

Topas® COC: A New Binder Resin for Electrophotographic Printing

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Abstract

Topas® Cyclo-Olefinic Copolymers (COC) developed by Ticona, Germany, are an entirely new class of amorphous, thermoplastic materials. Their unique property combination leads to a wide range of applications in pharmaceutical & medical packaging, capacitor films, food packaging films, optical parts/lenses, diagnostics and electrophotographic printing. As a toner binder resin Topas COC offers significant advantages over existing products especially when high process speed or improved image quality is required. The unique combination of excellent optical, thermal, rheological, mechanical, electrical and ecologically-friendly properties and its benefits to toner performance are described in the following article. Due to the flexible continuous production process the glass transition temperature, molecular weight and molecular weight distribution can be tailored independently according to the requirements of our customers. The introduction of Topas in commercial scale from the year 2000 on marks the beginning of a new era of high performance printing.

Future Printing Trends

Printers based on the electrophotographic toner process have become an essential element of modern life and business.[1] The increasing demand for high quality, full color printing at moderate to high printing speeds and reduced printing costs will finally capture a substantial share of the commercial printing market that is today held by offset printing. Current printer categories like duplicator, copier, office printer, fax machine and photo paper printer will be replaced by multi functional machines capable of printing variable, personalized information from different electronic sources. Ecologically safe materials with improved fusing properties, reduced energy consumption and better printing quality with a minimum load of expensive pigments will be needed.

Binder resins which are currently in use for full color printing like polyester resins, styrene-butylmethacrylate copolymers and polyether polyol resins[2] have reached an intrinsic performance borderline and can not fulfill all these demanding requirements. The insufficient properties of the base polymer constitute a major obstacle for new imaging applications.

Topas® Cyclo-Olefinic Copolymers (COC) form an entirely new class of amorphous, thermoplastic binder resins which offer significant performance benefits over existing materials especially when high process speed or improved image quality is required. Furthermore, it is an ecologically friendly substance due to its olefinic, hydrocarbon nature.

What is Topas®?

The Topas polyolefin product family[3] recently developed by Ticona, the technical polymer business of Celanese AG, consists of amorphous, transparent copolymers of the cyclo-olefine norbornene and ethylene. The efficient production of these materials in optical quality and high purity is achieved by sophisticated metallocene catalyst technology. A 30,000 t/year production facility in Oberhausen, Germany, is scheduled for startup in Q3 / 2000.

COC exhibit a unique combination of properties that can be customized by varying the structure of the polymer. The glass transition temperature (Tg) is primarily controlled by the norbornene content in the COC. The full range of Tg between 0 and even 200 °C can be obtained with these catalyst systems. In connection with a fine tuned microstructure of the polymer and an optimized molecular weight, different Topas grades with Tg in the range from 60 to 180 °C are commercially available.

The key performance benefits delivered by Topas resins are optical, mechanical, electrical and moisture barrier properties. This unique combination leads to a wide range of applications in:

- Pharmaceutical & Medical Packaging
- Capacitor Films
- Food Packaging Films
- Optical Parts / Lenses
- Diagnostics
- Electrophotographic Printing

where materials like glass, PVDC/PVC, polysulfone, PMMA, polycarbonate and specialty polyesters are commonly used.

Characteristic Properties

High Color Fidelity-Less Pigment Required

A UV-VIS spectrum of Topas COC in comparison to a typical polyester toner binder resin is shown in figure 1. Topas grades are crystal clear as indicated by the high light transmission at wavelengths larger than 400 nm. It does not show any yellowing like polyester or styrene acrylate copolymers. In addition Topas COC has no carbonyl groups or double bonds and thus remains highly transparent in the UV region down to approximately 250 nm. This excellent transparency together with good pigment dispersability ensures high color fidelity of the printed image and decreases the amount of required pigment.

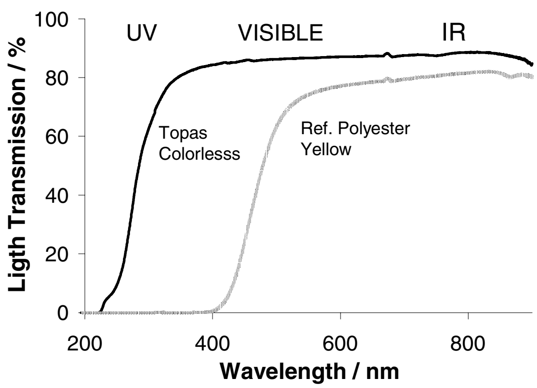

Figure 1: Typical UV-VIS spectra of 7 mm thick plaques of Topas COC and a reference polyester binder.

