Hot sealing of aluminium films on glass containers

Aluminium film hot sealing of containers is widely used to preserve different types of liquid and dry products. Even though the method is used mostly with plastic containers, glass packaging can be sealed in the same way, provided a proper coupling agent is applied on the glass finish. Originally published in *Glass Worldwide* (preferred international AIGMF journal), Dr Alberto Biavati comments on hot sealing specifications and requirements for food, perfumery and pharmacy airtight packaging.

Together with screw caps with aluminium or rubber gaskets in contact with the container brim, it is common to find screw caps that after unscrewing leave an aluminium film sealed on the container brim, that must be peeled off to open the container. Many containers are only sealed by an aluminium film, without an additional closure. This is the case, for example, with yogurt pots etc.

Aluminium films are sealed on the container brim by hot sealing at temperatures in the range 100°C-150°C. This type of closure is actually widely used to preserve different types of liquid and dry products to ensure the content against external contamination, to prevent the risk of air and oxygen penetration and leakage, giving to the consumer a good inviolability guarantee (figure1). More often, plastic containers are sealed in this way but glass containers can also be conveniently sealed in the same way.

A hot sealing film is essentially made from a thin layer of aluminium (~30-60µm), coextruded with a polymeric film thin layer that is melted or softened to stick to the container brim surface during the hot sealing process. Aluminium is an optimal barrier against air, oxygen and moisture penetration but its role is also to give to the film good mechanical resistance and to accumulate the thermal energy to seal the polymeric layer onto the container brim.

Figure 1: Example of induction sealing with screw closure and multi-layer gasket.

In the case of induction sealing where there is no direct contact between a hot sealing device and film, screw caps containing a gasket system made by a carton layer, a wax layer and the aluminium-polymer film are generally used. When the aluminium layer is heated by a strong inductive electromagnetic field, wax melts and the aluminium-polymer film seals on the container brim under a constant pressure by the screwed cap. At the cap, unscrewing the melted wax lets the cap separate from the aluminium-polymer film that remains sealed on the container brim (figure 1).

Aluminium mechanical resistance is important to let the film peel from the container brim without tearing. By using polymeric layers of similar nature of the plastic container, good sealing can be easily obtained.

Due to the different nature of glass from the film polymeric layer, the use of proper coupling agents is also necessary to obtain longlasting sealing performance with fatty and aqueous products.

The polymer that can seal on glass is a proper ionomer ethylene-methacrylic acid or ethylene-acrylic acid, where the carboxylic groups have usually been neutralised by Na or Zn. Polymer carboxylic groups are responsible for the chemical bonds with glass or coupling agent functional groups.

Under the effect of temperature and pressure, ionomer carboxylic groups react with glass oxydrilic groups with water shift as a reaction product. Figure 2 shows that the

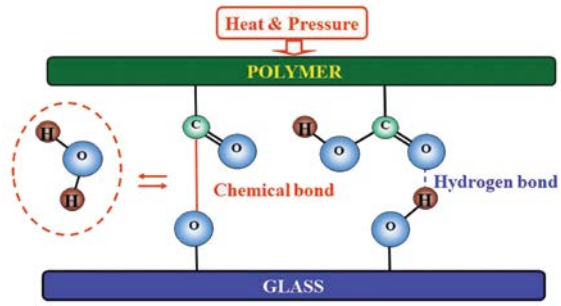

Figure 2: Simplified drawing of ionomer to glass direct sealing.

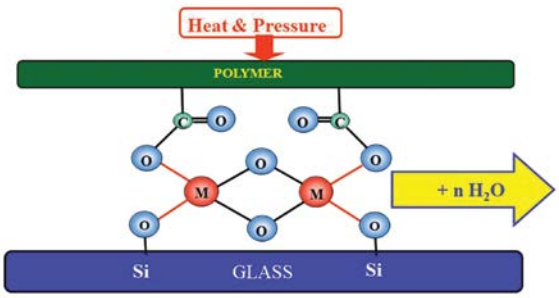

Figure 3: Simplified drawing of ionomer to organometallic coupling agent treated glass seal.

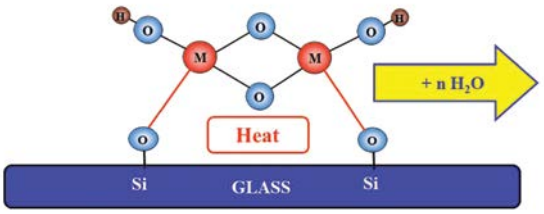

Figure 4: Simplified drawing of organometallic coupling agent treated glass.

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so-formed chemical bond can be shifted to the reactants due to the possible water penetration that can occur in the case of aqueous filling products or environmental humidity. In other words, the direct ionomer-glass bonds are reversible, with consequent film detachment due to water or moisture penetration. To consider that the glass surface is always hydrated due to its hydrophilic properties when exposed to air and further subjected during storage to weathering phenomena (hydrated sodium carbonates formation after the reaction between the sodium present on the glass surface and atmospheric CO_2 and moisture) that increase the degree of glass surface hydration. Film detachment usually occurs just after tentative hot sealing.

Since water is the main detachment agent, dry products have the main longlasting perspective.

