/situation-of-wind-energy-in-spain-and-in-the-world/75762 ■

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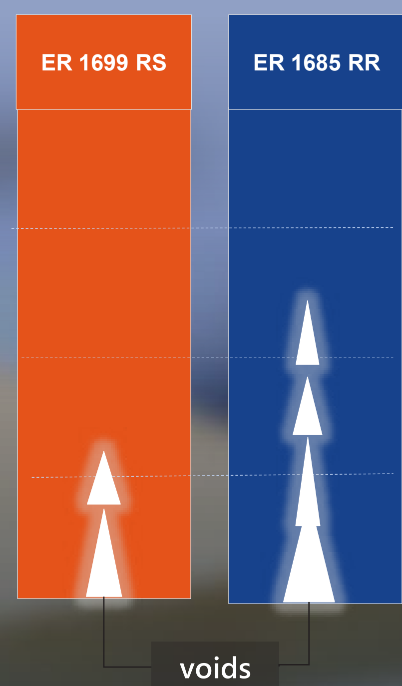

Benefits

- Longer lifetime than RR filled
- Lower upward drilling corrosion at the bottom

Glass in Information and Communication Technologies (ICT) and Photonics*

Prof. Giancarlo C. Righini

Prof. Setsuhisa Tanabe

Prof. John Ballato

The area of information and communication technologies (ICT) includes all technologies related to the accessing, retrieving, transmitting, manipulating and storing of information in a digital form. As such, ICT play a significant role in all aspects of present life. The rise of ICT in the last decades would not have been possible without two fundamental material groups: semiconductors (for laser diodes, and most notably silicon for computers and processing devices), and glasses (for optical fibers and photonic components). This Chapter provides a brief overview of the properties of various types of glass and of their applications to the development of optical fibers and photonic components.

INTRODUCTION

The 20th century has been described by many authors as the Electronic Age, due to the advent of electronic components, computers, and digital information. Silicon has certainly been the dominant material, with a large impact on the modern world economy.

The 21st century, on the other hand, may well be considered the Photonic Age, to recognize the vital role that light plays in our daily lives, from architecture to biology and medicine, not to neglect that internet communication, today a pillar of the global society, is only possible because of lasers and optical fibers. Not by chance, 2015 was celebrated by the United Nations as the International Year of Light and Light-Based Technologies. In this frame, one must also recognize the fundamental role that glass plays among the relevant materials for photonics. Glass is a complex material with unique properties, and technological demands now require greater use of its properties in relation to light, transparency being only the most common and most evident. Again, it is not by chance that the General Assembly of United Nations unanimously approved the resolution declaring 2022 the International Year of Glass.

This Chapter aims at briefly reviewing the role that glass (or, better, the many types of glass that the scientific research has synthesized and characterized) is playing in the generation, transmission and displaying of information.

GLASS AND OPTICAL FIBER

Fiber optics represents a field of significant daily consequence where light and glass are intimately linked. Indeed, all modern means of communications and data/information technologies are enabled by hair-thin strands of glass that can carry light over hundreds of kilometers before

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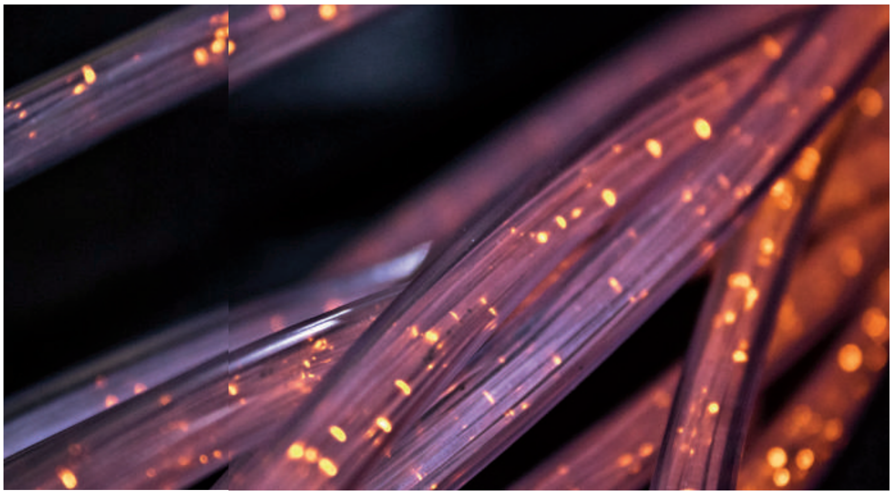

needing (optical) signal amplification. The Internet, namely the word-wide system of connected computers and other electronic devices, already offers fast personal and business communications and access to information databases. There is, however, a continuous search for faster and higher capacity data technologies, with 5G being one upcoming solution. 5G, in fact, is the fifth generation of cellular networks, and promises to be up to 10 times faster than the 4G technology currently used by most cellular phones. The development of internet and 5G will require a further expansion of the fiber optic lines that will remain the data-transport backbone of the overall network. Presently, over 500,000,000 kilometers of communications glass optical fiber are manufactured globally each year, a remarkable indication of the importance of glass and light [1].

The history of fiber optics, particularly from a glass-perspective, is as intriguing as it is timely. For a fuller treatment of this synergy, the reader is referred to Ref. [2]. Briefly, it had long been appreciated that the use of light as a medium onto which information could be encoded was far superior to electricity from the standpoint of capacity (bandwidth). Considerable efforts were already underway in the 1950s concerning free-space optical communications and gas-filled or mirrored pipes as microwave guides. The conceptualization and construction of the maser, and, subsequently, its shorter wavelength sibling, the laser, further accelerated research into communications using visible or near-visible optical carriers. With a collimated and coherent light source in the laser, studies into waveguiding materials were an obvious complement. The pioneering realization that glass could enable suitably high transparency (low loss) fibers was made by Charles Kao, in 1966, for which he was awarded the 2009 Nobel Prize in Physics. In 1970, Corning won the race to fabricate the first < 20 dB/km low loss fibers by implementing a chemical vapor deposition (CVD) process enabled by a flame hydrolysis method developed there in the 1930s. Soon thereafter, consistent pioneering achievements in silica glass-based optical fibers, both passive and active, were made by Corning, Bell Labs, NTT, and the University of Southampton, among others, into the late 1980s. This period, from 1966 through to, about, 1990, represents a critical first phase of glass development for fiber optics.

By the early 1990s, optical fiber communication systems were beginning to be installed globally and materials efforts began to focus on glasses whose performance could exceed, at least in theory, that of silica. The most significant efforts focused on three thematic areas, predominantly driven by the growing needs for longer distance and higher capacity communication links: (i) ultra-low loss glasses, (ii) broadband optical amplifiers, and (iii) nonlinear glasses for low power switching and wavelength conversion.

Regarding ultra-low loss glasses and optical fibers, considerable effort focused on the development of non-oxide glasses, specifically chalcogenides and fluorides. Relative to SiO_2, weaker bonding and heavier atomic constituents in both these glass families lead to reduced vibrational energies. This causes absorption due to multiphonon processes to shift to longer wavelengths (lower frequencies), which leads to lower minimum intrinsic attenuation values than silica when Rayleigh scattering is considered (decreasing as $(\text{wavelength})^{-4}$). A great many glasses and fibers in the ZrF_4- and InF_3-based fluoride systems, and As_2S_3, As_2Se_3, and Ga-La-S chalcogenide systems, were explored. However, while intrinsic ultra-low loss was possible, extrinsic losses, dominated by impurities in these melt-quenched glass systems, ultimately ended their consideration for amplifier-less long-haul systems. The near-intrinsic purity of SiO_2, enabled by chemical vapor deposition manufacturing methods, coupled with the remarkable strength of silica and scalability of CVD, has led to the present condition where nearly 2 meters of fiber is manufactured every day for each person on Earth. Figure 1 shows a phase of the CVD process of manufacturing a glass preform from which an optical fiber will be drawn.

Though the first optical fiber amplifier dates to 1964, the 1990s and early 2000s saw a frenzied focus on optical fiber amplifiers research, initially focused on erbium doped fiber amplifiers (EDFAs), then on praseodymium (Pr) and dysprosium (Dy) doped analogs. The EDFA enabled long haul communications since weakened signals could be all-optically amplified without electro-optical conversion and regeneration. Further, EDFAs operated at 1.55 μm, the wavelength of minimum loss for silica, and are highly efficient. Other wavelengths of interest, such as 1.3 μm where silica glass exhibits zero chromatic dispersion, were expected to afford greater information carrying capacities than operation at 1.55 μm. However, the emissions from Pr and Dy at 1.3 are fully quenched given the relatively high vibrational energies in SiO_2 glasses and, so, such amplifiers required low phonon energy glasses, for example the aforementioned fluoride and chalcogenide glass systems. Though much progress was made, including operational networks, in the end, optical fiber systems moved instead to all-silica based components using EDFAs as the amplifiers and dispersion-shifted or compensated fiber designs, originally developed in the late 1970s, to control dispersion and bring together lowest loss and low dispersion at a single wavelength.

Optical fibers, and their ability to confine and guide light, are not only useful for transmission and amplification, but also for nonlinear processes, such as frequency conversion and switching. Whereas transparent fibers usually benefit from low nonlinearity, optical switching and frequency generation require high nonlinearities, where glasses generally gain from components that are weakly bound and heavy relative to, for example, silica. During the 1990s to 2000s, much focus on nonlinear optical fibers centered on chalcogenide and heavy-metal oxide glasses, such as tellurites and germanates [3]. In these glasses, because the nonlinear coefficients can be orders of magnitude larger than those of silica, fiber device lengths are short (cm to meter) and, accordingly, losses are not as critical.

Figure 1. The deposition section of a modified chemical vapor deposition (MCVD) lathe. The white glass is the porous silica soot deposited inside of a pure silica substrate tube prior to sintering and consolidation

Source: Clemson University

Following the "dot-com" boom of the late 1990s to early 2000s, optical fibers have enjoyed considerable growth and attention in two main areas. The first is microstructuring including photonic bandgap and microstructured fibers. Though outside the scope of this Chapter, such fibers generally rely on conventional glasses, primarily silica, and performance results typically from periodic structures in the glass(es), or air channels created by stacking rods and tubes together. The second area is in the materials from which fibers are made. Indeed, there has been a renaissance in optical fiber materials, not just in the range of new materials but also in the length scales and interconnectivities ranging from nano-scale engineered structures, including glass-ceramic, phase-separated and nanoparticle infused cores, to multimaterial fibers where glasses, plastics, and metals run the full length [2].

GLASS INTEGRATED OPTICS

In the mid-1960s it became clear that optical fibers had the capability of winning the competition with metal pipes for long-distance high-capacity communication. Correspondingly, the need emerged for optical connecting elements analogous to existing parallel-plate metal microwave waveguides. Thus, optical thin-film waveguides were designed and fabricated, where light was trapped due to total internal reflections at upper and lower surfaces, i.e., by the same mechanism operating in optical fibers but in a planar geometry rather than a cylindrical one. Shortly thereafter, the new field of integrated optics arose, providing a complete tool for locally manipulating the light coming from a laser source or carried by an optical fiber [4]. Once again, glass immediately emerged as a very convenient material, which had the advantage of full compatibility with optical fibers and provided an easy and low-cost tool to develop technological processes that later could also be transferred to other optical materials.

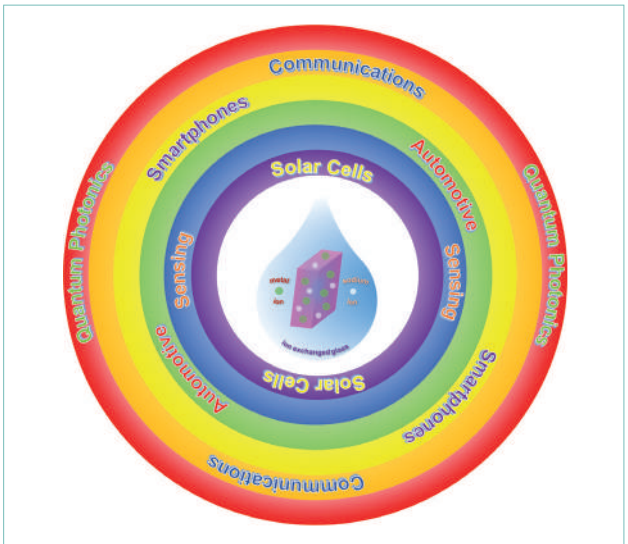

Figure 2. A simple sketch of the many application areas of photonic devices implementing the ion-exchange technique
Source: Courtesy of S. Berneschi

The fundamental requirement for confining the light is that the guiding layer has a refractive index higher than the surrounding media; this goal, in glass integrated optics, is easily achieved by two dominant approaches, namely a local modification of the bulk glass or the deposition of a thin glass film on a lower-index glass substrate. Indeed, one of the first technologies employed for planar waveguide fabrication, in the early 1970s, was that of ion-exchange in glass, exploiting the same process used for chemical strengthening of glass and already known since the beginning of the 20th century [5]. In fact, the in-diffusion of ions having different atomic size in the pristine glass matrix (e.g., larger potassium ions K^+ from a molten salt KNO_3 substituting smaller sodium ions Na^+ in the glass), while increasing its mechanical strength by preventing or healing over the formation of superficial micro/nano-cracks, at the same time induces an increase of the refractive index at the surface.

