

How Aluminium Foil Improves the Hot Tack of Packaging Laminates

Günter Schubert*

* Hydro Aluminium Deutschland GmbH, Georg von Boeselager-Strasse 21,
R&D, 53117 Bonn, Germany

Abstract

In descriptions of sealing performance of flexible packaging, specialists mostly emphasize the magic property of “hot tack”.

They merely concentrate on the melt adhesive strength of the sealant thermoplastic material used and disregard other prerequisites for good sealing.

This article explains why hot tack is a system property and describes the sealing performance of a number of packaging laminates, some containing aluminium foil.

With its outstanding thermal conductivity, which is far higher than that of any other flexible packaging component, aluminium foil favours the rapid cooling of seal seams and helps to speed up the packaging process.

In addition, the dead fold characteristic of aluminium foil allows seal seams to retain their given shape and makes seams more reliable.

1. Introduction

The primary reason for using aluminium foil in flexible packaging is its outstanding barrier properties. The absolute barrier performance achievable with aluminium foil and the unrivalled barrier/cost efficiency of foil laminates are not surpassed by any other material.

Alufoil's good temper behaviour in converting, such as its wettability which allows excellent coverage of adhesives, lacquers or extrusion coatings or the reception of printing inks, along with its temperature-resistance and dimensional stability when passing through a drying tunnel are also important and often taken for granted.

Looking at modern packaging, the focus is not just on laminate properties. The whole system, including packaging scrap, machine speed and packaging closure safety and the related costs have to be taken into account and weighed up.

When sealing robustness and low reject quota are primarily required, but higher throughput and productivity are demanded, the hot tack performance of a packaging laminate has to be improved. Hot tack depends on the multilayer structure, the individual layer thicknesses, the placement of the layers, the choice of material and the packaging environment/conditions but is generally simplified to be of the responsibility of the sealant only [1]. In fact, higher productivity, improved safety and lower overall cost per packaging unit can be achieved by employing more expensive and better performing sealants, but also other factors must be considered as well.

This article attempts to define the role of aluminium foil in sealing performance and pays particular attention to the part played in hot tack of packaging laminates.

2. What is hot tack?

Hot tack is usually defined as the strength (or resistance) of a hot seal measured at a specified time interval after the completion of a sealing cycle but prior to the temperature of the seal reaching ambient [2]. Hot tack curves typically describe this maximum force in relation to the heat seal jaw temperature. Another way of describing hot tack, this time from a different point of view, is to monitor the resistance of a just-sealed seam being peeled at constant peeling speed over time at a high rate of data collection [3]. This type of measurement describes the solidification time indirectly.

Another method allows the two sealed faces to drop immediately onto a wedge or via deflecting rollers using a floating weight and splitting the hot seal seam under a (pseudo-) constant force. The length of the split seam thus characterises the hot-tack properties of the material.

Sealing consists of different steps, such as the intimate contact of the sealants with each other, the heat transfer through and heat dissipation in the different component layers of the laminate, the sealant layers melting, wetting or interpenetrating with their counterparts, then after opening the heat-seal jaws, heat dissipation, the cooling down and solidifying or crystallising of the seal.

Hot tack describes the processes which occur after the heat-seal jaws are opened.

Hot tack is a combined value, comprising the superposition of the sealing conditions, time, temperature and pressure as starting condition, melting and solidification temperatures and the mechanical properties especially of the sealant, as a melt and as a solid, and also of the adjacent layers.

3. Thermal conductivity of flexible packaging components

Similar to silver and copper, aluminium displays high thermal conductivity, making it an ideal material for the use in heat exchangers. Therefore aluminium foil can transport heat into and away from the seal efficiently. In contrast, the heat transfer properties of plastics are rather poor - as a rule, about 600 times lower than that of aluminium. The heat transfer coefficients of plastics differ markedly depending on the type of plastic, its density and the degree of crystallinity. When thermoplastics melt, only slight changes in their heat transfer capability occur.

Paper, on the other hand, conducts heat to a varying degree since its compactness differs, making its behaviour more difficult to predict.

Combining materials with different heat transfer coefficients leads to widely differing temperature gradients in the individual layers during the sealing progress. Looking perpendicularly at the different plies of the materials, the higher the thermal conductivity, the lower the temperature gradient is seen to be in the material.

