Polymer hybrid materials for planar optronic systems

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We report on our recent results in polymer hybrid material development for planar optronic systems. The focus in this report is on the flexibility of optical polymer waveguides which was enhanced by introducing a component with a low glass transition temperature to the copolymer synthesis.

1 Introduction

On the way to planar optronic sensor foils entirely made of polymers we develop polymer materials with adjustable properties. One of the main challenges are the adhesion of the microstructures under stress and their stability e.g. during heating or bending of the optical foil. To ensure both, we employ C,H-insertion crosslinking (CHic) [1] using a thermal crosslinker which allows a one-step-process for fabricating thermally stable polymer waveguides which adhere firmly to the substrate foil due to chemical attachment. [2]. However, the crosslinking reduces the flexibility of the polymeric structures . This leads to micro-cracks inside the polymer waveguides and the transmission of the light is strongly decreased which results in the end in a complete failure of function. To circumvent this problem we synthesized copolymers with components with a low glass transition temperature (T_G).

2 Experimental Section

PMMA (poly(methyl methacrylate)) and PMMA-PnBA (poly(n-butylacrylate)) copolymers with the thermal crosslinker MAz (malonic acid diazoester) and the UV crosslinker MABP (methacryloyloxybenzophenone) [3] were synthesized via standard free radical copolymerization. MABP was not used to crosslink but to increase the refractive index due to its conjugated electron system [4] to enable light guiding properties [2].

Polymer waveguides were processed by filling a PDMS stamp with a highly viscous solution of the specific polymer in toluene (ca. 300mg/ml), adding a PMMA substrate foil (Plexiglas 99524 GT, Evonik, Germany) on top of the stamp and hot embossing all together at a maximum temperature of 160°C and a maximum pressure of 8kN (MB 25200VC, Schmidt, Germany).

Results

To achieve higher flexibility of our polymer material we synthesized copolymers of PMMA and PnBA with varying compound ratios by standard free radical polymerization to lower the copolymer's glass transition temperature T_G. Fig. 1 shows the linear behavior of T_G and the polymer composition; the higher the amount of the low T_G monomer nBA, the lower the T_G of the copolymer.

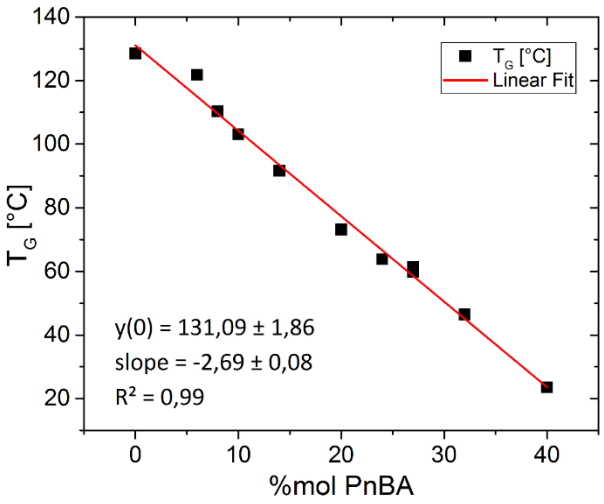

Fig. 1 *DSC measurements show a linear relation between T_G of the PMMA-PnBA copolymer and the fraction of the low T_G PnBA.*

We synthesized copolymers containing small amounts of crosslinker (2-3%mol MAz, 6-7%mol MABP) at three different MMA/nBA ratios (A: 0%mol PnBA; B: 18%mol PnBA; C: 30%mol PnBA (values are in relation to PMMA)), which slightly differ in T_G to the ones without crosslinker (A: T_G=123°C; B: T_G=72°C; C: T_G=61°C). This polymers were then used to hot emboss polymer waveguides (height: 300µm, width: 1000µm) on PMMA substrate foils for flexibility tests (Fig. 2).

We expected that if we go below a certain bending diameter, microcracks inside the polymer waveguide occur and we can observe a drastic drop in transmitted light intensity due to absorption and

DGaO Proceedings 2016 – *http://www.dgao-proceedings.de* – ISSN: 1614-8436 – urn:nbn:de:0287-2016-A001-1

submitted: 24.Jun.2016 published: 3.Aug.2016

scattering events. This will give us then the minimum possible bending diameter d_{min} for the respective copolymer composition.