Ion exchange was also used in 1968 by Nippon Sheet Glass (NSG) and NEC Corporation for an innovative method to vary the central and peripheral refractive indices of a glass fiber in a parabolic profile, with the aim of reducing the spreading of the envelope of a propagating optical pulse and thus increasing the fiber transmission capacity. Ten years later, these fibers were introduced in the market under the product name of SELFOC®. The major advantage of ion-exchange in integrated optics is the simplicity of the technique, requiring only a furnace, a container of the nitrate salt to be melted, and a proper holder of the sample; its applications in creating optical devices are countless (Figure 2).

Regarding material properties, the only strict requirement for the glass is to contain an alkali ion (K^+, Na^+, Li^+ being those most frequently employed). Different glass matrices may be used, depending on the application; soda-lime and borosilicate glasses are among the most common. An example of a glass ion-exchanged integrated optical power splitter device of use in fiber communication systems, is shown in Figure 3 [6]; some twenty years were necessary to move from laboratory demonstration (Figure 3a: a multi-mode highly scattering sample) to a Telcordia 1209 and 1221 compliant, single-mode, commercially available splitter (Figure 3b).

Many other processes have been developed to produce glass optical waveguides and photonic devices, e.g., depositing thin glass films with radio frequency (RF) and magnetron sputtering, chemical vapor deposition (CVD, and in particular plasma-enhanced chemical vapor deposition-PECVD), flame hydrolysis deposition (FHD), spray pyrolysis (SP) deposition, pulsed laser deposition (PLD), and sol-gel coating. Besides ion-exchange, the local modification of refractive index may be achieved by ion implantation, UV irradiation, and femtosecond laser writing; the latter two techniques are also suitable for the direct definition of a channel waveguide circuit.

The continuous advances in microsystems for communication, computing, sensing, and biomedical applications require a higher integration of micro-electronic, optoelectronic and micro-optical components. Even in this area, glass offers unique properties, and advanced hybrid packaging technologies are often based on glass substrates, where photonic integrated circuits (PICs), laser diodes, modulators, isolators, beam splitters, microlenses, and detectors may be interconnected through electrical stripes (i.e., metallized glass) and optical waveguides (possibly with mode field expansion sections). There are, of course, some challenges for the use of glass, such as its poor thermal conductivity and difficulties in free-form cutting and cleaving, but technology keeps advancing to find proper solutions [7]. Several optical, electronic, and mechanical interfaces can be designed in a way that multiple glass boards can be stacked on each other; different modules can be fabricated, ready for assembly on a main glassy board. Figure 4 shows as an example a glass main board with size 100 mm x 50 mm, hosting various sub-assemblies: on the left, a system for frequency modulating and splitting the laser light coming from a fiber, and on the right two smaller glass boards detecting the light coming from an

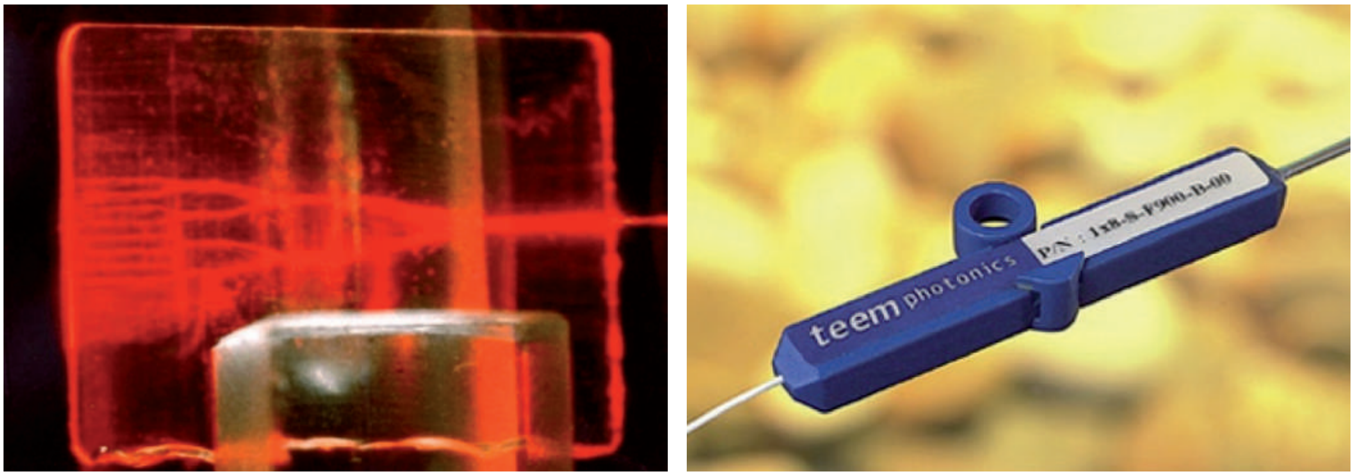

Figure 3. An example of a photonic device (1 x 8 power splitter for optical fiber communication systems) made in glass by ion-exchange: (a) laboratory demonstration in 1986; (b) qualified pigtailed and packaged device produced some twenty years later by Teem Photonics

Source: Reprinted from Ref. [6] under a Common Creative license

external sensing unit through two separate optical fibers [8].

Some innovative guided-wave devices have also been developed thanks to glass properties: an example is constituted by glass microspherical resonators, which find application in narrow-band and add-drop optical filtering, feedback elements for external lasers, multiwavelength and very low-threshold laser sources, nonlinear photonics, and optical sensing. These miniaturized optical resonators are based on dielectric structures having circular symmetry, like cylinders and spheres, which sustain the so-called Whispering Gallery Modes that can be interpreted as circulating electromagnetic waves that are strongly confined within the structure [8]. The peculiar properties of these microresonators are best exploited in the area of sensing: if scattering losses at the surface and absorption of light in the material are very low, the trapped photons are able to circulate for a very long time, providing a very long optical interaction path. Any minimal change at the resonator's boundaries induces a change in the quality factor of the resonator or a shift in the resonance frequency. Thus, detection of small forces, either mechanical or optical (optomechanics), or of micro- or nanoscopic objects (biological ones too, e.g., a bacterium or molecule) is possible with very high sensitivity, even better than the frequently used surface plasmon resonance (SPR) sensors. In the last decades, microspherical devices have fully demonstrated their capability of detecting even single molecules, virions, DNA, antibodies, enzymes, and aptamers. Most of these excellent results have been possible thanks to glass. Pure silica represents the preferred material, due to the very high purity and nanometer-scale surface smoothness available. These two characteristics have made possible the achievement of a top quality factor for the resonator of $Q \approx 8 \times 109$, with a corresponding finesse $F \approx 2.2 \times 106$. Single spheres with the desired diameter and reproducible high quality are produced very simply by melting the tip of a glass fiber, a very cheap method that allows excellent control of the microsphere diameter.

Another field that has emerged rapidly in recent years to become a hot topic in photonics research is flexible photonics. Its growth has mirrored the rapid development of flexible components and devices (LEDs, OLEDs, displays, wearable sensors) in the area of consumer electronics. At first sight, organic materials would appear the most convenient fabrication platform, due to their mechanical flexibility, low cost and large-scale manufacturing potential; inorganic materials, however, remain the long-term choice for making stable and high-performance photonic devices. Thus, glasses may play an important role even in this area, both as highly transparent, and mechanically, thermally and chemically robust substrates which can also be bent, and as a material platform for optical interconnects and sensor applications. Very thin glasses are now marketed by major glass producers worldwide, with thicknesses in the range 30-200 μm, and are widely used in solar panels and in cellular phones (including foldable phones). There is strong interest in the development of monolithic glass integrated photonic circuits, made in these very thin glasses by direct laser writing, ensuring novel mechanical properties suitable for easier three-dimensional integration of electronic and photonic components. On the other hand, chalcogenide glass waveguides made by thin films thermally evaporated onto polymeric substrates from As_2S_3 binary system or $Ge_{23}Sb_7S_{70}$ ternary alloy have already exhibited excellent

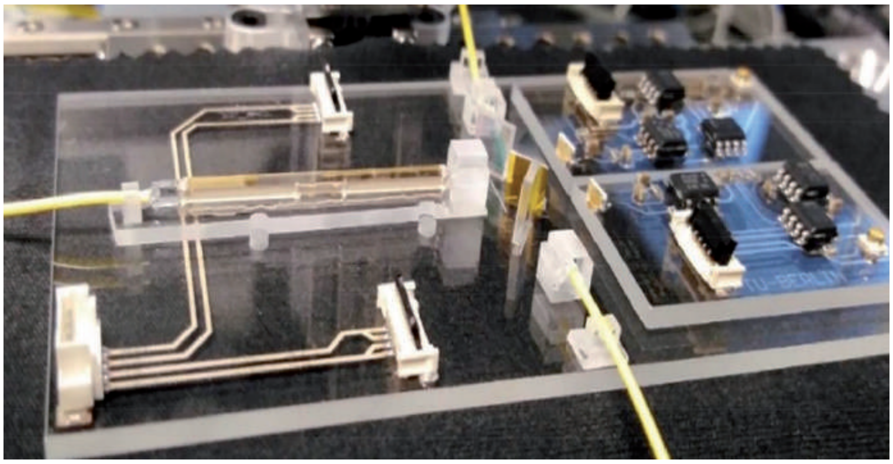

Figure 4. Photo of a glass main board: on the left side the light from a fiber-pigtailed external laser is modulated by separately mounted electrodes; at the center, the modulated light is split and coupled into opposite optical fibers, connected to an external sensing device (not visible in the photo); on the right, two separate glass boards detect the light from the sensing unit coming through the same fibers

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characteristics, namely their low deposition temperature, tunability of their refractive index (from 2 to 3.5, depending on composition) and very low propagation loss (less than 1 dB/m) in the band around the 1.5 μm wavelength [9]. This approach appears very promising for new applications such as high-bandwidth-density optical interconnects, conformal wearable sensors and ultrasensitive strain gauges.

ACTIVE GLASSES AND 3D DISPLAYS

The first glass laser, using a neodymium-doped silicate glass, was developed in 1961 [10], just after the invention of the first laser (ruby) [11] for humankind in 1960. Subsequently, several important developments in glass-based active devices followed, before the global installation of optical fiber telecommunication [12, 13]. Most active devices utilize the luminescence and/or its stimulated emission of lanthanoids' 4f electronic transitions. Figure 5 shows the principle of optical amplification with electronic energy levels and representative emission bands of active lanthanoid ions in comparison with the (silica) optical fiber loss spectrum, which has the minimum loss at 1.55 μm.

As noted in Section 2, relating to telecommunication systems, the invention of the EDFA [14] can be likened to that of the transistors in electronics in terms of its technological impact. The technology to amplify the light signal directly without the conversion of light/electricity/light is achieved by stimulated emission of a 4f optical transition in rare-earth-doped silica glass fibers and realizes ideal amplification with high gain and low noise. The technological development of optical telecommunication is based on the growth of technologies of fiber fabrication and those of laser diodes (LD). In fact, the invention of efficient III-V LDs and their fiber coupling has also enabled efficient pumping of Er^{3+} with its three-level system. In addition, the history of the technological transition from passive fibers to active fibers also demonstrates the interesting relationship between active ions and the host glasses.

Although fiber amplifiers are already playing crucial roles in the optical networks both at the 1.55 μm and 1.3 bands, further requirements exist to fully utilize the windows of optical fibers with superior performance. The requirements are a wide and flat gain spectrum around 1.53~1.65 μm (C+L band) in a novel EDFA and around 1.4~1.51 (S-band) in Tm^{3+} (TDFA) for wavelength division multiplexing (WDM) systems [15], and greater gain per pump-power at 1.31 μm in Pr^{3+} [16].