4. Viscosity progress of sealants in the sealing temperature window

Using a customary rotational rheometer, temperature sweeps can be made to follow the viscosity of a sealant melt over the sealing window while applying a constant shear rate at small deformation amplitude or constant strain rate in oscillation mode. Major changes are to be seen when the sealant melts and solidifies again. Although heating and cooling rates are low (1-4 K/min.), significant undercooling takes place, especially in PP resins. With rapid cooling (rates) as occurring in a real seam, an even stronger undercooling in PP melts can be expected than observed in the rheometer. From the temperature, PP solidifies at low cooling rates, the true solidification of PP at high rates can be seen to occur at around 100°C.

5. Tracking interfacial temperatures during sealing

Microthermocouples can be inserted in between the sealant layers, are subsequently surrounded by the melt and embedded in the seam during sealing (the method is described in [4]) and the interfacial temperatures are recorded during the sealing phase (i.e. heat introduced into the seal) and cooling phase (i.e. heat being dissipated or hot-tack phase). When the cooling curves indicate that the sealant is crystallising by a small deflection or a slight relative increase in interfacial temperature, an amount of sealant, sufficient for proper sealing, had been melted.

This method allows us to compare material compositions with differing heat transfer properties.

6. Comparing the heat transfer properties of laminates with their packaging performance

6.1 Aluminium/paper laminates for pouches

Complaints were received about a pouch laminate regarding poor sealing. The laminate composition did not show any difference in the aluminium, paper or coating gauge, compared with another “good” batch, when determined gravimetrically. Sealing the laminates at 200°C for 2 s and recording interfacial temperature showed that it increased at a slower rate and reached a maximum temperature about 15°C lower than that for standard “good” material. The paper in the poorly sealed laminate was compressed to a lower degree, leading to insufficient heat transfer to the PE sealant in the sealing process.

6.2 Dairy lidding materials

To achieve higher resistance against puncture in dairy lidding materials, the well-proven heat-seal-lacquered 30µm aluminium strip for form-fill-seal machines can be replaced by a laminate comprising a thinner aluminium foil adhesive-laminated with a PET film. The interior PET film is coated with the same sealant lacquer as the aluminium foil in the traditional lid.

Immediately after sealing (i.e. opening the heat-seal jaws), a bulge test is performed to check the seal tightness of the filled pudding cups. Replacing the aluminium lid by the Al/PET laminate lead to a tremendous increase in the number of open cups, suggesting that the heat-seal lacquer was responsible for the problem. Comparing the seal performance of the lidding

materials by tracking the interfacial temperature in the seal seam showed that the lid holding the PET film inside caused a slow-down in cooling with the consequence of the PP solidification exceeding the delay for the bulge test. The bulge test itself was actually responsible for the seal damages of the cups. Adjusting the bulge test at a respective retard time solved the problem.

6.3 Laminates for coffee vacuum packages

In Europe, classical PET/Al/PE triplex laminates or others comprising metallised PET and PE are widely used for ground coffee vacuum packaging. The choice of material is less a question of barrier performance than more of business philosophy, i.e. whether to pack a high-quality product in the best materials or simply have a product at the cheapest price (i.e. lowest cost).

Coffee packagers imply that the use of laminates containing aluminium foil would result in considerably higher line speeds.

We therefore compared coffee laminates consisting of PET 12 μ m/adhesive/aluminium 9 μ m/adhesive/LDPE 70 μ m (3-ply) with another made of PET_{metallised}/adhesive/LDPE 80 μ m (2-ply).

LDPE layers were used in different thicknesses to allow similar total gauges to be compared. At a sealing-jaw temperature of 140°C, which is the lowest recommended for ensuring safe sealing, the crystallisation of the LDPE takes place after about 3.5 seconds, indicating the solidification of the seal. Leaving aluminium foil out of the laminate, LDPE takes about 4 seconds longer to crystallise. Owing to the slower cooling rate, crystallisation starts at a slightly higher temperature. Aluminium foil dissipates heat away from the seal seam very quickly and efficiently and reduces the hot tack time until solidification occurs. This allows earlier stressing of the seam and the filled package, which in turn facilitates higher throughput.

Sealing at 160°C, the delay in LDPE crystallisation with aluminium foil occurs only parts of a second later than sealed at 140°C. For the laminate containing no aluminium foil, the increase of sealing bar temperature postponed the crystallisation to more than 10s!

Using aluminium foil, the solidification time is not prolonged markedly by increasing the sealing jaw temperature. When leaving aluminium foil away, there is a strong extension of the hot tack time, increasing sealing temperature.

7. Summary

Heat transfer properties are often disregarded when choosing or designing packaging materials to be heat-sealed.

