Novel UV-transparent 2-component polyurethane resins for Chip-on-Board LED micro lenses

M. Gutke[a], J. Bauer[a], V. Stoycheva[a], A. Kaltenbach[b], M. Burkhardt[b], M. Gruenefeld[c], M. Gamp[c], M. Edling[a], P. Steglich[a], F. Heinrich[a], S. Steffen[e], C. Gerhard[d], M. Herzog[a], C. Dreyer[a,e], S. Schrader[a]

[a] Technical University of Applied Sciences Wildau, Hochschulring 1, 15745 Wildau, Germany
[b] resintec GmbH, Hellsternstr. 1, 04895 Falkenberg/Elster, Germany
[c] EPIGAP Optronic GmbH, Koepenicker Str. 325, Hs. 40, 12555 Berlin, Germany
[d] University of Applied Sciences and Arts, Von-Ossietzky-Straße 99, 37085 Göttingen, Germany
[e] Fraunhofer Institute for Applied Polymer Research IAP, PYCO, Kantstrasse 55, 14513 Teltow, Germany

Abstract

An optical high-performance plastic based on polyurethane elastomer (PU) was developed, which combines excellent UV transparency with high thermal stability, good hardness, high surface tension and a long pot life. The material is well suitable for microlens applications for Chip-on-Board (CoB) LED technology.

Goal

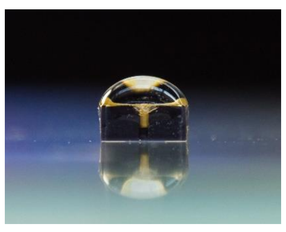
Lighting optics with micro lenses and LEDs must be manufactured in a particularly cost-effective and flexible manner. The major challenge is to achieve excellent transparency, high temperature stability, good mechanical strength and long-term stability of the polymers.

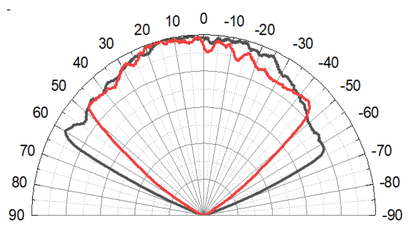
PU material and component specification

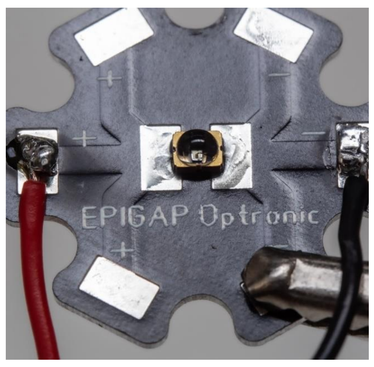
Polyurethane resPUR	OT-3000	OT-T24000	OT
A-component	Polyester polyol		
Polyol OH contend [mg KOH/g]	> 130	> 50	> 130
B-component	P-MDI**	HDI*	HDI*

*Aliphatic isocyanate hexamethylene diisocyanate oligomer (HDI)
**Aromatic methylenediphenyl diisocyanate polymers (P-MDI)

Packaging and lens forming

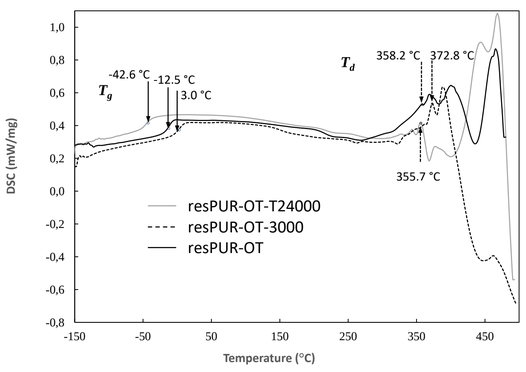




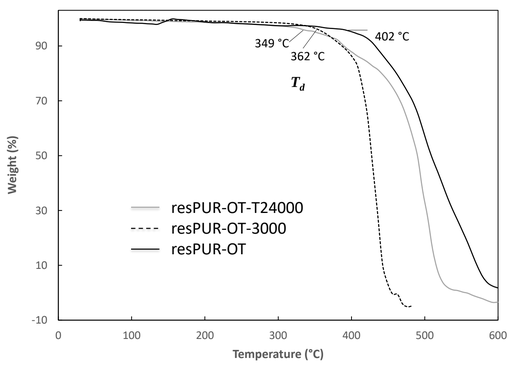


Fabrication results dome-type package of InGaN-CoB-LED with resPUR-OT at different surface tension and corresponding light distributions at λ = 525 nm.