In the research history of rare-earth doped glasses, also noteworthy are various efforts to develop blue and green lasers by up-conversion luminescence of Pr^{3+}, Ho^{3+}, Er^{3+} and Tm^{3+} ions, mainly in fluoride glass hosts, during the late 1980s and early 1990s, before the invention of blue LED or LD based on GaN [17,18]. Some of these transitions are shown in Figure 6. High-power LDs in the NIR developed for fiber telecommunication in the late 1980s have stimulated research because of the possibility of a visible laser by pumping with the LDs.

Fluoride glasses developed so far [19] are an ideal host to give the lanthanide dopant ions a low-phonon-energy environment and thus long excited state lifetimes, enabling efficient multi-step pumping and high luminescence quantum efficiency for the excited levels even with a narrow energy gap to the next lower level [20]. According to studies and theories [21,22], the lower the phonon energy of the host is, the smaller are nonradiative losses due to multiphonon relaxation yielding longer fluorescence lifetimes from the excited states. This situation becomes critical when the energy level separation between associated electronic levels is not large, which is true for most excited states of Pr^{3+}, Ho^{3+}, Er^{3+} and Tm^{3+} ions [23]. A long fluorescence lifetime gives a higher probability of the second- (sometimes also the third- and fourth-) step excitation to intermediate excited

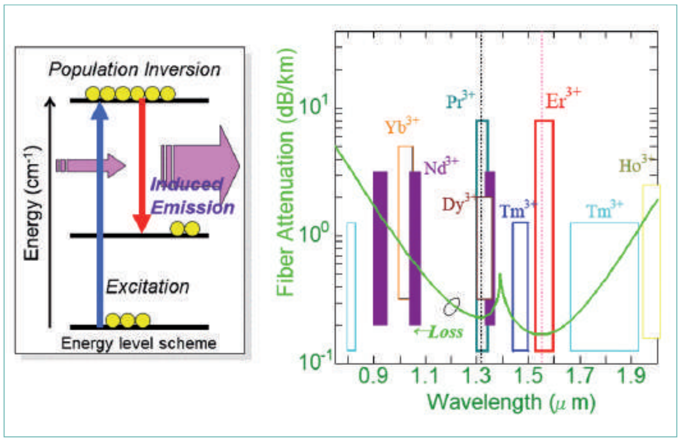


Figure 5. Principle of optical amplification with electronic energy levels and some emission bands of active lanthanoid ions in comparison with optical fiber loss spectrum

Source: S. Tanabe

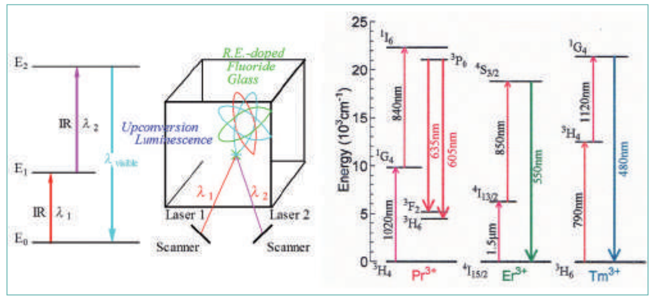


Figure 7. Principle of 3D color display utilizing the dual-NIR-pumped visible upconversion and the energy levels of RGB luminescent ions; Pr^{3+}, Er^{3+}, Tm^{3+} [23]. Some intermediate excited levels of lesser importance are omitted for simplification

Source: S. Tanabe

levels and then, a higher radiative quantum efficiency to the luminescent terminal state.

Intrinsically, fluoride hosts have a wide optical transmission window, because of their short ultraviolet (UV) absorption edge (band gap) and long infrared absorption (multi-phonon) edge. The UV edge of fluorides is short enough to be a UV laser host for ions like Tm^{3+}, and the infrared (IR) edge is long enough for IR pumping or to be an IR light source.

One interesting application of up-conversion is a 3D display by dual wavelength pumping schemes for three active centers, which was proposed in 1996 by E. Downing [24]; the scheme of operation and the relevant energy levels are illustrated in Figure 7.

Fluoride glasses remain one of the best possible hosts due to their stability and efficiency. It is interesting to note that three active lanthanide ions for red/green/blue (RGB) colors (Pr, Er, Tm) are also active centers for the telecom amplifiers at O-, C- and S-bands, respectively, in the near-IR (NIR). Figure 8 shows the photoluminescence spectra of the three elements in relation to the NIR telecom bands [24].

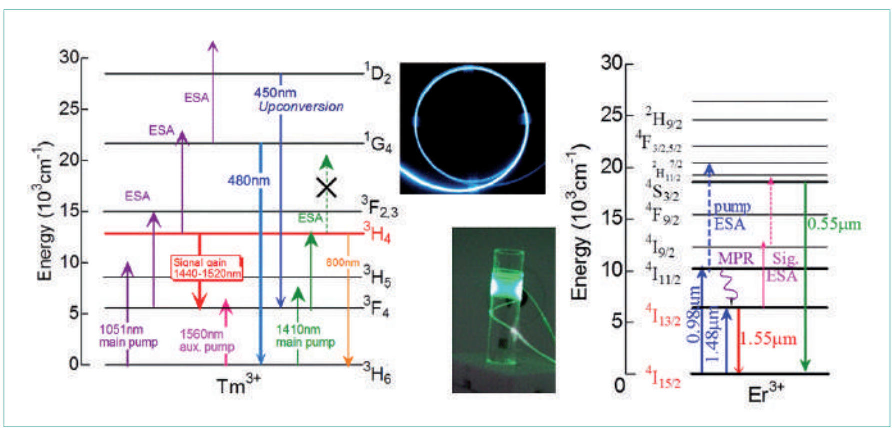


Figure 6. Energy level diagrams and important electronic transitions of Tm^{3+} and Er^{3+} ions for optical amplifications and infrared-to-visible upconversion by excited-state absorption (ESA) mechanisms. Blue and green luminescent fibers in two photos are Tm-doped and Er-doped ones excited by the corresponding NIR LD for telecom amplification.

Source: S. Tanabe

SUMMARY

The future of glass is even brighter than the past, given the centrality of data to virtually all sectors of modern life. Infrastructure modernization, autonomous mobility, 5G and quantum communications will all rely on ultra-high capacity and information-secure glasses, whether in bulk, planar or fiber form. Areas deserving special attention relating to the future of optical fiber glasses include: high energy fiber lasers where performance is presently limited by already weak nonlinearities in the glass; thermal management using fibers such as laser cooling and radiation-balanced lasers and amplifiers; and long wavelength (>2.5 μm) infrared fibers and fiber lasers for chemical and biological sensing and power-delivery. In parallel, one can expect further advances related to glass integrated optics, including planar active devices (lasers and amplifiers) and photonic guided-wave components for frequency modulation and multiplexing (mux-demux) and optical switching, based on nonlinear optical properties of high-index and nanostructured glasses. Optical interconnects for high integration of optoelectronic components will also exploit the properties of various glasses; in this regard, a wider use of ultrathin glasses (now mainly employed for the

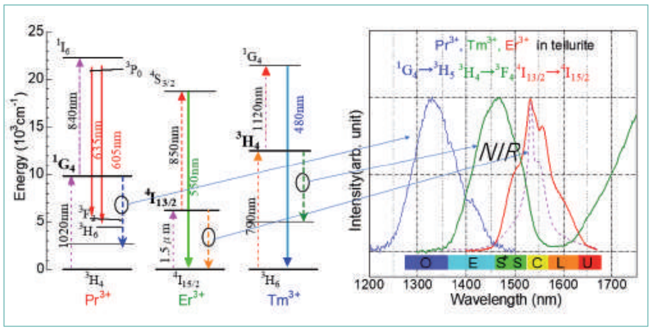
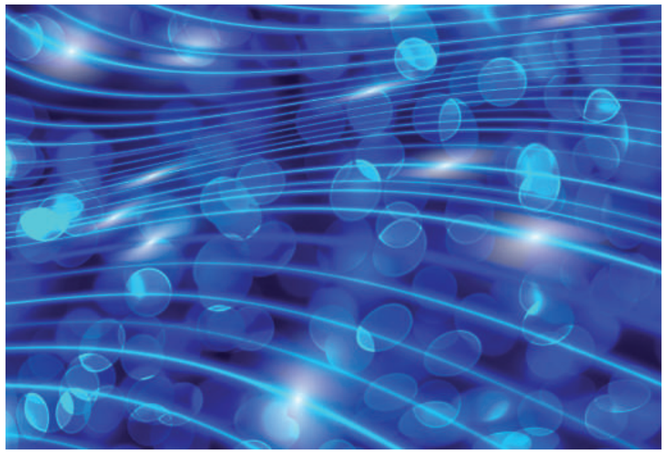


Figure 8. Left: Energy levels of RGB luminescent center ions, Pr^{3+}, Er^{3+}, Tm^{3+}, showing NIR amplification transitions at the O-, S-, and C+L-bands of optical fiber telecommunication. Right: NIR PL spectra of these same ions [25]



Source: S. Tanabe

cover of cell phones and displays) is envisaged, because of the addition of mechanical flexibility to the pristine optical properties of glass.

In summary, we have entered an age that is dominated by light and glass and there is a growing appreciation that glass science and optical waveguide engineering are the best approaches to address current limitations in a wide variety of glass-based photonic systems.

REFERENCES

1. Ballato, J. & Dragic, P. D. (2021): "Glass: The carrier of light (Part II). A brief look into the future of optical fiber", *International Journal of Applied Glass Science*, 12: 3-24.
2. Ballato, J. & Dragic, D. (2016): "Glass: The carrier of light. A brief history of optical fiber", *International Journal of Applied Glass Science*, 7: 413-422.
3. Ballato, J. & Dragic, P. D. (2016): "Glass: The carrier of light. A brief history of optical fiber", *International Journal of Applied Glass Science*, 7: 413-422.
4. Tao, G. *et al.* (2015): "Infrared fibers", *Advances in Optics and Photonics*, 7: 379-458.
5. Righini, G. C. & Pelli, S. (2020): "1969-2019: 50 years of integrated optics", *Integrated Optics*, 1: 1-38.
6. Berneschi, S.; Righini, G. C. & Pelli, S. (2021): "Towards a Glass New World: The Role of Ion-Exchange in Modern Technology", *Applied Scinces*, 11: 4610.
7. Broquin, J. E. & Honkanen, S. (2021): "Integrated Photonics on Glass: A Review of the Ion-Exchange Technology Achievements", *Applied Sciences*, 11: 4472.
8. Schröder, H. *et al.* (2021): "Hybrid photonic system integration using thin glass platform technology", *Journal of Optical Microsystems*, 1: 033501.
9. Righini, G. C. *et al.* (2011): "Whispering gallery mode microresonators: fundamentals and applications", *Rivista del Nuovo Cimento*, 34: 435-488.
10. Li, L. *et al.* (2014): "Integrated flexible chalcogenide glass photonic devices", *Nature Photonics*, 8: 643-649.
11. Snitzer, E. (1961): "Optical maser action of Nd^{3+} in a barium crown glass", *Physical Review Letters*, 7: 444-446.
12. Maiman, T. H. (1960): "Stimulated Optical radiation in Ruby", *Nature*, 187: 493-494.
13. Koestner, C. J. & Snitzer, E. (1964): "Amplification in a fiber laser", *Applied Optics*, 3: 1182-1186.
14. Snitzer, E. & Woodcock, R. (1965): "Yb-Er glass laser", *Applied Physics Letters*, 6: 45-46.
15. Mears, R J. *et al.* (1987): "Low-noise erbium-doped fibre amplifier operating at 1.54 μm", *Electronics Letters*, 23: 1026-1028.
16. Komukai, T. *et al.* (1995): "Up-conversion pumped thulium-doped fluoride fiber amplifier and laser operation at 1.47 μm", *IEEE Journal of Quantum Electronics*, 31: 1880-1889.
17. Ohishi, Y. *et al.* (1991): "A high gain, high output saturation power Pr^{3+} -doped fluoride fiber amplifier operating at 1.3 μm", *IEEE Photonics Technology Letters*, 3: 715-717.
18. Akasaki, I. *et al.* (1995): "Stimulated Emission by Current Injection from an AlGaN/GaN/GaInN Quantum Well Device", *Japanese Journal of Applied Physics*, 34: L1517-L1519.
19. Nakamura, S. *et al.* (1996): "Room-temperature continuous-wave operation of InGaN multi-quantum-well structure laser diodes", *Applied Physics Letters*, 69: 4056-4058.
20. Lucas, J. (1985): "Rare earths in fluoride glasses", *Journal of the Less Common Metals*, 112: 27-40.
21. Tanabe, S. (1999): "Optical transitions of rare-earth ions for amplifiers: How the local structure works in glass", *Journal of Non-Crystalline Solids*, 259: 1-9.
22. Layne, C. B.; Lowdermilk, W. H. & Weber, M. J. (1977): "Multiphonon relaxation of rare-earth ions in oxide glasses", *Physical Review B*, 16: 10-20.
23. Tanabe, S. (2002): "Rare-earth-doped glasses for fiber amplifiers in broadband telecommunication", *Comptes Rendus Chimie*, 5: 815-824.
24. Downing, E. *et al.* (1996): "A three-color, solid-state, three-dimensional display", *Science*, 275: 1185-1189.
25. Tanabe, S. (2015): "Glass and Rare-Earth Elements: A Personal Perspective", *The International Journal of Applied Glass Science*, 6: 305-328 ■

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Reflections on Reflection: Glass in Architecture

Arch. Sol Camacho

To speak about glass in architecture is to speak about the history of architecture of the past two hundred years, and that is a daunting task for an architect who has merely been studying this for a few years. I arrived at this subject almost randomly. My research on the subject grew as a derivative of my interest in the life and work of the Italo-Brazilian architect Lina Bo Bardi (1914-1992), who pioneered in the use of the material with two of her most iconic buildings, her own house in Morumbi —today known as the *Casa de Vidro* (1951) (Figure 1) and the Museu de Arte de São Paulo Assis Chateaubriand (1968), also known as MASP (Figure 2).