Low Density-Volume Advantage

The density of Topas resins is 1.01 g/cm and thus about 20 % lower than that of polyester binder meaning that more pages can be printed with the same weight of binder resin.

Excellent Minimal Fixing Temperature

Single site metallocene catalysts allow a narrow molecular weight distribution with a polydispersity index (Mw/Mn) of approximately 2 so that the melt viscosity decreases strongly with respect to temperature. This sharp melting behavior offers an excellent fusing ability at low temperature which is essential for high quality imaging.

Due to the narrow molecular weight distribution the oligomer content for a given molecular weight is much lower than in other resins. This offers the potential to prolong machine lifetime because the sensitive electronic and mechanical parts of printers will be less contaminated by low molecular weight components.

In addition the production process offers a large flexibility in designing the molecular weight distribution without impairing the excellent optical quality of the toner binder resin. The molecular weight distribution of the monomodal grade Topas® TM and the bimodal grade Topas TB 1 is shown in figure 2. Topas TM and TB are completely amorphous, linear copolymers with glass transition temperatures of 65 °C. In contrary to bimodal polyester toner binder resins Topas shows no branching or crosslinking thus the transparency remains excellent.

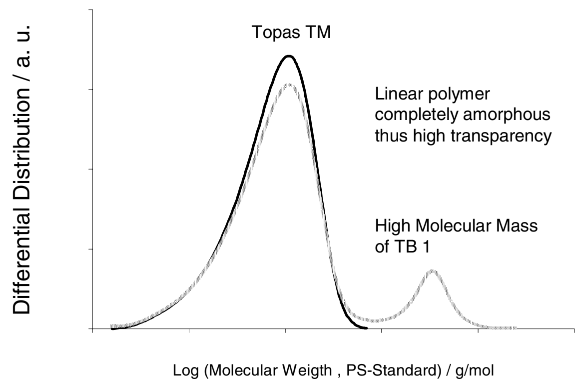

Figure 2: Molecular weight distribution as measured by GPC for different Topas products.

Improved Fusing Latitude

Although different contact or non contact methods can be used to fix the toner particles on a substrate, heat roll fusing is most commonly used. The process window where fusing is possible without difficulties depends on the hot roll temperature and the paper transportation rate[4].

Cold Offset The lowest temperature necessary to fuse the image, the cold offset temperature, is regarded as the minimum temperature required for melting of the toner and depends on Tg.

Hot Offset The temperature at which the adhesive energy of the resin to the heated roll surface exceeds the cohesive energy of the binder resin so that a ghost image is observed after the next revolution of the hot roll is considered as the hot offset temperature.

Anti-offset Window The temperature difference between hot offset and cold offset is called fusing latitude or anti-offset-window and constitutes the most critical parameter for the toner design in heat roll fusing. It has already been shown that the fusing latitude is predominantly controlled by the rheology of the toner binder.[5]

The viscoelastic behavior of plastic materials is usually described by time-temperature superposition. Figure 3 shows some examples of viscosity mastercurves for different Topas® binder resins in order to highlight the flexibility that Topas and the production process offer.

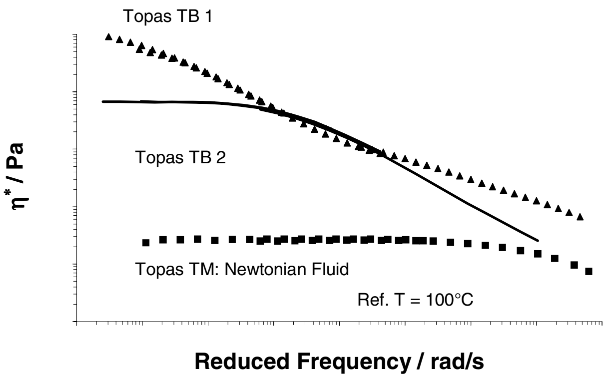

Figure 3. Viscosity mastercurves for different Topas products.