The thermal conductivity of each component used in a laminate is linked with the overall sealing and packaging performance.

Seal seams take surprisingly long times to solidify or longer than expected.

Aluminium lids fit almost completely to the contours of seal seams and retain their given shape. There is no springback effect as in plastic counterparts and so seal seams remain closed in near total safety.

Aluminium foil plays a significant role in efficient heat transfer during sealing and heat dissipation during cooling (to reduce the hot tack time) and so contributes to both sealing performance and safety.

The use of aluminium foil in packaging has the potential to increase line speed in processes where seal seams are subjected to loads in subsequent handling.

8. Literature

1. James R. Garavilla, Sealing in Brand Equity with Hot Tack, www.dupont.com/packaging/knowledge 2005
2. Theller Engineering, www.theller.com 2005
3. ASTM Standard F 1921-98 Hot Seal Strength of Thermoplastic Polymers and Blends comprising the Sealing Surfaces of Flexible Webs.
4. Guy Boiron, Guenter Schubert, TAPPI European PLACE 2001 Barcelona, Spain: Sealing Performance with Aluminium Foil – Heat Seal Lacquer in Contrast to Extrusion Coating

9. Acknowledgements

The author gratefully thanks Claudia Seeger and Michael Lennarz for their good advice in lab and Wolfgang Winkels, Mike Clark and Don Polson for providing valuable ideas, comments and for reviewing patiently.

2006 TAPPI PLACE Conference September 17 – 21, 2006
Cinergy Center Cincinnati, Ohio

Hydro Aluminium


How Aluminium Foil Improves the Hot Tack of Packaging Laminates

Günter Schubert
Hydro Aluminium Deutschland GmbH
Research & Development Bonn

Structure

- What is Hot Tack?
- Thermal conductivity
- Melt flow behaviour during sealing
- Tracking interfacial temperatures during conductive sealing
- Case studies for heat transfer and sealing performance
- Summary

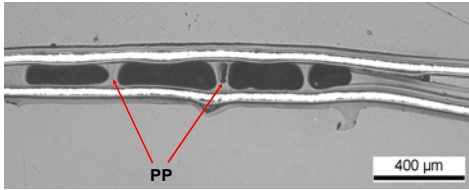
Günter Schubert • Datum: 29-06-2006 • Seite: 2 •

Structure

- What is Hot Tack?
- Thermal conductivity
- Melt flow behaviour during sealing
- Tracking interfacial temperatures during conductive sealing
- Case studies for heat transfer and sealing performance
- Summary

Günter Schubert • Datum: 29-06-2006 • Seite: 3 •

What should not happen.....



Cross-section of a seal seam PET/Al/PP-PP/Al/PET

Günter Schubert • Datum: 29-06-2008 • Seite: 4 •

Structure

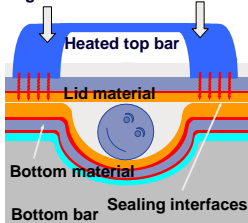
- What is Hot Tack?
- **Thermal conductivity**
- Melt flow behaviour during sealing
- Tracking interfacial temperatures during conductive sealing
- Case studies for heat transfer and sealing performance
- Summary

Günter Schubert • Datum: 29-06-2008 • Seite: 5 •

Conductive Sealing of Packages

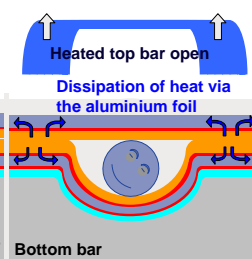
Phase 1

Pressure and heat transfer from hot bar(s) to the sealant to contact the interfaces intimately and weld them together



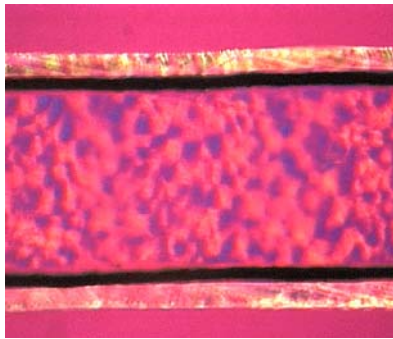
Phase 2

Removing the pressure bar, the molten seal seam cools and solidifies



Günter Schubert • Datum: 29-06-2008 • Seite: 6 •

“Perfect“ Seal Seam of a 3-Ply-Laminate



PET 12µm
Al 7µm

PP 2 x 70 µm

Al 7 µm
PET 12µm

Günter Schubert • Datum: 29-06-2006 • Seite: 7 •

Thermal Characteristics of Packaging Components

	Cp	Density	Specific heat/ volume	Heat transfer coefficient
	[J/g·K]	[g/cm³]	[J/cm³ · K]	[W/m·K]
Al	0.9	2.7	2.43	220
PET	1.1	1.38	1.52	0.28
PP	2.0 (it 1.8)	0.905	~ 1.8	~ 0.3
PE	2.2	0.92	2.02	0.40
PVC	1.2	1.38	1.66	0.18
PS	1.3	1.1	1.43	0.16
Paper	1.3-1.7	1.2-1.7	0.9-2.0	< 0.1

Aluminium conducts heat about
600 times better than polymers!

