

Transparent and Temperature-Resistant up to 100°C

Cooperation Project for Recyclable Packaging

Sukano and Illig have a long-standing development partnership in the field of thermoforming. The latest development for recyclable and temperature-resistant PET applications for packaging is called CPET-light. Sukano has created a nucleating masterbatch that can be used to extrude a transparent film that is dimensionally stable up to 100°C. At its in-house Technology Center, Illig tested the result for possible applications.



Quite transparent: three materials competed against each other in a practical test. APET on the left, CPET-light in the middle and PP on the right © Illig

The sustainability of plastic packaging is increasingly determined by its recyclability. Circular economy is the megatrend. Polyethylene terephthalate (PET) is the world's most recycled plastic and is ideal for packaging food. Building on this knowledge, Sukano and Illig have launched an initiative to enable the use of PET in cups and trays for microwave and hot fill applications. The result is a possible alternative to the PS and PP applications that are often

used today but that are either unsuitable for recycling or are not food compliant.

Crystalline and opaque CPET variants, such as CPET trays that are heat-resistant up to 220°C, are currently used for temperature-resistant applications. Conventional thermoformed APET cups and trays do not reach the lower – and usually only briefly reached – temperature threshold of 100°C, which is typical for microwave applications and hot filling. Therefore, the high-tempera-

ture-resistant CPET does not necessarily have to be used as a packaging material either. The Swiss additive and masterbatch specialist Sukano and the German thermoforming systems manufacturer Illig have developed a new material for this purpose.

CPET-Light Closes the Gap

The two companies have developed the temperature-resistant CPET-light based

on CPET thermoforming technology. The goals here were to realize a transparent application for use in microwaves and for hot filling while simultaneously increasing the productivity of the selected thermoforming system.

For this project, Illig developed a more efficient thermoforming process that delivers improved productivity compared to conventional CPET. It involves producing CPET-light cups by means of precise temperature control of the film nucleated with the Sukano masterbatch and a specially developed tool. These cups offer the benefit of being suitable for reuse as food packaging in the PET raw material cycle and therefore offer an alternative to PS and PP.

Production of Transparent Cups for Hot Filling

The joint project aimed to produce hot-fillable cups for dairy products that have sufficient transparency and a temperature resistance of 100°C. In this series of tests, an RDM 70K thermoforming machine and a single-cavity mold were used at the Illig Technology Center. An identical molding tool was used to produce samples from PP-H (PP homopolymer) and APET as a reference. For the test series, the masterbatch specialist produced both transparent and white CPET-light films with a thickness of 1.1 mm and a width of 240 mm on the laboratory extruder in its in-house Technology Center. This resulted in a test series with PP-H, APET, CPET-light (white) and CPET-light (transparent).

The cycle rate for the cups made of CPET-light was optimized during the thermoforming tests. The maximum cycle rate achieved during the process was 20 cycles/min. The cups made of PP-H and APET were also produced with 20 cycles/min. It was important to achieve comparable wall thickness distributions in order to obtain meaningful results for the optical and mechanical tests.

Table 1. Test criteria for the upset pressure test Source: Illig

Parameter	Setpoint
Preload value	0.5 N
Preload speed	10 mm/min
Measuring speed	50 mm/min
Force cut-off threshold	10 % F_{max}



Fig. 1. Position of the wall thickness measurement in mm removed from the sealing rim

Source: Illig, graphic: © Hanser

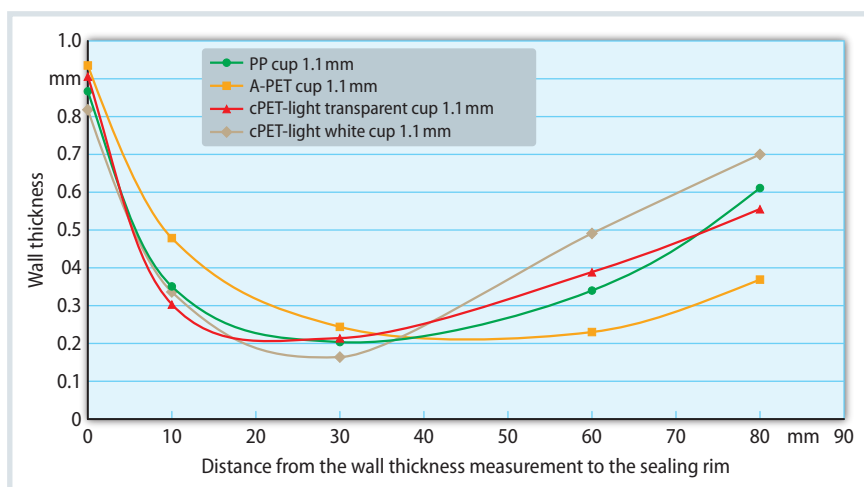


Fig. 2. Wall thickness measurement of the cups at the characteristic points after 24h storage

Source: Illig, graphic: © Hanser

The following investigations were carried out:

- wall thickness measurement of the cups at characteristic points after 24h of storage,
- determination of tool shrinkage after 24h of storage,
- top load measurement of the formed cups
- temperature resistance in the oven test,
- temperature resistance with hot water, and
- transparency measurement.

The measurements of the wall thickness clearly showed that, with the exception of the APET cups (bottom too thinly formed) and the white CPET-light cups (tear-off under the sealing rim), the wall thickness distributions achieved in the thermoforming process were very comparable. This made it possible to draw meaningful conclusions from the top-load measurements. Five cups each were tested with the Magna Mike 8600 Hall Effect thickness gauge.

Determination of Tool Shrinkage after 24h of Storage

Preliminary tests had already indicated that the tool shrinkage of APET and CPET-light were comparable. They corresponded to the values of approx. 0.5% known in tool design. The shrinkage »

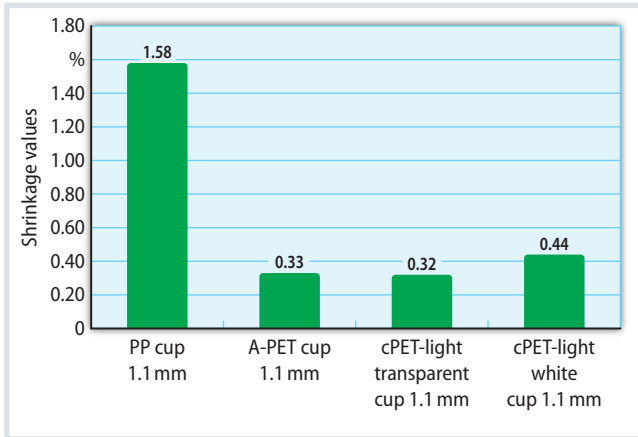


Fig. 3. Mold shrinkage values for PP cups, APET cups and CPET-light cups determined more than 24h after production Source: Illig; graphic: © Hanser

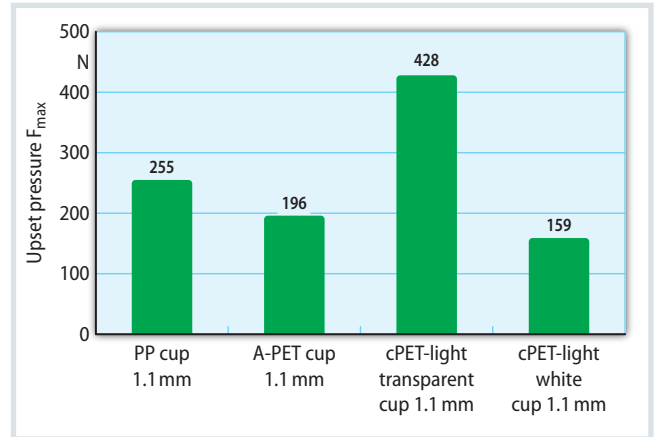


Fig. 4. F_{max} values from the upset pressure tests

Source: Illig; graphic: © Hanser



Fig. 5. Comparison of the tested samples before and 30min after the oven test at 100°C © Illig

value of 1.58 % for PP was also within the tolerance range. There was a tendency for the shrinkage values determined for APET, CPET-light and PP to be slightly lower, which was due to the tempering in the heated mold. The diameter of five cups was measured optically for each film

material and compared with that of the die contour.

Upset pressure measurements of the formed cups were also carried out (top-load measurements). A Zwick/Roell zwickiLine 2.5 kN and two plane-parallel compression plate dies were used for this purpose. The test method was based on the DIN 55440 compres-

sion test. The test criteria are shown in **Table 1.**

Ten cups were tested per test point. The following became apparent when considering the maximum force values (F_{max}) from the tests: the lower wall thickness of the white CPET-light cups below the sealing rim had a negative effect on the maximum compression force of the

What Is CPET-light?

- Thermoformed, partially crystalline application made of PET
- Available as opaque and transparent application
- Temperature-resistant up to 100°C thanks to formulated additives and a special processing method
- Suitable for use in microwaves and hot filling
- Recyclable
- Good barrier properties thanks to PET

Sample	Height before the oven test	Height after the oven test
PP cup	54.52 mm	54.39 mm
CPET-light transparent cup	54.38 mm	50.38 mm
CPET-light white cup	54.37 mm	52.18 mm

Table 2. Measurement of the cup height before and after the oven test Source: Illig

Sample	Height before the hot water test	Height after the hot water test
PP cup	54.43 mm	54.17 mm
CPET-light transparent cup	54.39 mm	52.89 mm
CPET-light white cup	54.33 mm	53.04 mm

Table 3. Cup height before and after the hot water test at 95°C, 60 s Source: Illig