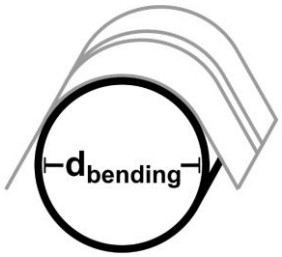

Fig. 2 *Definition of the bending radius: the substrate foil with polymer waveguides was bend over a rod with a specific diameter.*

We recorded the transmitted light intensity before and after bending the waveguide to determine the minimum bending diameter. Fig. 3 shows an example for the difference in transmitted light intensity before bending and after bending with a diameter smaller than d_{min}.

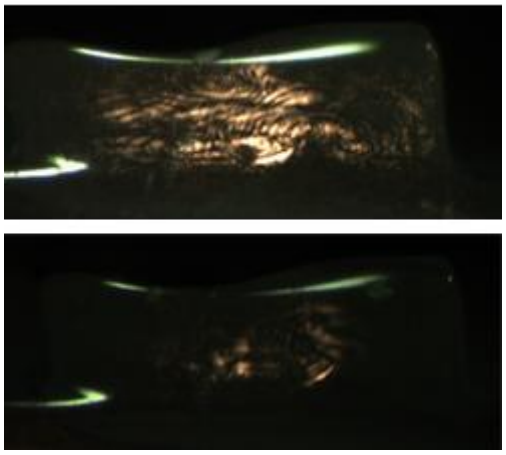

Fig. 3 *Drastic drop in light transmission: waveguide before bending (top) and after bending with d< d_{min} (bottom, λ=750nm, 0,2mW, d=15mm, 92%PMMA-2%MAz-6%MABP).*

We see in fig. 4 the normalized transmitted intensity of waveguides made of the three different polymers. The maximum value for each bending radius is plotted because the transmitted intensity varied due to coupling effects. Obviously there is no big difference in flexibility of waveguides including 0%mol and 18%mol nBA. Waveguides made out of these polymers show a high transmission loss for bending diameters below d_{min}=20,3mm. Whereas waveguides containing 30%mol nBA transmit around 60% of the incoupled light intensity after bending them with diameter of 1,2mm.

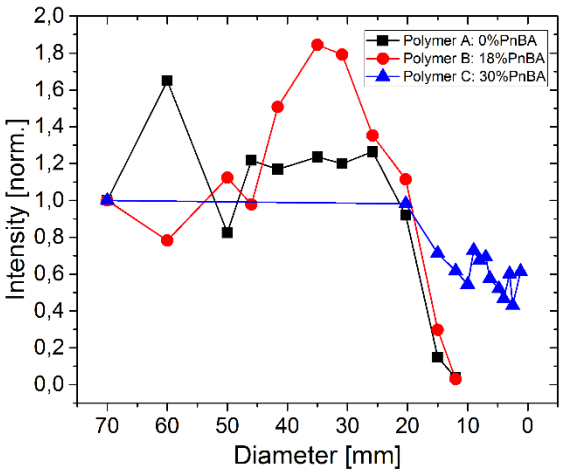

Fig. 4 *Normed intensity of the transmitted light after bending the waveguide. Values bigger than 1 occur due to non-reproducible incoupling.*

3 Conclusion

We showed that increasing contents of PnBA as a low T_G component decreases linearly the glass transition temperature of a P(MMA-nBA) copolymer. Furthermore we investigated the flexibility of P(MMA-nBA) polymer waveguides with different contents of nBA and therefore different T_G. Bending tests showed a superior flexibility for waveguides containing 30%mol nBA which resulted in a transmitted light intensity of around 60% after bending the waveguide with a diameter of 1,2mm.

Acknowledgement

We gratefully acknowledge the financial support by Deutsche Forschungsgesellschaft (DFG) within the Collaborative Research Center “Transregio 123 – Planar Optronic Systems”.

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