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CONDITIONING OF FLEXIBLE SUBSTRATES FOR THE APPLICATION OF POLYMER OPTICAL WAVEGUIDES

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Abstract

The printing of polymer optical waveguides is in focus of current topics in research. This publication describes the conditioning of flexible substrates for the spray coat application of polymer optical waveguides by using an Aerosol-Jet. We show the capability of preparing the carrier material by experiments concerning the influence to the surface energy. Lines with hydrophobic behavior were applied by using a flexographic printing machine to accomplish the basis for creating polymer optical waveguides with high lateral resolution. The subsequent wetting showed a successful self-structuring of the fluid polymer.

INTRODUCTION

Optical technologies become increasingly important in modern sensor and communication applications. The advantage of optical transmission to electrical primarily consists in higher transfer rates and less susceptibility to electromagnetic fields [1]. Furthermore, polymer optical waveguides have a sufficient bandwidth, less weight and better mechanical resilience compared to fibres made of glass. Applied onto flexible substrates, it is possible to monitor the structural health of different components.

The development of flexible substrates with integrated optical sensors is part of the present research projects “Flexible Artificial Optical Skin” (FAOS) and “Photonic Skins For Optical Sensing” (PHOSFOS). Their topic is to record mechanical quantities by means of optically sensitive foils [2] [3]. Graf showed the variety of manufacturing planar optical waveguides in his work [4]. Contrary to this, the goal of the present research project is not to investigate new production processes to apply optically transparent waveguide material but to affect the quality of optical waveguides produced with Aerosol Jet® printing technologies by prior conditioning of the carrier material [5]. The methods to realize this are described in the following section.

METHODS

Printing with optical polymers on flexible substrates by using a flexographic printing machine is presently carried out. This is a relief printing procedure where cylinders with different functions produce the light conducting structure by rolling of on each other. Waveguides generated by this have parabolic shapes with dimensions in mid double-digit micrometre width. [6]

In this work the surface properties are affected to selectively increase the wetting behaviour of the substrate by adjusting its surface energy. For this purpose the flexographic printing is used to improve the lateral resolution of existing production processes and to support the downstream process for printing the waveguide itself.

Adjusting the surface properties in relation to its wetting depends on the surface energy. A high surface energy enables a good wetting by materials in the liquid phase. A low surface energy leads to a rejection of fluids. Two procedures for conditioning the carrier material to utilize self-structuring are described below (see Fig. 1).

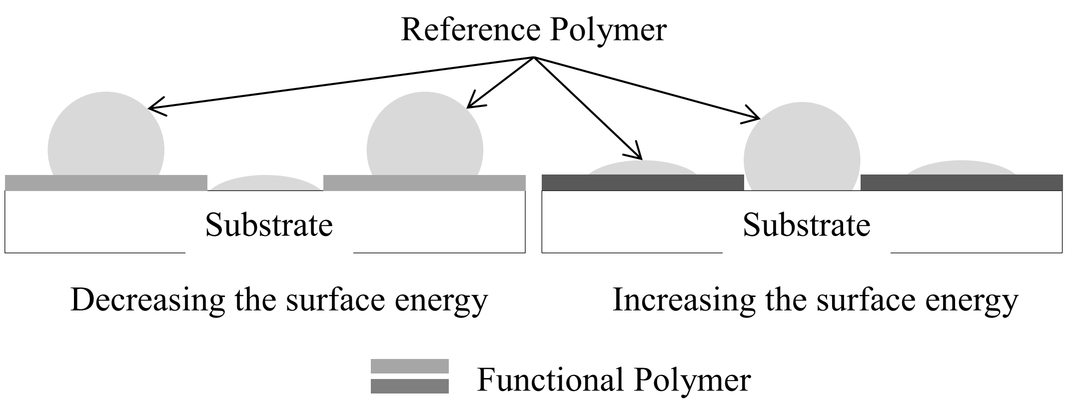


Fig. 1: Methods of generating boundaries for the polymer

The first possibility to increase the lateral resolution for printing waveguides is to selectively decrease the wetting capacity on the substrate. This process is schematically illustrated in figure 1. Areas with low surface energy are generated on an easily wetted carrier material. It allows the optical polymer only to stick on this part because of the disparity between the functional borders and the substrate itself. The other possibility is to increase the wetting capacity by applying paths of functional polymer on the substrate which attract the light conducting polymer.

EXPERIMENTAL

To investigate the interactions between the used polymers and carrier materials, experiments for contact angle measurements were accomplished. A list of the used materials is shown below (Table 1).

Table 1: Materials used for experimental work

Substrates	**Varnishes**
PMMA	390120 – containing silicone
PET	390119 – acrylate
PVC	391629 – highly reactive

In addition to this, contact angles on already coated substrates were measured to investigate influences on wetting phenomena (see Fig. 2). Furthermore, representative areas of the generated surface were measured by using a confocal microscope to allow a conclusion concerning its roughness.