Thermal properties

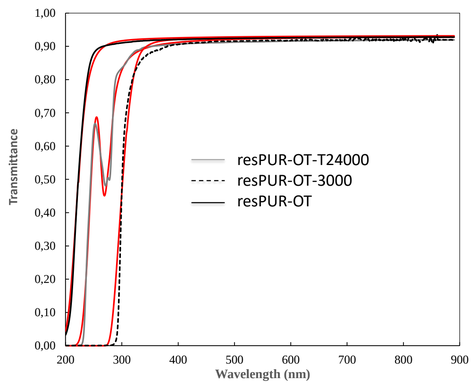


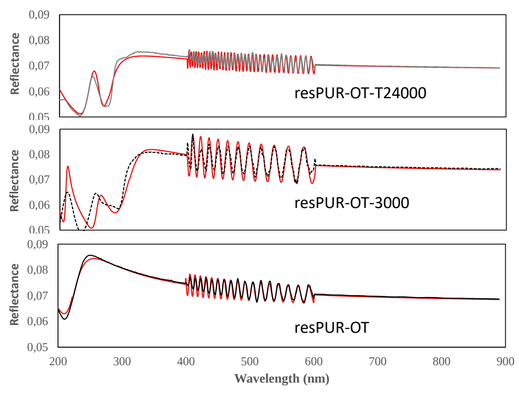
Differential scanning calorimetry (DSC) measurements at temperatures from -150 to 500 °C. The points indicate the glass transition temperatures T_g and the degradation temperatures T_d of the PU. Secondary reactions of the isocyanates are shown in the range from 150 to 220 °C.



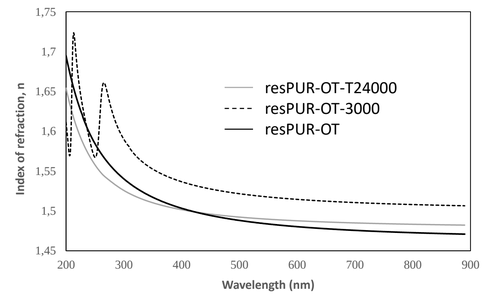
Thermogravimetry (TGA) curve of the polyurethane. Temperature program: Heat from 20 °C to 600 °C with heating rate of 10 °C/min, in nitrogen atmosphere with a purge rate of 10 mL/minute. Marked are the 5 % weight loss temperatures.

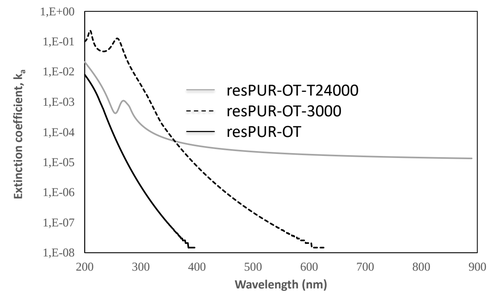
Optical properties



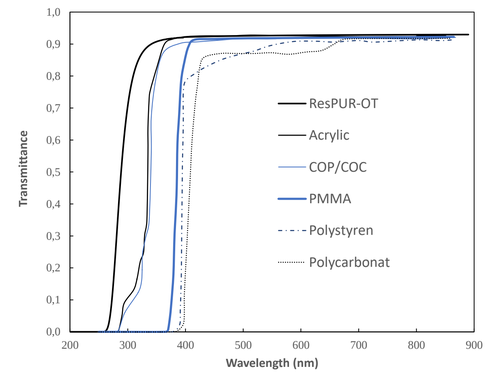


Simulated (red) and experimental (black) transmission and reflection spectra of PU thin films, measured with the low resolution (λ = 200 – 890 nm) and superimposed with high-resolution reflection (λ = 400 – 600 nm) spectrometer. The thin film interferences are used to determine the film thickness.