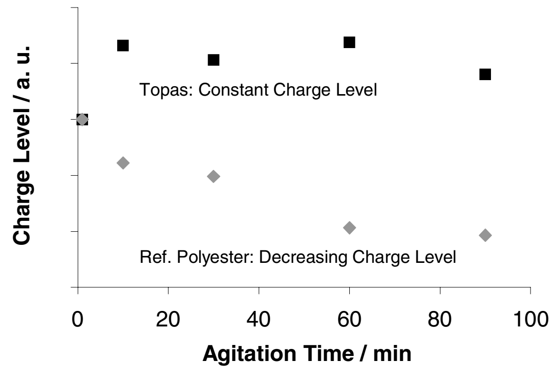

Figure 4: Tribocharge behavior of Topas in comparison to a reference polyester toner.

The reference temperature for this plot is 100 °C. Elevated reduced frequencies correspond to low temperatures, low frequencies to higher temperatures.

The monomodal grade Topas TM shows a Newtonian flow behavior, i.e. the viscosity is independent of the applied frequency indicating that the molecular weight of this polymer is well below the entanglement molecular weight. The viscosity decrease as a function of temperature can be described by the Arrhenius equation.

The bimodal resin Topas TB 1 with a small amount of a a high molecular weight fraction shows a strongly non Newtonian flow behavior leading to significant shear thinning. The Newtonian plateau with an elevated viscosity is only observed at very small reduced frequencies. Consequently the viscosity change with respect to temperature is by far less than expected from the Arrhenius equation. With toner based on this binder resin an anti-offset-window of more than 100 °C is achieved, by far more than any other competitive product offers.

Viscoeleastic properties can be tailored to meet end-use requirements by changing the amount and the molecular weight of the higher molecular weight fraction as seen with Topas TB 2. For this material the Newtonian plateau extends to higher reduced frequencies due to the lower molecular weight of the high molecular weight fraction compared with Topas TB 1.

Stable Triboelectric Charging

Figure 4 depicts the tribo charge behavior as a function of agitation time in dual component development. The toner based on Topas® binder resin shows almost constant charge level over the whole period of time under investigation. In comparison the charge level of a reference polyester toner is strongly decreasing with time.

Due to its olefinic nature Topas shows very low water uptake. This ensures a triboelectric charge level which does not depend on temperature or humidity. Consequently the image quality is independent on the environmental conditions.

Ecologically Friendly Material

Topas COC is used in many pharmaceutical, medical and food applications. It is listed in CAS (26007-432), MITI registered and has a FDA Drug Master File. Standard grades show excellent bicompatibility, meet the requirements for U.S.P. Class 6 and have a very low level of extractables well below the limits of national pharmacopoeias. The U.S. Food and Drug Administration has issued a regulation for the use of Topas COC in dry-food-contact applications. In addition it complies with the EU regulations for food packaging.

A Universe of Solutions from Ticona

Ticona can provide complete service from laboratory trials to commercial plant scale in order to tailor the best Topas toner binder resin for a particular printing process. Due to the flexible continuous production process the glass transition temperature, molecular weight and molecular weight distribution can be tailored independently according to the requirements of our customers.

The continuous pilot plant can provide sample quantities in the low ton scale for larger field studies and allows optimization of the process conditions for a fast and reliable scale-up to the commercial plant.

Conclusions

Topas® toner binder is a 3rd generation toner binder following styrene acrylate copolymers and polyester resins thanks to its unique combination of excellent optical, thermal, mechanical, electrical and eco-friendly properties. The introduction of Topas COC in commercial scale from the year 2000 on marks the beginning of a new era of high performance printing.

References

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Biography

Klaus Berger received his Ph.D. in Physical Chemistry from the university of Paderborn, Germany, in 1995. He then worked on biodegradable polymers at the Federal Institute for Cereal, Potato and Starch Research in Detmold, Germany and on the rheological properties of associating polymer solutions at the Laboratory for Ultrasounds and the Dynamics of complex Fluids in Strasbourg, France. In 1997 he joined the research and development group of Topas® within Hoechst and later Celanese/Ticona. He is currently working on Topas® toner binder resins for high quality printing. He is a member of the IS&T.