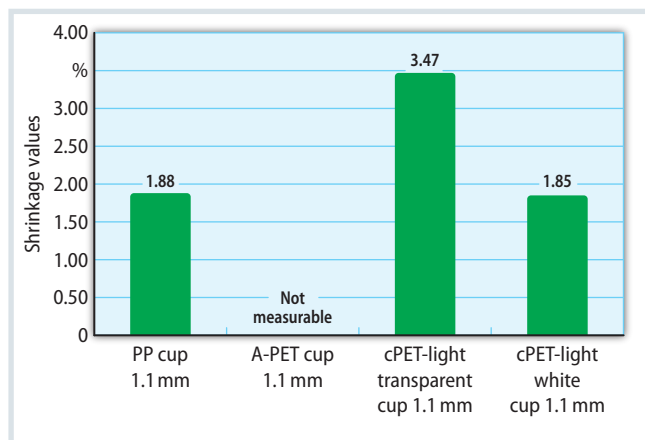


Fig. 6. Oven shrinkage values after the oven test, measured optically

Source: Illig; graphic: © Hanser

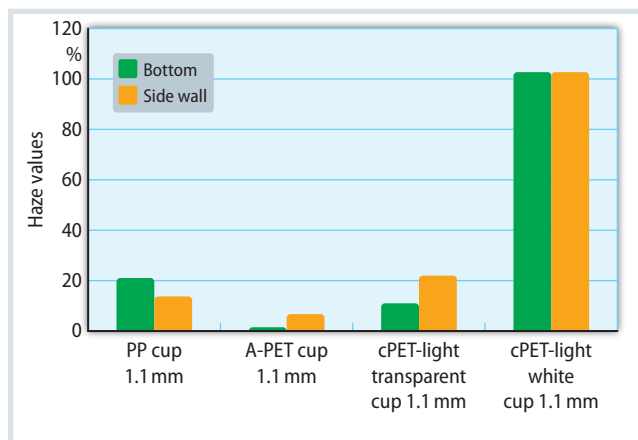


Fig. 7. Comparison of cup transparency based on Haze values

Source: Illig; graphic: © Hanser

cups (Fig. 2). This could also be observed during the test in the form of an earlier onset of deformation. The APET cups with their thinner wall thickness in the bottom showed a similar behavior with an earlier deformation and lower F_{max} value. When comparing the PP cups with the transparent CPET-light moldings, a clear difference in the F_{max} values was observed, which can be attributed to the differences in the Young's modulus of PP (approx. 2000 MPa) and PET (approx. 3800 MPa).

Temperature Resistance in the Oven Test

The cup samples were exposed to 100°C for 30 minutes in the oven test. Subsequently, the shrinkage values were checked visually by measuring the cup diameters at the sealing rim.

The APET cups could no longer be measured due to the massive deformation (Fig. 5). The decrease in cup height was smallest for the PP cups (Table 2). However, deformation of the CPET-light samples was further reduced by optimization of the tool geometry.

The cups were filled to the brim with approx. 95°C hot water. After one

minute the water was emptied and after another 30 minutes the cup dimensions were measured (Table 3). The transparency was measured with a haze meter – Hazegard plus from BYK Gardner – according to ASTM D-1003. Here, the transparent CPET-light cup showed only a slight increase in Haze values compared to the APET cup (Table 4).

An optical inspection of CPET-light transparent and PP revealed that they could be considered visually equivalent.

CPET-Light Cups as an Efficient and Recyclable Alternative

The combination of the film nucleated with the Sukano masterbatch, the appropriate molding tool, thermoforming machinery and the two companies' many years of know-how have led to the successful development of a CPET-light cup with a temperature resistance of up to 100°C. The good barrier properties of PET also ensure that the cups are grease-resistant. Efficient production is also ensured due to the machine speed of up to 20 cycles/minute.

The transparent variant, which includes additives from the specially for-

mulated nucleation masterbatch from the Swiss specialist Sukano, also offers a possible alternative to the PP cups that are frequently used today. PET's excellent recyclability, especially for food-compliant recycling, can make a significant contribution to a successful circular economy. ■

The Authors

Daniel Ganz works as Global Product Manager for Thermoform Applications at Sukano AG; daniel.ganz@sukano.com

Janine Wyss is Marketing Communication Manager at Sukano; janine.wyss@sukano.com

Sven Engelmann is Head of Packaging Technology and in charge of the Illig Technology Center (ITC); sven.engelmann@illig.de

Christoph Stoye is Packaging Developer at ITC; christoph.stoye@illig.de

Georg Sposny is Marketing Communication Manager at Illig; georg.sposny@illig.de

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References & Digital Version

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Cup	Base thickness μm	Haze base %	Wall thickness μm	Haze wall %
APET	342	2.08	410	6.38
CPET light transparent	512	10.6	276	22.2
CPET light white	586	103 opaque	278	103
PP transparent	513	21.3	263	14.4

Table 4. Measurement of wall thicknesses and transparency Source Illig