Optical properties of PU, refractive index n and extinction coefficient k_a determined by reflection and transmission measurement and Tauc-Lorentz [1, 2] and Lorentz exciton [3 - 5] oscillator model fit of thin films and thick plane-parallel plates of PU. The relatively high k_a in the long wavelength region of resPur-OT-T24000 is caused by the exciton absorption and scattering effect.



Transmittance of optical polymers [6] at a film of 3.174 µm compared to resPUR-OT . thickness

a) b) c)

Laser scattering properties:
a) resPUR-OT-3000 material, shows fluorescence and has a scattering coefficient of $k_s = 5.1E^{-6}$,
b) resPUR-OT-T24000, $k_s = 7.5E^{-6}$
c) resPUR-OT, $k_s = 3.9E^{-7}$
The scattering coefficient k_s was determinded by using Lambert-Beer's law.

Summary:

- This optimized material (resPUR-OT) has an excellent transparency, high thermal stability up to 344 °C and provides the possibility of a simple and cost-effective dispensing technique to ensure a stable encapsulation of LEDs with the possibility of lens formation [7, 8].
- The optical properties and the parameters of the band structure of PU can be changed in a wide range by the mixing ratio of the material components.
- The method presented here turns out to be a useful approach for the development of optical materials. The result confirms that highly transparent PU can be produced from aliphatic isocyanates and polyester polyol with optimized mixing ratios.

References:
[1] G. E. Jellison and F. A. Modine, *Parameterization of the optical functions of amorphous materials in the interband region*, Appl. Phys. Lett., 69 (3), 371-373 (1996).
[2] Erratum, G. E. Jellison and F. A. Modine, Appl. Phys. Lett., 69(14), 2137 (1996).
[3] M. Cardona, *Modulation Spectroscopy*, Suppl. vol. 11 of Solid State Physics, edited by F. Seitz, D. Turnbull, and H. Ehrenreich, Academic, New York (1969).
[4] P. Lautenschlager, M. Garriga, S. Logothetidis and M. Cardona, *Interband critical points of GaAs and their temperature dependence*, Phys. Rev. B 35, 9174 (1987).
[5] D.E. Aspnes: *Modulation spectroscopy/electric field effects on the dielectric function of semiconductors*, In Handbook of Semiconductors, Vol. 2, ed. by M. Balkanski (North-Holland, Amsterdam, 1980) pp. 109–154.
[6] W. S. Beich, N. Turnera, *Polymer optics design, fabrication, and materials*, Proc. of SPIE Vol. 7788, 778805 (2010), edited by David H. Krevor, William S. Beich, GS Plastic Optics, 408 St. Paul Street, Rochester, NY 14605 (2010).
[7] J. Bauer, M. Gutke, M. Edling, S. Schrader, and C. Gerhard, *Verfahren zur Herstellung asymmetrischer oder asphärischer Linsen sowie Leuchteinheit mit einer derart hergestellten Linse*, Patent EP19196944, filed on 09/12/2019.
[8] M. Burghardt, A. Kaltenbach, D. Krüger, J. Bauer, M. Gutke, S. Schrader, *Polyurethan Gießharz mit hoher UV Transparenz und hoher Temperaturstabilitat*, Patent DE 10 2019 133 078.5, filed on 12/04/2019.
[9] J. Bauer, M. Gutke, F. Heinrich, M. Edling, V. Stoycheva, A. Kaltenbach, M. Burkhardt, M. Gruenefeld, M. Gamp, C. Gerhard, P. Steglich, S. Steffen, M. Herzog, C. Dreyer and S. Schrader, *Novel UV-transparent 2-component polyurethane resin for chip-on-board LED microlenses*, Vol. 10, No. 9 / 1 September 2020 / Optical Materials Express 2085

www.th-wildau.de/photonik

Arbeitsgruppe: Photonik, Laser- und Plasmatechnologien
Projektleiter / Professor: Prof. Dr. rer. nat. habil. Sigurd Schrader
Telefon: +49 (0) 3375 / 293
E-Mail: schrader@th-wildau.de

ZIM Zentrales Innovationsprogramm Mittelstand
Gefördert durch: Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages