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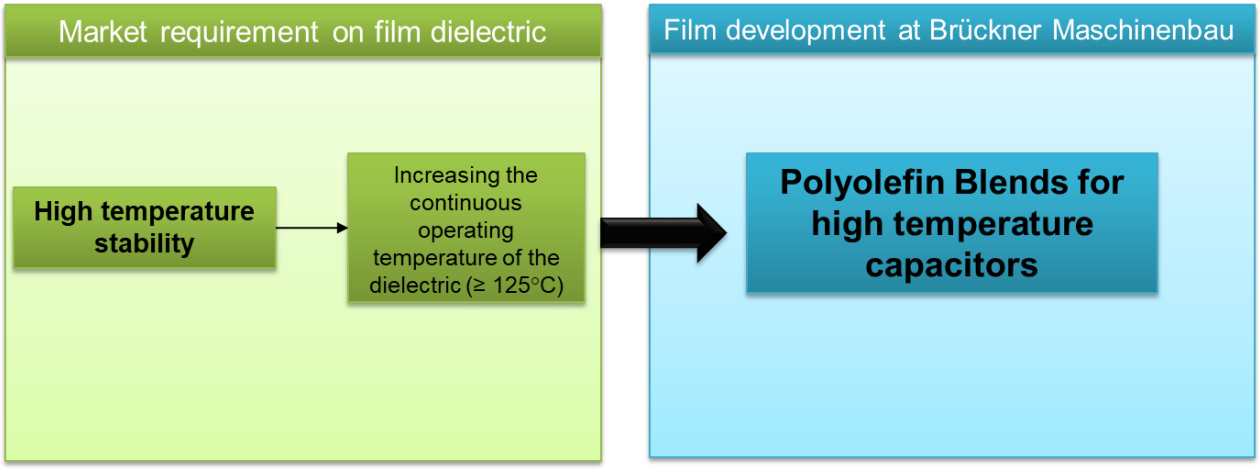
Polyolefin Blends – A new film for high temperature film capacitors

Applications like renewable energy sources and electro-mobility create a fast growing market for inverter circuits for power conversion – an important component in these applications are film capacitors. Depending on an effective heat management and miniaturization there is a demand for film dielectrics with an increased temperature stability (required operating temperatures ≥ 125°C).

The preferred film dielectric for power film capacitors is polypropylene (PP) – Biaxially oriented PP (BOPP-C) films show low dielectric losses (used for AC and DC applications), high breakdown voltages (high voltage rating) and excellent self-healing properties. By using BOPP you are faced with limitations regarding the maximum operation temperature - the operating temperatures rarely exceeding 105°C with required down ratings in voltage and current. For this reason BOPP-C is not applicable for high temperature film capacitors.



In order to fulfil the required temperature stability (≥ 125°C), Brückner started in a cooperation with the raw material supplier Topas Advanced Polymers to test polyolefin blends based on polypropylene and cyclic olefins (PP/COC blend).

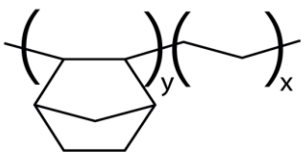
Why Cyclic Olefin Copolymers?

Cyclic Olefin Copolymers (COC) are well known for their purity and barrier properties. A wide range of products with heat deflection temperatures up to 170 °C is commercially available. Cyclic Olefin Copolymers have been known as desirable high temperature dielectric for capacitor films since more than 20 years, but stretching ratios and process temperatures for this amorphous polymer are not compatible with industry standard film technology.

Cyclic Olefin Copolymer Key Properties

- Amorphous polyolefin
- Compatible with standard polyolefins
- High purity
- Rigid up to 3.2 GPa
- Dielectric constant 2.35
  Dielectric loss factor < 0.02
- Heat deflection temperatures from 30 to 170 °C

Random metallocene copolymers of
Cyclic Olefin (Norbornene) and Ethylene



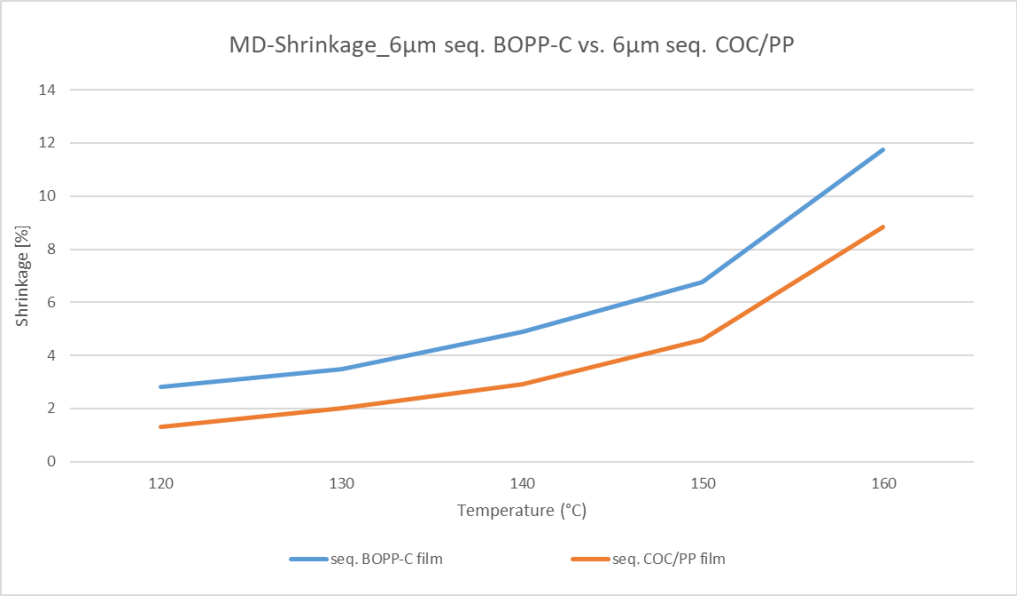
Film properties PP/COC blend

Polymer blends with a content of 5 – 40% Cyclic Olefin Copolymer show well-known properties of a BOPP-C film with an increased temperature stability. Films made of PP/COC blends can be processed on standard BOPP capacitor lines (sequential & simultaneous stretching). By controlling the process parameters it is possible to produce PP/COC films in a thickness range of 3 – 8µm with the required film roughness for handling (no further additives are needed).

In the following table, film and dielectric properties for a 6µm film consisting of 80% PP and 20% of COC with a glass transition temperature of 140°C is shown in comparison to a common BOPP capacitor film.

				BOPP-C film	PP/COC Blend
▶	**Thickness**	TD	µm	6	6
▶	**Modulus of Elasticity**	MD	N/mm²	2953	2747
		TD	N/mm²	5268	4216
▶	**Surface Roughness**	Ra	µm	0,07	0,09
		Rmax	µm	0,7	0,8
▶	**Dielectric Strength**		kV/mm	702	627
▶	**Dielectric constant at 23°C**			2,2	2,3
▶	**Loss factor 1kHz / 23°C**		1,0E-04	2	< 2