I arrived to live in São Paulo in 2011 and these two canonic examples of Brazilian Architecture were my introduction to the city; by studying about them I was able to connect with people and the history of the fascinating South American metropolis. These buildings condense the life and work of Lina —as she is locally known— and Pietro Maria Bardi (1900-1999), her husband, journalist and art critic founder of the MASP.

The couple arrived in 1946 from a torn-down Italy to a promising Rio de Janeiro and soon met Assis Chateaubriand (1892-1968), a media mogul[1] who commissioned Bardi to found and direct an art museum in São Paulo in 1947, first inside the office building of *Diários Associados* on *Rua 7 de Abril*. With his critical eye and knowledge of European Art, Bardi built during the years one of the largest and most important art collections in Latin America with a pioneering educational program that weaved the arts with other disciplines in the style of the Bauhaus. His knowledge and understanding of architecture had been acquired in his years as journalist in Italy, Bardi was an active member of modernist circles and exchanged letters to Le Corbusier, Walter Gropius and Richard Neutra.

Italy at the time was under the fascist regime that came into power in 1922 and modernism was in a delicate situation, if it enjoyed state sponsorship, it was also being persecuted by opposing factions. As there was no official-promoted art, exhibitions and building commissions were disputed to gain favor with the state. While Giuseppe Terragni was working in his *Casa del fascio de Como* that became one of the icons of Italian Modernism and of glass architecture, Marcelo Piacentini consolidated through politics his position as leading architect with neoclassicism as the core architecture movement.

The dispute over modernism and neoclassicism would extend even further than Italy. Brazil had open relations with Fascist Italy due to the populist dictatorship of Getúlio Vargas. If Bardi went to Brazil before the war to promote modernism to the Americas, Piacentini came to São Paulo on a diplomatic mission invited by the Italo-Brazilian industrialist Matarazzo family.[2] Later political changes, such as a surprising pro-USA stance of Vargas in the event of the Second World War, would lead the Matarazzo to a pro-modernist stance with the sponsorship of the Museum of Modern Art of São Paulo in 1948 at the same building of MASP at *Rua 7 de Abril*, and later to its location at Ibirapuera Park designed by Oscar Niemeyer.

During the years 1938-1943 [1], in what can be interpreted as one of Bardi's last contributions to Italian critics before immigrating to Brazil, he worked in the magazine *Il Vetro* (Figure 3); but, he was forbidden by the regime to sign his text and his name wasn't listed on the credits. *Il Vetro* was, as the Italian name implies, a magazine around themes and uses of glass. In his contribution, Bardi wrote not only about technical uses of glass, but also wrote about glass architecture. Italian fascism had tried

[1] Assis Chateaubriand owned and directed the media conglomerate *Diários Associados* and was a pioneer entrepreneur with the TV Tupi, the first TV in Brazil.

[2] Piacentini designed for the Matarazzo family their corporate headquarters in Vale do Anhangabaú and their mansion at Avenida Paulista. The corporate headquarters was later acquired by the state and since 2004 is São Paulo's town hall. The mansion at Avenida Paulista was demolished to give place to a shopping mall.

Figure 1. Lina Bo Bardi's Casa de Vidro

Source: Nelson Kon

to incorporate in its rhetoric glass as a metaphor for the State, a metaphor which Terragni heavily leaned on as the new foundation of Italian architecture, but ultimately lost to Piacentini's neoclassicism.

However, *Il Vetro* was one later addition to the ample debate of glass architecture as modern architecture, if not one of the last magazines to debate glass architecture before and during the Second World War. There is no easy answer for when the concept of glass architecture begins, contemporary critics tend to inscribe the beginning of glass architecture to the first decades of the 20th century; but Walter Benjamin in the 1920s studied a possible transition of glass as material to glass as architecture in the 19th century. On the words of his notes of the incomplete project on the arcades of Paris:

Glass before its time, premature iron. In the arcades, both the most brittle and the strongest materials suffered breakage; in a certain sense, they were deflowered. Around the middle of the past century, it was not yet known how to build with glass and iron [2].

Nevertheless, Glass has fascinated men over centuries way before any modern possibilities. Europe was dotted with colorful cathedrals, mirrored hallways and fogged greenhouses, and glass was used in artifacts and buildings all around the world without direct correlation to European arts and crafts.

This fascination was always hindered by a limited supply and production of glass, a limitation that reduced the material to a luxury status. The Industrial Revolution unleashed new ways to mass produce glass in panes or common artifacts. Ample supplies and cheap production turned glass into a more affordable material to build even the simplest of structures (Figure 4).

What Benjamin's research argues is a change in the cultural and popular consensus around the use of glass with the construction and inauguration of Paxton's Crystal Palace. While the arcades of Paris were a modern life predecessor of the Crystal Palace, it was Paxton's work to set the material of a modern architecture in Europe, correlated to the industrial progress of its time. Benjamin also argues that the 19th century glass architecture was correlated to velocity and temporary structures [3], since it was used mostly on railroad stations and

Figure 2. Lina Bo Bardi's MASP

Source: Nelson Kon

exhibitions palaces[3], while the 20th century glass architecture was seen as stable and solid due to a change of social perception of time.

As new materials and structural principles were discovered and pioneered in the 19th century such as the glass curtain wall and reinforced concrete, mostly developed due to the zealous work of engineers and pioneer architects, a search for a transcendental meaning for glass architecture pertains to art and architecture debates of the 20th century.

Literature led the way before architecture, German author Paul Scheerbart was one of the first to attribute to glass a new spiritual sense and utopic possibility both in a manifesto and novels. Also the French authors André Breton and Louis Aragon would explore the glass at the arcades in surrealist novels. Scheerbart would be of great impact to Bruno Taut's early works and publications on modern architecture, Taut's book *Alpine Architecture [4]* and the construction of the Glass Pavilion for the 1914 Werkbund (Figure 5) were among the first works to present colorful glass as a medium of modern spirituality, architecture and industry. On the other hand, Breton and Aragon would be the bases of Benjamin's critics of bourgeois privacity and defense for a transparent glass architecture of the

Figure 3. Il Vetro magazine covers

Source: Instituto Bardi

[3]Other famous palaces of glass and iron besides the English Crystal Palace were the French Galerie des Machines and Grand Palais.

Figure 4. Bureau of Standards making extensive tests of glass building blocks (Washington DC)

Source: Library of Congress

proletariat, one that could not bear traces of ownership.

Another major debate was in the meaning of the American skyscraper and how to translate the typology to Europe. While the USSR saw the skyscraper as a symbol of American capitalism, even with important unrealized projects such as El Lissitzky's Cloud Iron, the German architects were among the first to correlate the stained-glass cathedral to the glass skyscraper. Be it on Bruno Taut's *Stadkroner* [5], or on Walter Gropius' *Bauhaus Manifesto* cover illustrated with Lyonel Feninger's *Cathedral*, the skyscraper was understood as a modern spiritual equivalent to the historical cathedral [6].

In the Americas, Frank Lloyd Wright explored the possibilities of both stained-glass and transparent glass panes, as a medium that could overcome classicism and achieve a true representation of the modern ways of the United States [7]. The Larkin Building, famous for its glass skylights over the atrium, was deeply connected to a religious sense of work with its salomonic floor plan, carved inscription and a pipe organ. The later Johnson Wax Building had a more industrial and practical application of Pyrex glass, still the architect had planned the installation of a pipe organ to the main office. On the other hand, Albert Khan was applying glass skylights and glass curtain walls to all his designs of Ford Plants to improve working conditions and reduce operation costs. 20th century industrial plants were almost a new form of architecture in themselves, one that demanded new technologies and material applications. If there was the skyscraper, there were also the industrial plant inserted on the debate of the modern cathedral, it is not casually that Peter Brehens' AEG Factory was nicknamed "cathedral of work".

Still, it was transparent glass over its colorful counterpart that became the general norm to modern architecture. As Scheerbart and Taut were both debating over the spiritual sense of modernity, Le Corbusier and Walter Gropius were focusing on the technical applications and social benefits. Glass was not only the material to build a new transparent society after the Great War, as Beatriz Colomina's *X-Ray Architecture* [8] attest, glass was a material correlated to new sanitary measures against tuberculosis and other diseases. Sanatoriums were also a modern form where glass flourished, Alvar Aalto's Paimio Sanatorium being one of the exemplary cases of the relation of modern architecture, health and glass; however the same could be applied in a private dimension to Neutra's Lovell House and Mies van der Rohe's Tugendhat Villa (Figure 6).

What becomes clear from the 20th century debate is that there isn't a single common root or a primordial form of glass architecture. Even Paxton's Crystal Palace, being the most prominent candidate to the position, is a parallel event to the arcades of Paris, which cannot be considered as isolated from the city. However, it is possible to search for traces and correlations between different works in their historical context. As such, the Crystal Palace was a development of the techniques applied on the construction of English greenhouses, and the arcade of Paris were consequential to the urbanization of Paris from the late 18th century. While technology can partially explain the development of glass, it lacks means to explain the social reality behind glass architecture. Therefore, a typological study opens the possibility to create a non-exclusionary presentation of glass architecture, one that is capable of a critical reading of most works along a chronological distribution.

Figure 5. Bruno Taut's Glass Pavilion for the 1914 Werkbund
Source: Wikimedia Commons

Typology dictates both about constructed space and human interaction with space, if typology can be reduced to a list or diagrammatic distribution of spaces, it is meaningful only with human action on the space. Since glass architecture doesn't have a single theoretical root, it also doesn't have a single typological origin, opening the possibility to parallel typological developments. While it is straightforward with the arcades of Paris —because they can be traced as an origin point for the typological sequence of commercial galleries, department stores and even shopping centers—, the Crystal Palace, being the first exhibition palace, is typologically in between two distinct functions and spatial dimensions. As it's possible to trace back the structure of glass and iron to the greenhouse and the later to stone and glass orangeries of royal palaces, from the Crystal Palace onwards there is a development of typologies focused on human interchange such as other exhibition palaces, modern expositive pavilions and convention centers.

Modern Pavilions are another key typology to understand the development of glass architecture, many were constructed both as synthesis of an ideal and a proof of concept for architecture. All of them were built as temporary structures where architects experimented with new construction techniques and materials. Bruno Taut's Glass Pavilion, Le Corbusier's L'Esprit Nouveau Pavilion and Mies van der Rohe's Barcelona Pavilion are some of the most iconic examples that explored glass in relation to architecture; but specially with Le Corbusier and Mies van der Rohe it is possible to note a development of a language of glass architecture expressed in a synthetic manner on their pavilions. The same can be said of Oscar Niemeyer and Lucio Costa's New York Pavilion for the 1939 World's Fair in the context of Brazilian Modernism while the first major work, the Ministry of Education and Public Health, was still under construction.