A few fatty products can indirectly promote the sealing weakening by softening the ionomer layer.

To reduce the glass surface hydrophilic properties, a hot end treatment of tin or titanium oxide is conveniently applied on the finish but even if they give some benefit in terms of hot sealing duration, they alone cannot prevent film detachment from glass in presence of aqueous products.

So a coupling agent must be applied on glass in order to completely inhibit the water detachment action by establishing stronger, irreversible chemical bonds between ionomer and glass (figure 3).

Coupling agents and glass hot sealing requirements

Two main categories of coupling agent are available:

- Water solutions of organometallics (Al, Zr, Cr).
- Water dispersion of ethylene-acrylic copolymers.

Thick layers of glues (not considered in this presentation) are also sometime used for hot sealing of unaqueous paste or dry foodstuffs in jars but since they cannot be peeled off, they must be cut.

Very small amounts of coupling agent in the order of a few µg to less than one mg/cm^2 are enough for sealing. The glass brim is heated in the range 80°C-120°C and the coupling agent is applied by a proper wet roller (figure 4).

According to the nature of the product, foodstuffs, drugs, cosmetics or others, potential direct contact between the coupling agent and the product must be considered. A few coupling agents are suitable, as they comply with 'indirect food contact' regulations but since inner glass container dripping is sometime probable during coupling agent application, it is advisable that they comply with 'direct food contact' regulations.

Ageing stability of the treated glass is quite important to guarantee good sealing, even after months of storage. To achieve good sealing performance, the glass container brim must not be contaminated and both coupling agent chemical inertia and good storage conditions are necessary.

Usually, the following performance is required for the treated containers:

- Before sealing (storehouse time): One year or more.
- After sealing (packaging life): Three years or more.

Glass brim surface general requirements

The following requirements should be considered to optimise hot sealing:

- Hot end treatment to inhibit glass sweating and increase the chemical bond strength between coupling agent and glass.
- Clean glass finish surface, without any contamination (fingerprints, heavy cold end treatment, dust, lubricants etc).
- Even glass finish and parallelism with container base to have a regular pressure distribution.
- Glass finish flatness and thickness to increase the sealing surface.

Hot sealing performance

Electromagnetic induction is usually the preferred sealing method but also direct heat conduction sealing has good performance, provided an even and parallel glass finish is available.

Peeling force should be homogeneous in the range 4-12 N/m. With higher peeling force, usually the film can tear and shreds of ionomer remain on the container finish. On one hand, this behaviour is a demonstration of good sealing and tightness of the closure but on the other hand, it is less appreciated by the consumer for aesthetic reasons. Poor sealing homogeneity or weak adhesion could be a symptom of excessive treatment ageing, brim contamination or wrong sealing conditions.

Figure 5 shows the sealing performance generally observed over time. After coupling agent application, a slow trend of peeling force decreasing is observed due to the ageing of the treatment (slow oxidation phenomena, glass sweating, occasional contamination etc). Such slow ageing trends are interrupted as soon as the aluminium film is sealed on the glass brim, reasonably due to the stop to air exposure and environmental contamination risk. Considering the example shown in figure 5, if the sealing had been at the sixth month instead of at the tenth month, an approximately parallel horizontal line starting from 12 to 13 Nm should have been experienced. After the sealing step, the peeling force follows a far slower trend of performance decrease so that the peeling force can remain almost unchanged over many years of ageing.

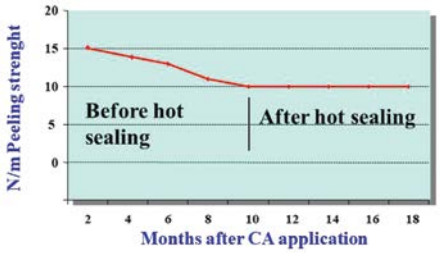

Figure 5: Typical plot of ageing to peeling performance after coupling agent (CA) glass treatment.

Sealing quality control is made by peeling the film manually or by a dynamometer after 10-15 hours of immersion in water of the container filled with water.

Conclusion

Aluminium ionomer films can be suitably hot sealed on glass containers in the range 100°C-150°C, to guarantee the ageing of all air-sensitive products, foodstuffs, cosmetics etc, by applying on the glass container brim a proper coupling agent to guarantee the consumer against possible packaging violation.

Due to the different nature of glass and aluminium films, coupling agents are necessary to guarantee longlasting sealing in the case of aqueous products to prevent water detachment action on the film sealing. Conventionally, a few organometallic Zr, Cr, Al-based coupling agents or ethylene-acrylic copolymer-based coupling agents are used.

To obtain good sealing, a few requirements must be satisfied: The correct choice of aluminium film and coupling agent, correct sealing parameters and glass container brim cleanliness. The choice of coupling agent that complies with direct food contact regulations is advisable.

Generally, a performance of one year or more is demanded before sealing (storehouse time) and three years or more after sealing.

Glass coupling agent treatment shows a slow trend of ageing, with the consequent peeling force reducing. This trend is interrupted as soon as an aluminium film is sealed on the glass brim, due to the interruption of air exposure so that the peeling force shows a completely different trend, often remaining almost unchanged for years. ●

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