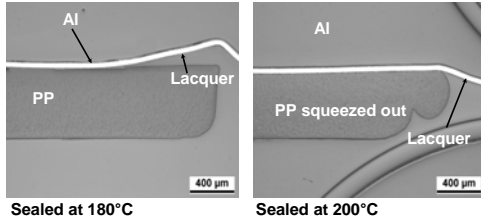
Günter Schubert • Datum: 29-06-2006 • Seite: 8 •

Structure

- What is Hot Tack?
- Thermal conductivity
- **Melt flow behaviour during sealing**
- Tracking interfacial temperatures during conductive sealing
- Case studies for heat transfer and sealing performance
- Summary

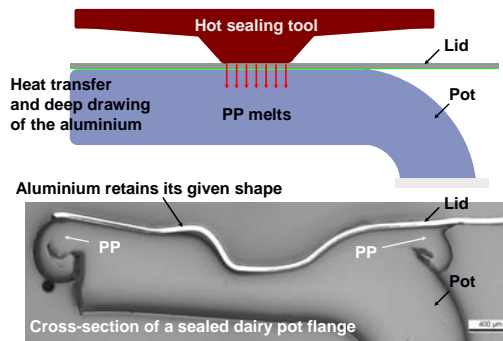
Günter Schubert • Datum: 29-06-2006 • Seite: 9 •

Melt Flow is Temperature Dependent



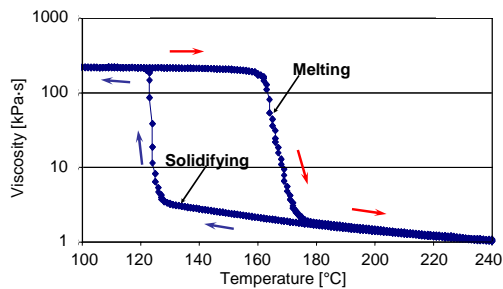
Günter Schubert • Datum: 29-06-2006 • Seite: 10 •

Real Contour of a Dairy Cup Seal Seam



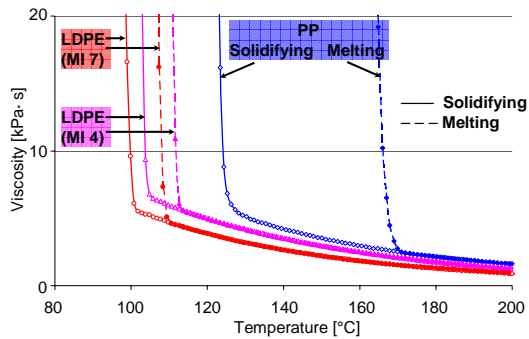
Günter Schubert • Datum: 29-06-2006 • Seite: 11 •

Viscosity Progress of Polypropylene in the Sealing Temperature Window



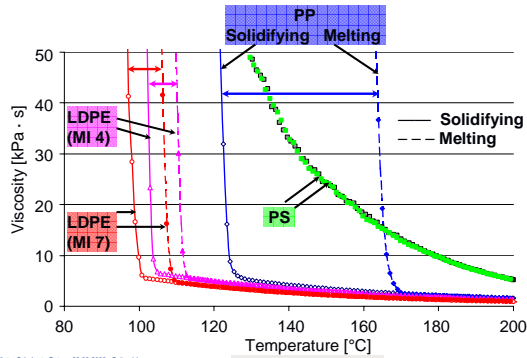
Günter Schubert • Datum: 29-06-2006 • Seite: 12 •

Viscosity Progress During Melting and Solidification of Sealant Thermoplastics



Günter Schubert • Datum: 29-06-2006 • Seite: 13 •

Viscosity Progress During Melting and Solidification of Sealant Thermoplastics



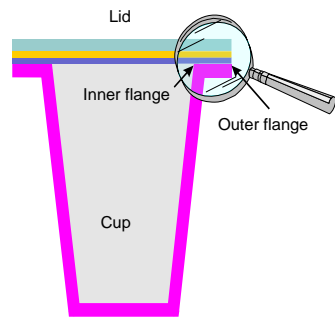
Günter Schubert • Datum: 29-06-2006 • Seite: 14 •