In the works of Mies van der Rohe, with both the Tugendhat Villa and Barcelona Pavilion, it is possible to note a correlation of modern pavilion and glass house. This correlation is also present in Le Corbusier and Niemeyer, among other early 20th century architects. As glass architecture consolidated itself as a modern language, the mid-century architects constructed a considerable amount of their glass houses in reference to early pavilions and glass houses. Philip Johnson and Lina Bo Bardi are prime examples of mid-century glass house architects.

Still, this transition from the pavilion typology to the glass house typology is an ample one, the glass house or modern house are both a convergence of the experiences of the modern pavilion with the traditional bourgeois house due to the clients' social status. Therefore, the glass house possesses a social dimension in relation to its owners and easily typological study becomes a biography of the relation of house and owners. While Dr. Edith Farnsworth complex relation with Mies' Farnsworth House is the most commonly known and well-documented example, here we should turn our attention back to Lina Bo Bardi and Pietro Maria Bardi with their *Casa de Vidro* (Figure 7):

The Bardi's history is interchangeable with the Museum of Art of São Paulo, with Pietro being the first director of the institution and Lina being the chief architect of the building at Avenida Paulista. Before the present day museum, Pietro and Lina organized

Figure 6. Mies van der Rohe's Tugendhat Villa

Source: Wikimedia Commons

Even when the network of guest houses was abandoned as a project, the main hall kept its concept as public space inside the private sphere. Pietro Maria's business as both director of MASP and art dealer made the place a diversified art gallery, and Lina's collections of Brazilian regional crafts juxtaposed high arts with local craftsmanship. Trees and other plants created a green landscape around the house as Morumbi was integrated in the urban landscape as an elite neighborhood. Glass transparency that was once defined by the hills, horizon and sky became a close shadow play of trees and nature (Figure 8).

the first gallery of MASP at Rua 7 de Abril, *while not in a proper sense a "pavilion" or glass architecture for the matter, it was an important experience on expography and museography, and Lina would adopt some solutions both in her glass house's bookshelves and in the new museum main exhibition hall*[4].

The *Casa de Vidro* was conceived as an extension of the cultural program of MASP, a centerpiece on a network of guest houses to be constructed for artists and curators that Bardi exchanged letters and critical essays. As such, the main hall glass of the *Casa de Vidro* with its dining room, living room and office was designed as a room for this network of houses, facing with three complete glass facades the landscape of an unoccupied suburb of Morumbi in São Paulo. Lina's glass house also kept a courtyard disposition of private spaces with a clear division between the owner's rooms and service spaces, striking an interesting equilibrium of modern lifestyle and traditional praxis.

Figure 7. Glass house's bookshelves designed by Lina Bo Bardi

Source: Instituto Bardi

[4]The second concrete-enclosed gallery of MASP at Avenida Paulista resembles to a certain degree the space *Rua 7 de Abril* gallery with a museographic approach varying with curatorship.

Figure 8. Reflections on the glass of the facade of the glass house

Source: Yghor Boy/Instituto Bardi

The MASP at the bustling Avenida Paulista also establishes a relation of art and landscape through glass in the main exhibition hall: as the southwest facade opens a view to the top of the trees at Trianon Park, the northeast facades creates a vista to the axis of Avenida 9 de Julho and the historic city center. While most of the time the facades are not completely open to the landscape to protect the art from adverse effects of sunlight, the "glass easels" (Figure 9) supporting the paintings create a "collage-effect" inside the main exhibition hall, with the visual juxtaposition of styles and ages.

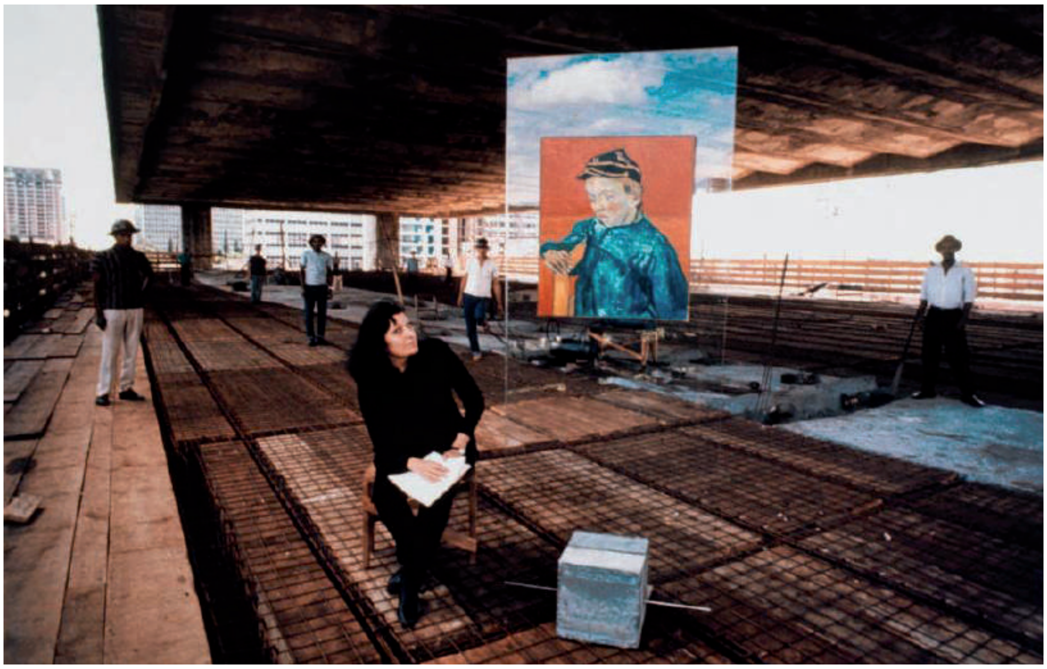

Figure 9. Lina and the "glass easel". MASP main exhibition hall under construction.

Source: Lew Parrella/Instituto Bardi

Glass architecture came to build not only a new perception of space and art, but a new material reality for cities across the globe. From idyllic houses to monolithic towers, glass became a common shared experience of modern and contemporary lifestyle; but it also became part of a problem as much as a technical solution. As one of its advantages is transparency and heating through solar radiation, its widespread use disregarding local climate leads to an increasing consumption of electricity and resources through air-conditioning machines, and both transparency and reflexivity contributed to the formation of urban heat islands and overall increase of a city's temperature. For that, the glass and glazing industry offers many technical solutions, and advances are now moving towards the construction of buildings that are energy neutral or even can contribute to the energy grid.

So, if Walter Benjamin argues that in the first half of the 19th century it was still known how to build with glass in the heights of the Industrial Revolution, today one could say that in the first half of the 21th century we are undoubtedly expanding the knowledge on how to build an environment-aware glass in the age of climate changes. Glass architecture goes beyond the debate of ethics and aesthetics, it is the practical reality of cities and can be an integral part of an environmental solution to contemporary challenges. The International Year of Glass presents this unique opportunity to recapitulate the past two hundred years of glass architecture and think of a new future for the city of glass, to overcome its challenges and create new social perspectives. It allows architecture to go beyond the traditional constraints of the disciplinary field and be part of a coordinated debate about glass.

To a certain degree, the International Year of Glass reinserts the debate of glass architecture in the 2020s and opens up the possibilities to review what was discussed only as utopies in the 1920s, perhaps even speculate what new typologies could develop from contemporary glass and new technological means of production. If there is urgency in solving pressing matters today, glass architecture should also concern with what comes of tomorrow as once it was seen as a clear future in itself.

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REFERENCES

1. Tentori (2000): 150-152. Esmeraldo, E. G. (2020): *AMER. A primeira América de Bardi: diário de bordo de P. M. Bardi (1933-1934)*, Unicamp.
2. Benjamin, W. & Tiedemann, R. (1999): *The arcades project*, Cambridge, Belknap Press: 150.
3. Benjamin, W. & Tiedemann, R. (1999): *The arcades project*, Cambridge, Belknap Press: 154.
4. Schirren, M. (2004): *Bruno Taut, Alpine Architektur. Eine Utopie, A Utopia*, Munchen, Prestel: 36.
5. Taut, B. (2015): *The City Crown*, Surrey, Ashgate Publishing.
6. Tafuri, M. (1987): *The Sphere and the Labyrinth: Avant-Gardes and Architecture from Piranesi to the 1970s*, Cambridge, MIT Press: 125.
7. Wright, F. (2008): *Modern Architecture: being the Kahn lectures for 1930*, Princeton, Princeton University Press: 38.
8. Colomina, B. (2019): *X-Ray architecture*, Zürich, Lars Müller Publishers.

FURTHER READING

1. Benjamin, W. (1986): "Surrealism: The Last Snapshot of European Intelligentsia", in S. E. Bronner & D. M. Kellner (editors), *Critical Theory and Society*, Routledge.
2. (1999): "Experience and Poverty" in *Walter Benjamin: Selected Writings* Vol. 2, Harvard University Press.
3. Benjamin, W & Tiedemann, R. (1999): *The arcades project*, Cambridge, Belknap Press.
4. Colomina, B. (2019): *X-Ray architecture*, Zürich, Lars Müller Publishers.
5. Esmeraldo, E. G. (2020): *AMER. A primeira América de Bardi: diário de bordo de P. M. Bardi (1933-1934)*, Unicamp.
6. Gropius, W. (1965): *The New Architecture and the Bauhaus*, Cambridge, MIT Press.
7. Le Corbusier (1964): *When Cathedrals were White*, McGraw-Hill Paperback.
8. Le Corbusier; Sirton, P. & Berton, T. (2012): "Glass the Fundamental Material of Modern Architecture", *West 86th: A Journal of Decorative Arts, Design History, and Material Culture*, 19 (2)
9. Schirren, M. (2004): *Bruno Taut, Alpine Architektur. Eine Utopie, A Utopia*, Munchen, Prestel.
10. Tafuri, M. (1987): *The Sphere and the Labyrinth: Avant-Gardes and Architecture from Piranesi to the 1970s*, Cambridge, MIT Press.
11. Taut, B. (2015): *The City Crown*, Surrey, Ashgate Publishing.
12. Wright, F. (2008): *Modern Architecture: being the Kahn lectures for 1930*, Princeton, Princeton University Press ■

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Digitalisation drives Innovations in Glass Inspection

Mr. Hans Renders explains how digitalisation of container inspection, as embodied in Heye's SmartLine 2 inspection machine, continues to advance, bringing increased speed, accuracy and efficiency to glass manufacture.

Pressures on customers' businesses drive innovation in glass manufacture. Heye's development of new inspection equipment responds to these market demands, which are currently dominated by two trends: premiumisation and the journey to net zero.

Premiumisation and customisation – as brand owners seek further differentiation through packaging design - make inspection more challenging. Glass manufacturers have to meet demand for more non-round, complex shapes and more mini-ware (as sampling and tasting become ever more important ways to launch new ranges in the drinks industry). Special operations like mini-ware and non-round containers are standard with Heye's SmartLine 2.

Simultaneously, the packaging industry must also meet the need to restrict emissions throughout the supply chain. Heye constantly updates its inspection technology to deal with these challenges because increasing inspection efficiency reduces false positive ejection and energy consumption and keep costs down for customers. Digitalisation and AI contribute strongly to the development.

Automated production driven by smart technology makes machine-powered processes more efficient, ultimately reducing raw material use, energy consumption and CO_2 emissions.

Heye uses AI extensively in the new software to train machines to read and react to different faults but also to understand when what may previously have been thought a fault is actually a design feature of the new container. This is explicitly demonstrated by the new AI-enabled Mould Number Reader KSL3.

A COMPREHENSIVE SUITE OF HI-TECH INSPECTION TOOLS

At the heart of Heye's operation is the HiSHIELD SmartLine 2 which integrates the newest technology combined with robust electrics and an electronic control system. Working at speeds of up to 400 articles per minute, up to six inspection stations can be configured from a wide menu according to users' needs.

The application of servo technology results in a high degree of flexibility. Fast and easy changes to an item's indexing positions and optimal use of the servo torque for up to four rotation stations are possible. Optimised motion sequences allow faster reactions to changing process parameters. The equipment's innovative design and its large and easy-to-open hood provide more working space between the inspection stations. Job changes become much easier.

The most up-to-date SmartLine 2 features extensive non-contact enhancements which include bore gauge, diameter and ovality inspection and wall thickness. One major advantage is that Heye uses the superior chromatic-confocal method, which is much more precise than other solutions. These non-contact features are available for retrofitting onto original SmartLine 2 machines.

Check detection is one of the most important quality inspections during

the production of glass containers. The HiSHIELD Ranger 2 enables manufacturers to fulfil the quality expectations of your customers when it comes to eliminating critical defects.

It has proved time and again to detect more than 99.8% of all critical defects.

Ranger 2 is now able to inspect pharmaceutical mini-ware. With this evolution the system can fulfill all customer requirements to container sizes and shapes.

AI INSPIRES LATEST DEVELOPMENTS

The latest addition to the glass manufacturer's arsenal of inspection technology is Heye's new Mould Number Reader KSL 3. This innovation is at the forefront of digital, non-contact inspection, utilising AI (machine learning) to improve its own performance during operation.

It has two aims. Step One is the systematic ejection of ware from faulty moulds at the cold end, by scanning mould numbers even where they are not especially well defined. Step Two is the correlation of detected defects to repeating mould numbers and communicating this to the Hot End.

Older mould number readers sometimes struggle to recognise badly defined numbers. These are typically caused by faulty or worn embossing in the moulds. KSL 3 features a new evaluation algorithm, based on artificial intelligence which it uses to train itself to learn shape number deviations. These technologies allow the system to be set up faster and mould numbers that were previously not readable can now be read.

The result is that the KSL 3 increases the correct reading rate to over 99 percent of mould numbers. It also extends the equipment's ability to recognise standard digital mould and alpha numeric codes that are available on the market.

The simplified and intuitive Graphical User Interface (GUI) speeds up identification and enables more effective record keeping.

This data feeds all aspects of the production process. PlantPilot Information Management connects Cold End and Hot End and enables sifter rectification of identified problems within individual mould sections. The system collects and aggregates data from different sources and shares information on the spot. Tracking and tracing as well as the possibility of creating user-specific analysis are additional components, allowing continuous improvement processes to increase productivity.

On SmartLine 2 we constantly reduce mechanical elements and enhances the non-contact, digitised components of the inspection system. Powered by Industry 4.0, the new mould number reader augments the HiSHIELD suite of digital and non-contact inspection equipment to create a cutting-edge Cold End system to remove defective articles.

ABOUT HEYE INTERNATIONAL

Based at Obernkirchen, Germany, Heye International GmbH is one of the international glass container industry's foremost suppliers of production technology, high performance equipment and production knowhow. Its mechanical engineering has set industry standards for more than five decades. Extensive industry expertise, combined with the positive attitude and enthusiasm of Heye International employees is mirrored by the company motto 'We are Glass People'. Its three sub-brands HiPERFORM, HiSHIELD and HiTRUST form the Heye Smart Plant portfolio, addressing the glass industry's hot end, cold end and service requirements, respectively.

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A variety of Applications of Glasses - Part I

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Abstract

In various issues of Kanch on glasses during the last ten years or so, articles have been written on various types of glasses. For these types of glasses, one or more applications for a given glass have been mentioned to keep the readers abreast with the nature of such applications. In some issues of Kanch some of these applications have been elaborated with more details not only to get in-depth knowledge or rather get acquainted about such glasses but also different merits and demerits of such applications that are useful from the point of view of marketing. Various aspects of marketing and business angles have been highlighted in some of the cases that are relevant in today's competitive 'glass markets'.

In 2016, it was decided by AIGMF to compile all such activities up to this period in the form of a proper book **[1]**. Some of these applications that were included in subsequent issues of Kanch after March 2016, also need to be further elaborated. For the benefit of readers, the most important applications are compiled here so that a ready reference could be handy and dissemination of knowledge could be made to various government agencies as well as to various concerned Private sector entities. In Part - I of the paper flat or sheet glasses are described.

INTRODUCTION

It is very well known that by mixing various ingredients with silica sand as the main component that works as the network former and a range of other components, oxide glasses are mainly produced for a variety of applications as container glasses, float glasses, etc. of a variety of shapes and sizes. The latter with usage in construction are sheet glass in various forms as a very useful building material, while the former finds usage in a variety of areas as containers for food items, bottles for various drinks, laboratory glasses, storage for chemicals, etc.

There is no denying the fact that glass engineers as well as architects have more or less equal contribution in this field of construction activity for both domestic and commercial buildings. In this context, some special glasses such as laminated glass, wired glass, toughened glass etc. need a proper mention. The latter also has applications in the field of automotive industry as safety glasses. Most of these issues have been discussed in several articles in Kanch in the past **[1-3]**.

By controlling the melting and refining processes, many properties of glasses can be controlled, whereas chemical constituents play a major role. By engineering the chemical composition of glasses, a variety of new glasses can be made. All these are in the realms of various applications that are of great importance. Without making too much exaggerations, it could be safely said that glass touches our human life like no other material in the world **[1]**. Some of the applications are detailed below encompassing a wide range of glasses.

In the construction industry, there are various types of glass used for different purposes. The engineering properties and uses of these glasses are worth discussion. Glass is a hard substance which may be transparent or translucent and obviously brittle. The fusion process is used to manufacture glasses. In this process, sand is fused with lime, soda, and some other admixtures in a glass tank furnace with a refining zone at the end to get rid of bubbles, cords, etc. and the viscous glass is given a desired shape and then cooled rapidly

Figure - 1: Glass sheet is used as a Building Envelope

in an annealing furnace to get rid of stresses so that the glass gains its strength. Glasses used in construction purposes and architectural purposes in engineering. A typical glass envelope is shown in Figure-1.

For discussion, the choice of some Engineering Properties of glass are needed:

- Transparency
- Strength
- Workability
- Transmittance
- U value
- Recycling property

1. TRANSPARENCY OF GLASS

Glass is known to be transparent **[3]**. Transparency is the main property of glass which allows the visibility of the outside world through it. Hence it is used extensively for the building construction industry - both residential and commercial - mainly for the latter increasing the total sales volume. The transparency of glass can be from both sides or from one side only. In one side transparency, glass behaves like a 'mirror' from the other side.

2. STRENGTH OF GLASS

It is known that chemically glass can be made stronger. Aluminum ions inside glass always improves mechanical properties of glass. For chemical toughening, bigger ions are made to enter smaller ionic holes thereby creating compression and the glass becomes stronger. The strength of glass depends on the value of the 'modulus of rupture'. In general glass is a brittle material but by adding 'admixtures' and 'laminates', we can make it stronger. Glasses can also be stronger by 'thermal toughening' via stress removal/distribution inside the glass.

3. WORKABILITY OF GLASS

In all glasses, depending on the viscosity, various glass items are fabricated in different shapes and sizes. For every type of glass, there is a "working range" of viscosity when the viscosity is higher than that in the molten condition. A glass can be moulded into any shape, or it can be blown during melting. So, workability of glass is a superior property.

4. TRANSMITTANCE

The transmittance depends on the presence of transition metal ions that give rise to absorption thereby reducing the light transmission through the glass piece. The visible fraction of light that passes through glass is the property of visible transmittance. Very low quantities of metal ions give rise to very high transmission.

5. U VALUE OF GLASS

U value represents the amount of heat transferred through glass. If a glass is said to be insulated, i.e. heat does not pass through glass in a relative sense, then it should have lower U value. In order to keep the room cooler, the U value should be very low so that heat transmission does not take place to a significant extent.

6. RECYCLE PROPERTY OF GLASS

One of the most important aspects of glass properties is that it can be added to existing raw material batches thereby reducing not only the cost of batch, but also requiring less thermal energy to melt. Any glass can be 100% recyclable. In a given glass melt, about 25% (sometimes more) broken glass can be safely added after crushing it to small pieces. These are called "cullets". The use of more cullets makes economic sense in the production of glasses. It can also be used as raw material in the construction industry.

The types of glass used in the construction of buildings are:

- Float glass
- Shatterproof glass
- Laminated glass
- Extra clean glass
- Chromatic glass
- Tinted glass
- Toughened glass
- Glass Blocks
- Glass Wool
- Insulated Glazed units

1. Float Glass

Float glass is manufactured from sodium silicate and calcium silicate, so it is also called soda-lime glass. It is clear and flat, so it causes glare. Thickness of the float glass is available from 2 mm to 20 mm, and its weight ranges from 6 to 36 kg/m^2. The application of float glass includes shop fronts, public places, malls, wall separation, staircase sides, etc. A typical set of float glass is shown in Figure-2.

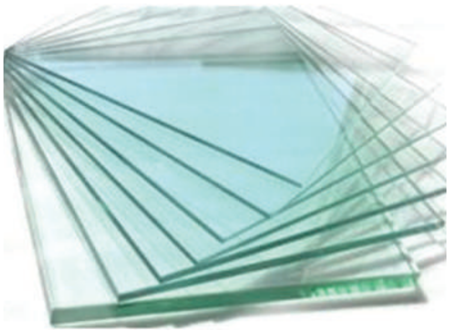

Figure - 2: A set of Float Glasses

2. Shatterproof Glass

Shatterproof glass is used for windows, skylights, floors, etc. Some type of plastic, i.e. polyvinyl butyral, is added in its fabrication process. So, it cannot form sharp-edged pieces when it breaks or shatters causing no damage to humans.

3. Laminated Glass

Laminated glass is the combination of layers of ordinary glass. So, it has more weight, thickness and is UV proof, and it is also soundproof than a regular glass. These are used for aquariums, bridges, and safety glasses such as automobile windscreen, side windows, etc. **[5-8]**

4. Extra Clean Glass

Extra clean glass has two unique properties, photocatalytic and hydrophilic. Because of these properties, it acts as stain proof and gives a beautiful appearance. The maintenance of such glasses is also easy.

Figure - 4: Laminated Glass Used in Building Construction

5. Chromatic Glass

Chromatic glass is used in ICU's, meeting rooms etc. it can control the transparent efficiency of glass and protects the interior from daylight. The chromatic glass may be photochromic which has light sensitive lamination, thermos-chromatic which has heat sensitive lamination and electrochromic which has electric lamination over it.

Figure - 5: Extra Clean Glass

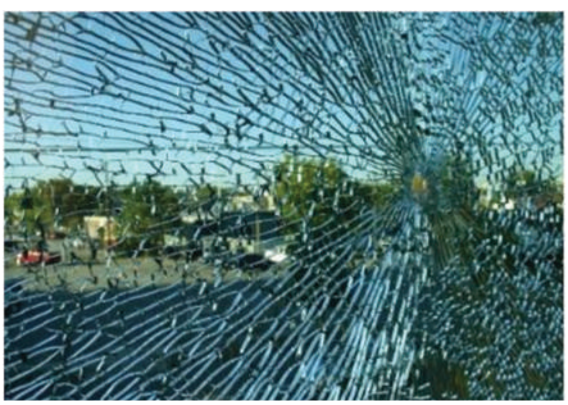

Figure - 3 A typical glass piece shattered by mechanical impact

6. Tinted Glass

Tinted glass is nothing but colored glass. A color producing ingredient is mixed to the normal glass batch to produce coloration which does not affect other properties of glass. Different color-producing ingredients are tabulated below:

Table 1: Different Types of Ions Used to Produce Various Colors in Glasses

Coloring ion	Color
Iron oxide	Green
Sulphur	Blue
Manganese dioxide	Black
Cobalt	Blue, Orange
Chromium	Dark green
Titanium	Yellowish brown
Uranium	Yellow

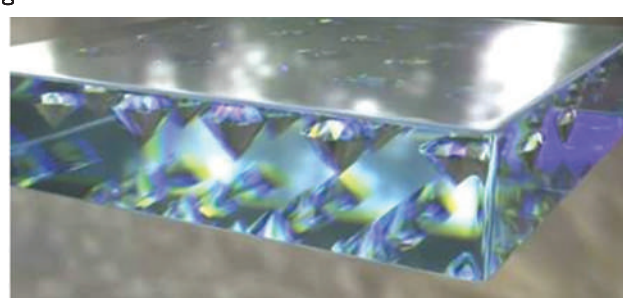

Figure - 6: Chromatic Glass

7. Toughened Glass

Toughened glass is a durable glass that has low visibility. It is available in

Figure - 7: Glass Block

all thicknesses, and when it is broken it forms small granular chunks that are dangerous. This is also called tempered glass. This type of glass is used for fire-resistant doors, mobile screen protectors, etc. **[6]**.

8. Glass Blocks

Glass blocks or glass bricks are manufactured from two different halves and they are pressed and annealed together during the melting process of glass. These are used for architectural purposes in the construction of walls, skylights etc. They provide an aesthetic appearance when light is passed through it.

Figure - 8: Blocks of Glass Wool

9. Glass Wool

Glass wool is made of fibers of glass and acts as an insulating filler. It is fire-resistant glass. It is extensively used in the construction of factories.