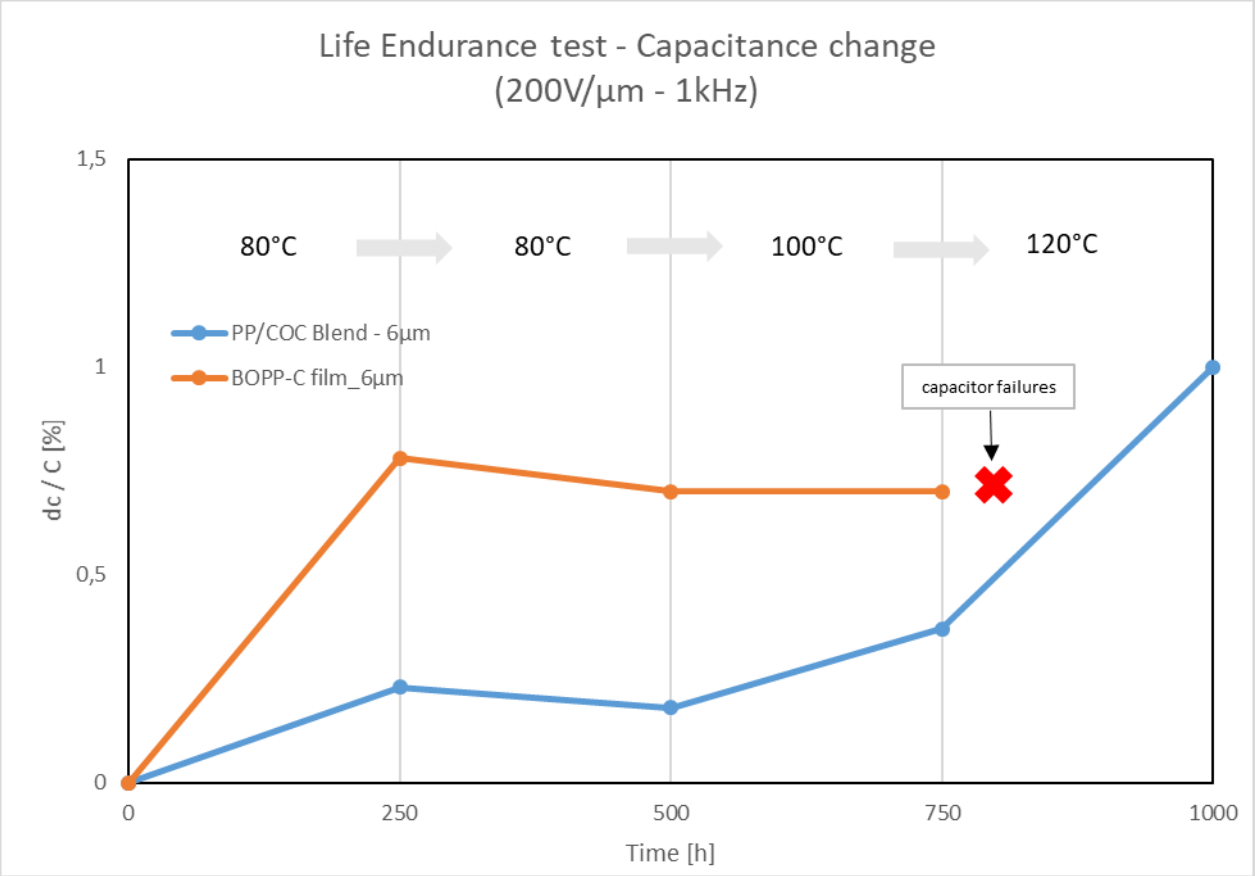
Mechanical, electrical and surface characteristics are in the same range as for PP films. PP/COC Blends show an improved dimensional stability - compared to a BOPP-C film the blend films have lower shrinkage values at elevated temperatures.



Capacitor manufacturing and evaluation

Further processing steps, i.e. slitting, metallization and capacitor manufacturing and testing have been conducted independently by industrial partners. The capacitor manufacturing with PP/COC film is quite similar to the processing of polypropylene films and all common process steps and formats - with the exception of oil filled capacitors - can be used.

In accelerated life endurance tests PP/ COC film capacitors have demonstrated functionality and stability for 1000h at 120 °C and voltages up to 200 V/µm. The following graphic shows the capacitance change at elevated temperatures in comparison to PP capacitors. Capacitors made from PP/COC films show lower capacitance change compared to PP at moderate temperatures. At 120 °C the comparative PP capacitors failed completely while capacitors made from blend maintained capacitance within low variation and without failures.



Polymer blends based on polypropylene homopolymer and cyclic olefins (5 – 40% content of COC) show potential to fulfil the market demand on film dielectrics with increased temperature stability.

Summary

- PP/COC films can be produced on standard BOPP-C lines.
- PP/COC films show very good dielectric properties and an outstanding temperature stability
- PP/COC is an auspicious material combination for high temperature applications

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