Structure

- What is Hot Tack?
- Thermal conductivity
- Melt flow behaviour during sealing
- Tracking interfacial temperatures during conductive sealing
- Case studies for heat transfer and sealing performance
- Summary

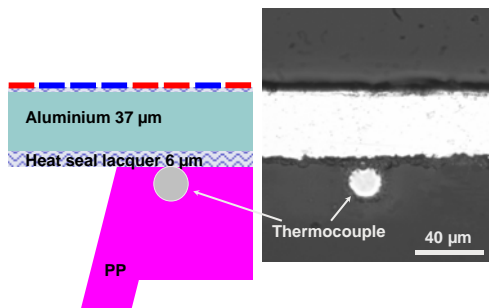
Günter Schubert • Datum: 29-06-2006 • Seite: 15 •

Sealing Lids on Cups and Trays



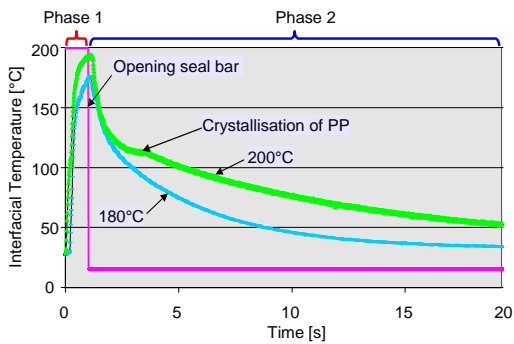
Günter Schubert • Datum: 29-06-2008 • Seite: 16 •

Following Temperature at Sealants' Interface



Günter Schubert • Datum: 29-06-2008 • Seite: 17 •

Interfacial Temperature Change During Sealing (Al/Lacquer/PP)



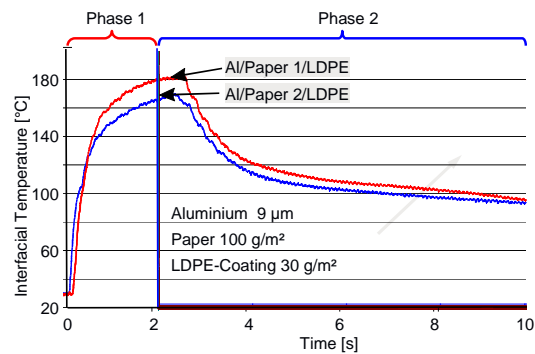
Günter Schubert • Datum: 29-06-2008 • Seite: 18 •

Structure

- What is Hot Tack?
- Thermal conductivity
- Melt flow behaviour during sealing
- Tracking interfacial temperatures during conductive sealing
- Case studies for heat transfer and sealing performance – paper laminates
- Summary

Günter Schubert • Datum: 29-06-2008 • Seite: 19 •

Sealing Aluminium/Paper/LDPE



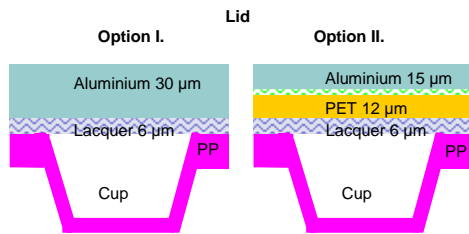
Günter Schubert • Datum: 29-06-2008 • Seite: 20 •

Structure

- What is Hot Tack?
- Thermal conductivity
- Melt flow behaviour during sealing
- Tracking interfacial temperatures during conductive sealing
- Case studies for heat transfer and sealing performance – dairy lidding
- Summary

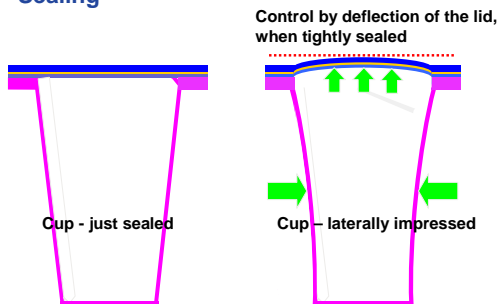
Günter Schubert • Datum: 29-06-2008 • Seite: 21 •

Sealing Dairy Cups with Different Lids



Günter Schubert • Datum: 29-06-2008 • Seite: 22 •

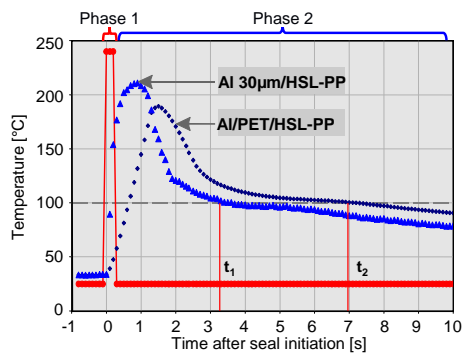
Checking Tightness of Dairy Cups after Sealing



But when seal seam is not yet solidified, lid can be reopened!

Günter Schubert • Datum: 29-06-2008 • Seite: 23 •

Sealing Different Lids on Dairy Cups – Progress of Interfacial Temperature



Günter Schubert • Datum: 29-06-2008 • Seite: 24 •

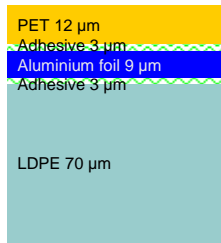
Structure

- What is Hot Tack?
- Thermal conductivity
- Melt flow behaviour during sealing
- Tracking interfacial temperatures during conductive sealing
- Case studies for heat transfer and sealing performance – coffee vacuum packaging
- Summary

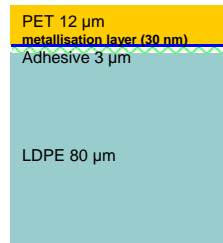
Günter Schubert • Datum: 29-06-2008 • Seite: 25 •

Comparison of Coffee Vacuum Pouch Laminates

Option I. (3-ply)

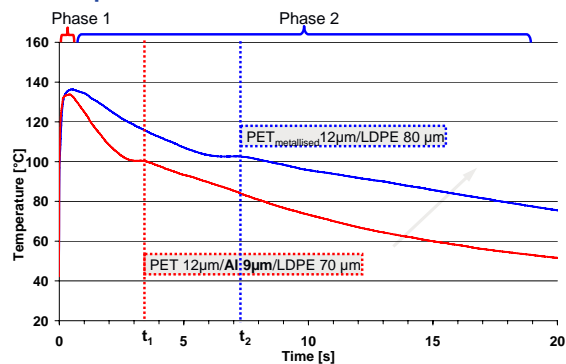


Option II. (2-ply)

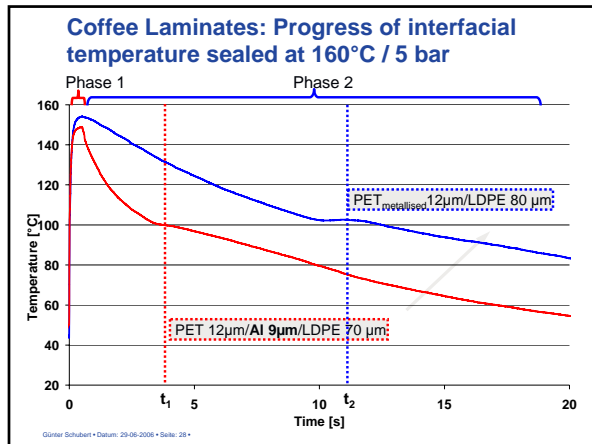


Günter Schubert • Datum: 29-06-2008 • Seite: 26 •

Coffee Laminates: Progress of interfacial temperature sealed at 140 °C / 5 bar



Günter Schubert • Datum: 29-06-2008 • Seite: 27 •



Structure

- What is Hot Tack?
- Thermal conductivity
- Melt flow behaviour during sealing
- Tracking interfacial temperatures during conductive sealing
- Case studies for heat transfer and sealing performance – coffee vacuum packaging
- **Summary**

Günter Schubert • Datum: 29-06-2008 • Seite: 29 •

Summary

- ✓ Heat transfer properties are often disregarded when designing packages for heat sealing
- ✓ Thermal conductivity of components like paper can vary and is difficult to compensate for
- ✓ Seal seam solidification can last surprisingly long
- ✓ The outstanding heat conductivity of aluminium foil accelerates solidification of seal seams and reduces the hot tack time
- ✓ Aluminium lids retain their given shape in the seal seam with no springback as in plastic counterparts
- ✓ Using aluminium foil in laminates bears the potential to increase packaging speed in a multitude of cases

Günter Schubert • Datum: 29-06-2008 • Seite: 30 •