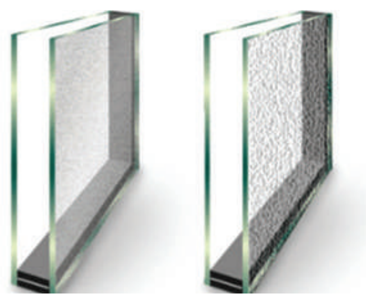

Figure - 9: Insulated Glazed Glass Unit

10. Insulated Glazed Units

Insulated 'glazed' glass units contain a glass separated into two or three layers by air or vacuum. They cannot allow heat through it because of air between the layers and acts as good insulators. These are also called double glazed units.

CONCLUSIONS

In the construction of buildings for both residential and commercial usages, the application of glasses is assuming a great importance. For residential purposes, the use is mainly made in the windows, but it is also partially used as bedroom and bathroom doors. In this case, the glass is mainly non-transparent. It can also be used with half wooden panels and half glass sheets for separation walls, as in the case of commercial offices. In the commercial arena, there are many more applications, such as shop fronts, public places (cabins, counters, etc.), windows, skylights, floors, aquariums, bridges, staircase sides, protection walls, stain proof, aesthetics, ICU in hospitals, meeting rooms, insulations, wall constructions, fire-resistant doors, and mobile screen protectors, etc.

In Part-II of the paper, more applications will be elaborated.

REFERENCES

1) A. K. Bandyopadhyay, "Glass - a Sustainable Building and Packaging Material", published by Vinit Kapur on behalf of AIGMF, New Delhi, (March, 2016).
2) A. K. Bandyopadhyay, "Technology of Float Glasses", Kanch, Vol. 5[3], (2012), 33-36.
3) A. K. Bandyopadhyay, "Transparency in Float Glasses and some Applications", Kanch, Vol. 2[3], (2014), 23-26.
4) N. D. Branz, "Recyclability of Laminated and Toughened Glass", http/www.level.org.nz, 2015.
5) S. J. Bennison, et al, "High performance Laminated Glass for Structurally Efficient Glazing", Intl Conf. (Hong Kong), 2008.
6) A. K. Bandyopadhyay, "Toughened Glass", Kanch, Vol. 7[4], (2019).
7) J. Schimmelpenningh, "Acoustic Interlayers for Laminated Glass – What makes them different and how to estimate performance", *Glass Performance Days South America, 2012*.
8) Zhang et al., "Lab Test and Numerical Simulation of Laminated Glass Windows to Debris Impact", Intl. J. Impact Engg., Vol. 55, (2013), 49-62 ■

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Using microwave heating to improve batch melting speed

Khaled Al-Hamdan, Sven Wiltzsch, Ralph Behrend, Valerie Grimm, Hartmut Krause and Wolfram Wintzer discussed with *Glass Worldwide* (preferred AIGMF international journal) enhanced microwave absorption in glass batch through batch pre-treatment and alternative raw materials.

The question of the efficient use of resources, reduction of emissions and 100% application of renewable energy is a primary goal for environmental policy and of strategic interest for the glass industry. One vision for the future concerns the process heat in glass melting tanks being mainly produced with electrical energy. An efficient use of electrical heat on a larger scale could therefore be microwave heating, and especially microwave glass melting.

According to our measurements, raw batch materials show penetration depths for microwaves in the range of 0.4m to 4m, depending on the temperature and composition.[1] In the case of glass melts at melting temperature, the penetration depth of the electromagnetic radiation is very small: a maximum of 1cm, which is lower than heat radiation. Thus, one could say that microwaves are less advantageous for glass melt heating at melting temperature in comparison to standard technology.

However, the batch melting area has to be evaluated completely differently! Here, the microwave offers the possibility of 'inside out' heating – a method most are familiar with from heating food in the microwave. Furthermore, in glass melting the most energy-intensive step is the primary melting of the main raw material components (roughly 80%). Thus, microwave heating in the batch melting zone[2] could be a 'melting booster', or a technology for the batch melting of sensitive glasses which cannot be melted easily with standard technology. In both cases, the improvement from 'inside out' heating, and correspondingly the absorption of the microwave by the batch (microwave coupling) is of special importance.

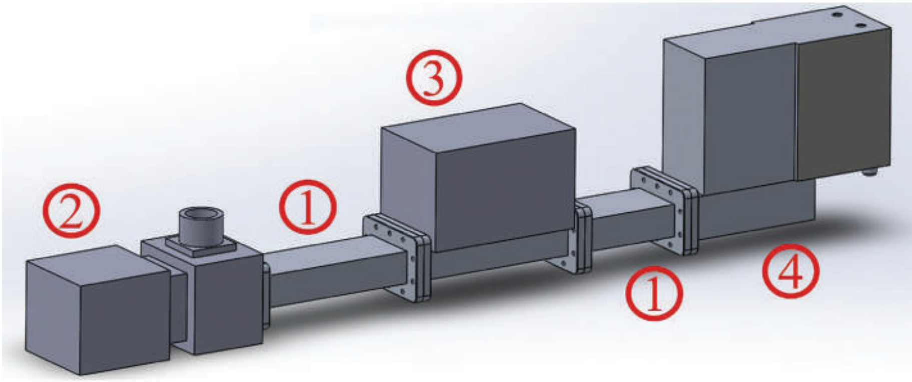

Figure 1: Apparatus for carrying out the comparative melting tests. 1) Waveguide; 2) Applicator with moving short; 3) Reflectometer and Tuner; 4) Magnetron.

Research parameters and microwave furnace

The aim of the investigations presented here is to evaluate the various influences when using microwave technology for the heating of raw materials, and thus to expand the possible applications for electric heating in the glass industry. The research parameters were:

- Raw materials (oxides, hydroxides)
- Cullet content (batch without cullet; batch with 50% cullet)
- Grain size of the raw materials (standard size and fine grain size)
- Batch preparation (standard loose batch; compacted batch[3])

The above-mentioned investigations were carried out with common raw materials and batches for container glasses.

The comparative melting tests were conducted in an apparatus consisting of the basic components of the microwave system for glass melting experiments, with the magnetron rated for power up to 3kW (see Figure 1). The applicator consisted of an aluminium housing (see Figure 2) with optical access and microwave filters for temperature measurement.

The tests were carried out in a crucible with a power input of 600W, and 20g of batch samples were irradiated with microwaves for 10 minutes.

Experiment results and discussion

a) Effect of microwave batch melting and compacting:

Figure 3 shows the heating curve progression of a loose batch and a compacted batch, both heated with microwaves. From the diagram, the following can be seen:

- The microwave coupling for both batch samples started in the same temperature region of 300–400°C, with a sharp increase in temperature within half a minute. The maximum temperature corresponds to a stationary melting temperature and this stationary phase demonstrates a relative low power input from the microwave into the glass melt. We see that microwave ▸


Figure 2: Applicator with moving short.

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Originally published in Glass Worldwide, preferred international journal of AIGMF

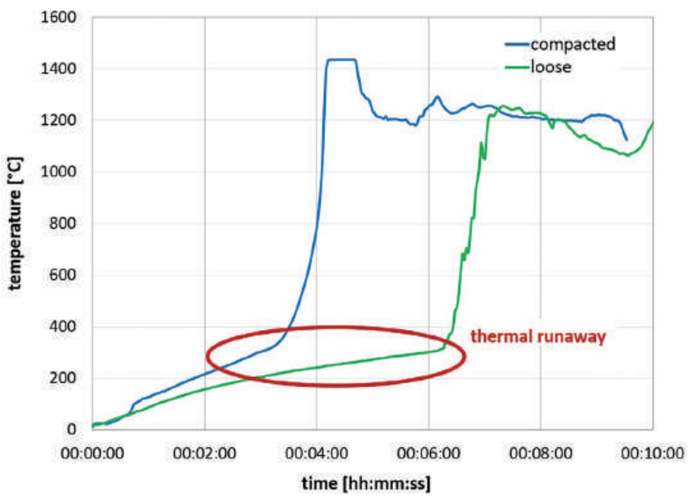

Figure 3: Heating curve progression of a loose batch and a compacted batch, both heated with microwaves.

heating is favourable for batch melting, but not for heat transfer into the glass melt.

- The batch melting is very fast! And compacting the batch further decreases batch melting time, offering a 50% faster rate compared to the standard loose batch.

b) Effect of cullet, grain size of raw material and oxides/hydroxides instead of carbonates:

The influence of cullet, grain size of the raw materials and application of carbon-free raw materials for soda and limestone on microwave heating is presented in Figure 4. In these experiments, the specific energy required to melt a 1kg batch inside the microwave furnace is used as a performance indicator of the microwave heating. Here, a low specific energy value indicates a fast batch melting.

From Figure 4 it can be concluded that the following measures are helpful to improve the energy efficiency or the batch melting speed by microwave heating, in this order:

1. Use of carbonate free raw materials such as CaO and NaOH
2. Use of fine raw materials
3. Use of cullet

From an environmental point of view, using carbonate-free raw materials and cullet might be preferable when using microwave heating. However, it should be mentioned here that carbonate-free raw materials cannot be taken for granted due to their specific technological challenges, which also need to be solved in the future.

Acknowledgments

Parts of this research were carried out in the framework of the Central SME Innovation Programme (ZIM). It was supported by the Federal Ministry for Economic Affairs and Energy (BMWi) through the AiF (German Federation of Industrial Research Associations eV) based on a decision taken by the German Bundestag. ●

1 DAPHNE, "Development of adaptive Production systems for Ecoefficient firing processes" Project ID: 314636, Funded under:FP7-NMP.

2 Wiltzsch, S. "Theoretische Betrachtung des Glasschmelzprozesses in Glasschmelzöfen" Dissertation Freiberg, 2014.

3 Al Hamdan, K.; H. Hessenkemper, "Herstellungsverfahren eines Agglomerierten Glasgemenges" europäische: Patent 2528872. 2015.

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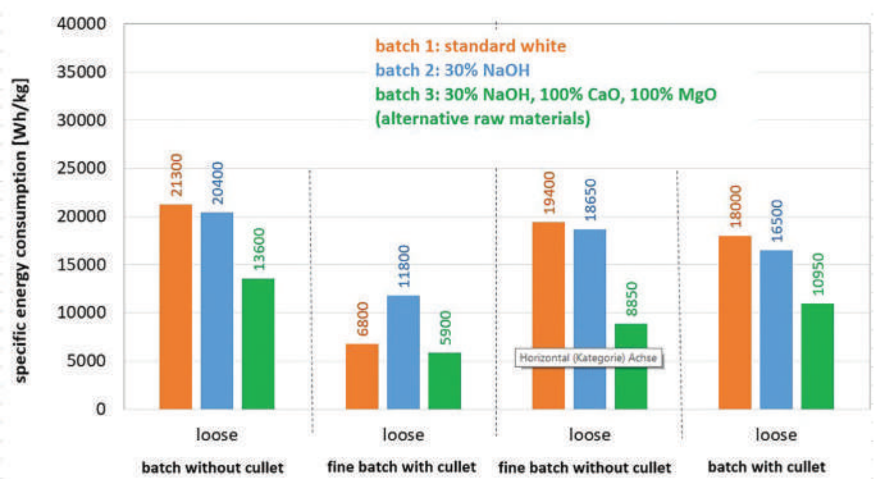

Figure 4: Specific energy required to melt 1kg batch inside the microwave furnace as a function of batch properties.

Better measures required for building renovation

GLASS FOR · EUROPE

To decarbonise the EU building stock and boost its sustainability, the European Commission is on the right track, but it needs to accelerate, advises Bertrand Cazes (originally published in *Glass Worldwide,* preferred international journal of AIGMF and Glass for Europe).

Bertrand Cazes, Secretary General of Glass for Europe.

glass WORLDWIDE Preferred journal of Glass for Europe

With the objective of boosting the rate and depth of building renovation in the European Union, in December 2021 the European Commission released a proposal to recast the Energy Performance of Buildings Directive (EPBD). The revision of the Energy Performance of Buildings Directive is part of the Commission's 'Fit for 55' package [to reduce net EU greenhouse gas emissions to 55% below 1990 levels by 2030] and sets the vision for achieving a zero-emission building stock by 2050.

Glass for Europe, the trade association for Europe's flat glass sector, believes that the proposal is future-proof and aligned with the 2050 carbon emission reduction ambitions when it comes to its provisions on new buildings. However, since most buildings that will be used in 2050 are already constructed, more efforts are expected on existing buildings. In the coming months, the compromise between the European Parliament and the Council will be crucial to ensure the success of the policy framework and put Europe on the right track to becoming the first climate-neutral continent.