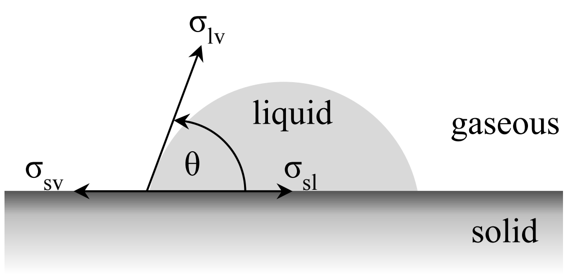
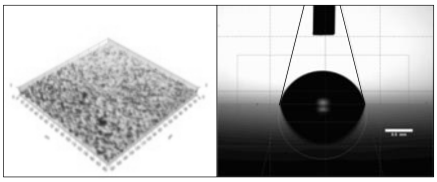


Fig. 2: Contact angle measurement

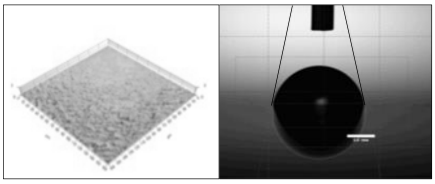
RESULTS AND DISCUSSION

By coating with a silicone containing UV-varnish 390120 compared with the uncoated material, the contact angle increased from $\theta = 76{,}6°$ to a contact angle of $\theta = 78{,}4°$. Coating with a highly reactive UV-varnish 391629 decreased the wetting capacity of the substrate and adjusted the contact angle to $\theta = 54{,}3°$ (see Fig. 3).



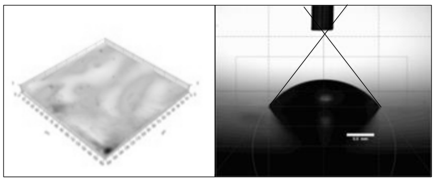
$\Theta = 76{,}6°$ $S_a = 0{,}181\ \mu m$
$S_q = 0{,}231\ \mu m$

Uncoated



$\Theta = 78{,}4°$ $S_a = 0{,}069\ \mu m$
$S_q = 0{,}091\ \mu m$

UV 390 120 (containing silicone)

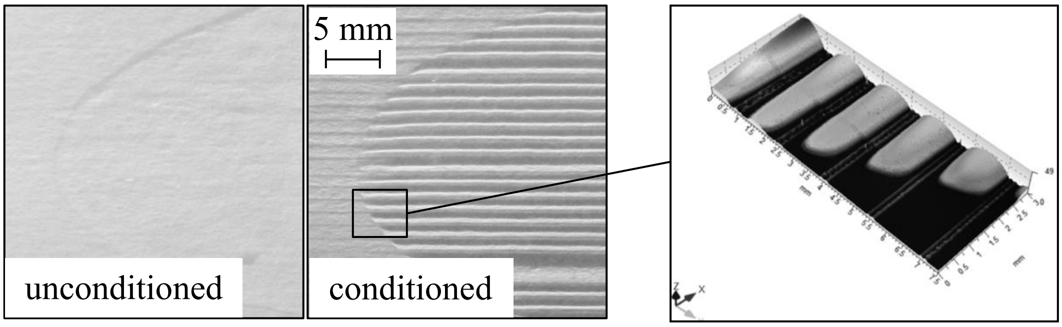


$\Theta = 54{,}3°$ $S_a = 0{,}135\ \mu m$
$S_q = 0{,}175\ \mu m$

UV 391 629 (highly reactive)

Fig. 3: Effect on the contact angle by conditioning the substrate

PVC–substrates conditioned by flexographic printed lines with the same silicone containing varnish were wetted with UV-varnish 390119 (acrylate) and demonstrated the self-structuring formation of light conducting structures on it. On the left side of Figure 4, the difference between the unconditioned and the conditioned substrate is shown. An image of the conditioned and coated substrate captured with a confocal microscope is illustrated on the right side of Figure 4.



conditioned with UV-varnish 390120 (silicone)
coated with UV-varnish 390119 (acrylate)

Fig. 4: Comparison of conditioned and unconditioned substrates

SUMMARY AND OUTLOOK

In this paper we described methods for modifying the surface properties of substrates with printing technologies to provide the production of optical waveguides with high resolution. This enables the manufacturing of optical three dimensional system components in downstream processes. We showed that the ability of affecting the wetting capacity is given by selective adjustment of the surface energy by flexographic printing.

Based on results of conditioning these substrates, the effect to improve the lateral resolution in spray coating processes remains to be examined. In the following approach reference waveguides have to be generated by using flexographic printing machines. The influence on properties of the waveguide in regard to its wavy edges and the geometrical shape will be another part of the research. One method to evaluate the structure is the measuring with a confocal microscope and generating algorithms to quantify its quality.

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