"The EC proposal has the merits of trying to bring into the legislation some of the proposed measures that were part of the Renovation Wave strategy", says Bertrand Cazes, Secretary General of Glass for Europe. "These measures need to be fine-tuned and added substance so that they can deliver their full impact and drive upward both the quantity and depth of building renovation," he concluded.

A zero-emissions building stock by 2050

Glass for Europe supports the increased drive to deliver zero-emission building stock. Windows equipped with high-performance glazing have the potential to deliver up to 75.5mtoe [millions of tonnes of oil equivalent] of energy savings in 2030, which corresponds to an annual CO_2 emissions avoidance of up to 94.2 million tonnes. Half of this could be achieved in 10 years just by doubling the current window replacement rate.

The zero-emissions goal for building maintains the EPBD's focus on energy efficiency and opens the opportunity for EU Member States to give more prominence to healthy indoor climate conditions. While not expressly specified, this should include the availability of daylight. Glass is the only component of the building covering that provides thermal insulation, access to natural light and a visual connection to the exterior. The benefits of access to natural daylight on human health are widely acknowledged in scientific literature and it is time to include measures ensuring natural lightning in all national legislations.

Supporting the Renovation Wave

The EPBD proposal [bases] several of its new measures on the Renovation Wave strategy which aims to double the renovation rate by 2030. Among these newly introduced measures, Glass for Europe supports the introduction of Minimum Energy Performance Standards (MEPS) as they could step up energy renovation and ensure the installation of energy efficient glazing solutions. The MEPS will be part of the National Building Renovation Plans that Member States will have to prepare to achieve higher energy performance classification in all building segments and stay on track towards a zero-emission building stock by 2050.

Other tools such as Energy Performance Certificates are being reviewed to become more reliable and allow better harmonisation across the EU. A new tool, 'renovation passports for buildings' is being introduced. These will equip building owners with works recommendations, possibly including windows retrofitting, when planning a staged renovation of a building.

Glass for Europe highly engaged

Glass for Europe regrets that the cost-optimality methodology used to define building components' minimum energy performance requirements, among other things, will not be reviewed before 2026. It is a missed opportunity to improve the assessment of the energy performance of windows, thanks to the energy balance approach. Access to subsidies and information on financial measures will be facilitated by different new tools.

The flat glass industry is already delivering on the ground with its low-carbon solutions: high performance glazing to save energy from buildings and solar glass to contribute to on-site renewables. To ensure the flat glass and glazing industry can maximise its contributions to a decarbonised and sustainable building stock, Glass for Europe will work with policy makers to help finalise a robust revision of the EPBD. ●

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National Day of Glass Conference

(April 5–7, Washington, D.C.)

The American Ceramic Society hosted the National Day of Glass Conference from April 5–7 in Washington, D.C., to kick off North American-based celebrations of the United Nations International Year of Glass; as one of many glass-related events.

The conference was designed to showcase the impact of glass—past, present, and future—and was envisioned as a celebration of glass science, technology, engineering, education and art. It brought together leaders from academics, glass industry, glass art community, museums and government agencies.

The U.N. has declared International Years since 1959 to highlight industries, concepts, or ideals that promote its objectives. This year marks the first time the U.N. recognized a material with the International Year designation. Dr. Manoj Choudhary, Chair of the IYoG North American Steering Committee, noted that glass has an indispensable role in addressing 11 of the U.N.'s 17 sustainable goals.

Opening Remarks were delivered by Prof. Kathleen Richardson, Chair-National Day of Glass; Dr. Manoj Choudhary, Chair- North American Steering Committee and Prof. Reinhard Conradt, President International Commission on Glass.

Important topics covered on April 6 were: *The Age of Glass - Affirmation and Celebration; Glass – Vital to our Future; (Inspire + Transform) x Sustain = Glass; Shaking the Etch-a-Sketch of America's Innovation Ecosystem; Innovation and Invention: The Importance of Investments in Fundamental Science & Engineering; How Specialty Glass is Energizing our Future: Enabling Health, Energy, and*

Celebrating women working with glass during the opening reception for the National Day of Glass Conference. The reception was held at the National Academy of Sciences in Washington

D.C. Credit: ACerS

Sustainability; Pilchuck 50 years of International Glass Art Education; From University Research to Clinical Use- A Biomedical Glass Story; Discovering the Glasses of the Future using Artificial Intelligence; Educating and Training the Next Glass Generation Workforce; The United Nations International Year of Glass- 2022: A Dream Come True; American Glass Manufacturing - A Love Letter; Glass: An Indispensable Material for a Sustainable World; Foundational Role of Non-oxide Glass to enable Electrophotographic Printing and Creation of Xerox Corporation; Igniting a Fusion Energy Future with Optics and Photonics; Bending Light with Glass: Images from the Cosmos to the Microbe; The Second Decade of the Materials Genome Initiative; The Art of Glass: Three Millennia of Creativity and Expression; and Art and Glass in Society. The program on 1st day concluded with a Celebratory Banquet: Glass Art in our World.

On April 7, following topics were covered: *Research for the Glass Age; Breakthrough Technologies; Glass the Ultimate Sequester and Self-Sustaining Product; Glass Window: Past, Present, and Future; The Story of IPS e.max® Glass-ceramic in the Dental Industry and its Potential for the Future; The Role of Fiber Glass for Contribution to Strategic Development Goals; A Rose is a Rose is a Rose: What Colorblindness Reveals about Perception; Upcycling Waste Glass into High Value Planet-saving Materials; Glass and Lasers – A Bright Future; Infrared Glass – Transforming Imaging; Alfred University and Glass Science and Art; On the Shoulders of Giants and Seeing the Future through Glass.*

Alfred University Dean Emeritus Prof. David Pye first suggested the idea to have a National Day of Glass as part of the celebrations. Prof. Kathleen Richardson and Prof. Mario Affatigato picked up the mantle and organized the two-day event. Prof. Richardson is Pegasus Professor of Optics and Materials Science and Engineering at CREOL/College of Optics and Photonics at the University of Central Florida. Affatigato is Fran Allison and Francis Halpin Professor of Physics at Coe College.

"It was an incredible few days of celebrating all things glass. By welcoming a range of leaders from all sectors of our glass community, we were able to share diverse perspectives on the rich history and promising future that glass has in our world," says Prof. Richardson.

The program was designed to showcase the impact of glass—past, present, and future—and was envisioned as a celebration of glass science, technology, engineering, education, and art.

Think, for example, about windows. Several speakers noted that the invention of flat glass revolutionized housing starting around the 17th century, perhaps even earlier. With access to transparent flat glass, fenestration in homes let in light and kept out weather, insects, and smells. Modern windows still serve that purpose, but they may also play a role in 5G networks by serving as antennas and signal boosters, according to Prof. Naoki Sugimoto, Executive Officer and General Manager of AGC's Materials Integration Laboratories.

Corning International CEO Mr. Wendell Weeks set the tone for the conference by focusing on four key attributes of glass: stability, strength, interaction with light, and

impermeability. Mr. Weeks artfully wove human history and scientific advances to show the impact of glass on the arc of human progress. One striking example was the development of transparent, colorless glasses with improved stability, which led to the development of eyeglasses and more reading after the printing press was invented. Glass enabled the growth of an educated population and the spread of ideas.

In another example, the British were at war in the early 17th century and conscripted all wood for shipbuilding. Glassmakers turned to coal as a fuel source and found that the hotter furnace temperatures allowed them to make bottles with higher silica content. These stronger bottles turned out to be perfect containers for the new bubbly wines French winemakers in the Champagne region developed. *"Talk about glass being essential to human progress!"* says Mr. Weeks.

Corning International CEO Mr. Wendell Weeks set the tone with his talk, "Glass—Vital to our future."

Other examples familiar to this audience included Gorilla Glass, optical fibers, and pharmaceutical packaging—all of which point to the impact of glass on the everyday as well as the extraordinary moments of life.

Thought leaders from government—NSF, DOE, DARPA—talked about the innovation enterprise, which integrates government investment, open science policies, and

workforce development. Prof. Kelvin Droegemeier, Regents' Professor of Meteorology and Teigen Presidential Professor at Oklahoma University, with nearly two decades of experience working in government (former director of the White House Office of Science and Technology Policy and former director of the National Science Foundation), introduced the notion of finding the "missing millions" of talent hidden in areas of the United States often outside the mainstream flow of opportunity, but whom it would behoove the nation to engage with resources and opportunity.

Top executives from Owens-Illinois, Schott Glass, AGC, Nippon Electric Glass Fiber America, and entrepreneurs raised the importance of sustainability in their supply chains and manufacturing processes. It was frequently noted that glass is infinitely recyclable but often poorly recycled, especially in the U.S.

Three panel discussions were at least as stimulating as the talks. The panels comprised leaders from academia, industry, government, and art with widely diverse perspectives, which led to vigorous conversation on the panel and also with the audience.

A gala banquet on April 6 featured a recorded presented by Dale and Leslie Chihuly and a live presentation by Narcissus Quagliata. Quagliata describes himself as a painter and an artist interested in light. He eventually discovered glass as a fascinating medium for exploring the interaction of light in art. Working with Bullseye Glass, he developed a technique for "painting" with glass. His glass paintings are fascinating visual essays, and Quagliata has won several commissions to install his work in prominent locations throughout the world. Hearing his story and seeing his work left no doubt that he is a master glassman with a keen understanding of glass composition and properties.

This write-up is based on the Ceramic-Chat report of Eileen De Guire of the American Ceramic Society ■

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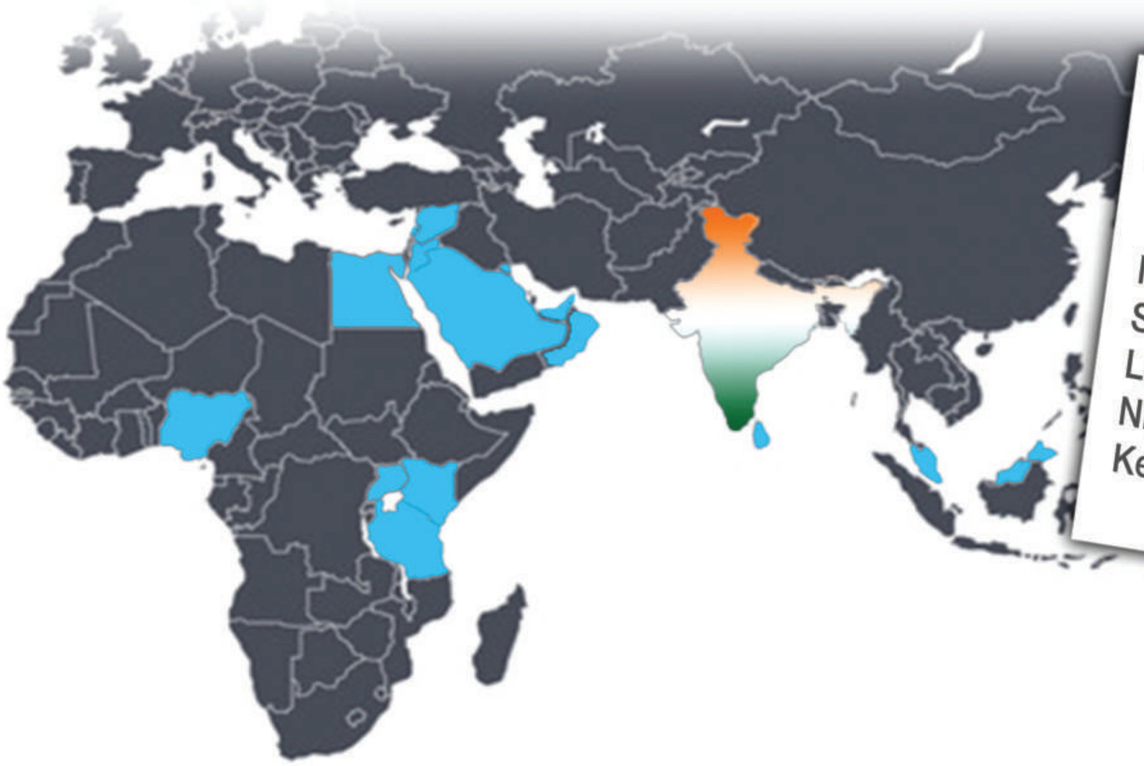

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