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Bibliographic note

Bio Based POF

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Abstract: In times of increasing resource scarcity, global warming and bio economics, bio based materials get more and more important. In this paper we show the possibilities and limitations of POF based on bio polymers. Two different bio-TPU were investigated regarding their optical potential and processed to fibers. Bio based POF are compared to PMMA based POF. It is shown that the reviewed material Estane® is not suitable as GI-POF for textile fabric due to missing color neutrality. While it is possible to process the second reviewed material Pearlthane®, its optical properties are improvable compared to PMMA based POF.

1. Introduction

Polymer optical fibers (POF) are used for data transmission, in sensor systems or in lighting applications. While they are already well-established in the fields of sensor systems and data transmission, POF offer great market- and development potential in lighting applications. Especially Graded-Index POF (GI-POF) have distinct advantages compared to Step-Index POF (SI-POF) or glass optical fibers in specific applications. A main deficit of GI-POF, its high production price, is approached in [1] by a novel continuous manufacturing process.

Today the mainly used material for POF is PMMA. Due to its high stiffness it is of limited suitability for further processing in textiles. Therefore, a material is needed which is spinnable, with high flexibility and good optical properties. Bio based thermoplastic elastomers offer the flexibility of elastomers while maintaining the ability to be used in melt spinning. Furthermore, the use of bio based polymers considers the increased importance of bio economics and conservation of resources.

During a bio economics focused project of the “Bundesministerium für Bildung und Forschung” two different thermoplastic polyurethanes were investigated and tested for their spinnability, their suitability for optical lighting applications and their suitability for further processing in textiles. Figure 1 shows the followed approach in four steps.

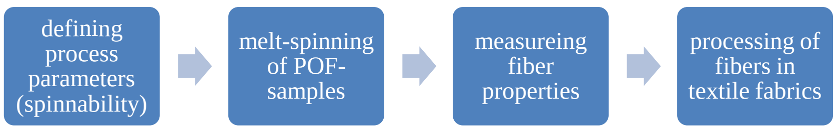

Figure 1: Four steps to evaluate the chosen thermoplastic polyurethanes

2. Experimental tests

The first step is to define process parameters for the chosen materials. The goal is to be able to melt-spin GI-POF with a diameter of 0.5-1 mm. In the next step POF-samples are melt-spun for the next steps. Then the properties of the fibers are measured. In step four different textile fabrics are processed from the fibers. Important properties for the POF are the damping of the light, tensile strength and diameter of the fiber.

2.1 Materials

The materials that are used in this study are two bio based thermoplastic polyurethanes (TPU) Estane® ECO 62A NAT 021 TPU and Pearlthane® ECO D12T80. The polymers are provided by the companies Lubrizol Advanced Materials BVBA, Westerlo-Oevel, Belgium and Lubrizol Advanced Materials Manufacturing Spain, S.L., Barcelona, Spain. Characteristic for the used TPU is their aromatic structure and the high amount of soft blocks that are responsible for the high flexibility.

2.2 Evaluation steps

Defining process parameters for spinnability: The process parameters for the melt-spinning process are the mass flow rate $\dot{m}$ and the haul-off speed v_w. These parameters are limited by constraints of the machine as well as theoretical considerations regarding their effect on spinnability and fiber properties.

Melt-spinning of POF-samples: Based on the previously determined range of process parameters, GI-POF-samples are spun. The melt-spinning process is based on a novel manufacturing process for GI-POF developed at the Institut für Textiltechnik der RWTH Aachen University [1].

Measuring fiber properties: After melt-spinning monofilament samples of the chosen TPU the samples are investigated regarding their fiber properties. To be applicable in lighting applications the POF need low damping, and good tensile strength. A diameter around 0.5-1 mm is needed to fit the available connectors.
The damping of the light is determined by measuring the light intensity of a fiber sample, shortening it and measuring the light intensity again. The difference in power is caused by the damping of the shortened fiber piece.
The tensile strength of the POF is measured with a tensile tester from Zwick-Roell, Ulm, Germany on the basis of DIN EN ISO 2062. The diameter of the fiber is measured using a light microscope.

Processing of fibers to textile fabrics: To bring proof of the suitability for further processing into textile fabrics, knitted and weaved fabrics are created from the spun POF-samples. As small diameters are beneficial for the process, GI-POF with a diameter of 0.5 mm are used.

3. Results and discussion

3.1 Defining process parameters for spinnability

Based on the machine-limited process parameters the range is narrowed down further to keep the diameter within the defined range of 0.5-1 mm. Figure 2 shows the range of the process parameters for Pearlthane®.

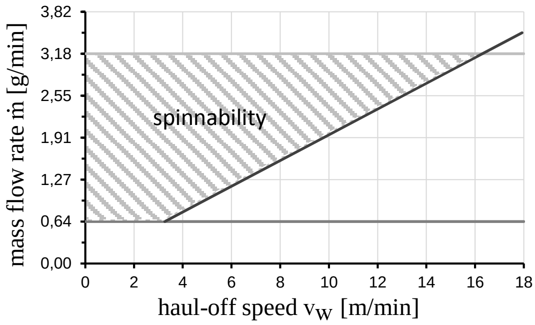

Figure 2: Range of process parameters for Pearlthane® ECO D12T80

3.2 Melt-spinning of POF-samples

A general suitability to melt-spin both chosen materials to GI-POF can be shown. The required diameters of 0.5-1 mm can be achieved. Both materials show some stickiness when spun out. This is believed to be caused by the cooling behavior and may be resolved by adjusting the spinning process.

The material Estane® ECO 62A NAT 021 TPU shows a yellow tint in the granulate material. The created monofilament still has the yellow tint. Therefore Estane® is not suitable for further processing into textile fabrics as a requirement is color neutrality. Pearlthane® ECO D12T80 is color neutral. Figure 3 shows a sample made of Estane®.

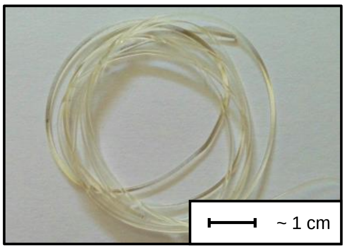

Figure 3: Yellow tinted POF-sample made of Estane® ECO 62A NAT 021 TPU

3.3 Measuring fiber properties

As spun fibers made of Estane® show a yellow tint they are not investigated any further.

The diameter of the POF-samples made of Pearlthane® show partly a significant deviation. This is believed to be caused by the experimental setup. POF-samples with low diameter deviation are suitable for further processing to textile fabrics.

Compared to typical used materials, the tensile strength of Pearlthane® is very low. As expected the use of TPU results in low tensile strength and high elongation. Figure 4 shows Pearlthane® in comparison to typical textile materials.

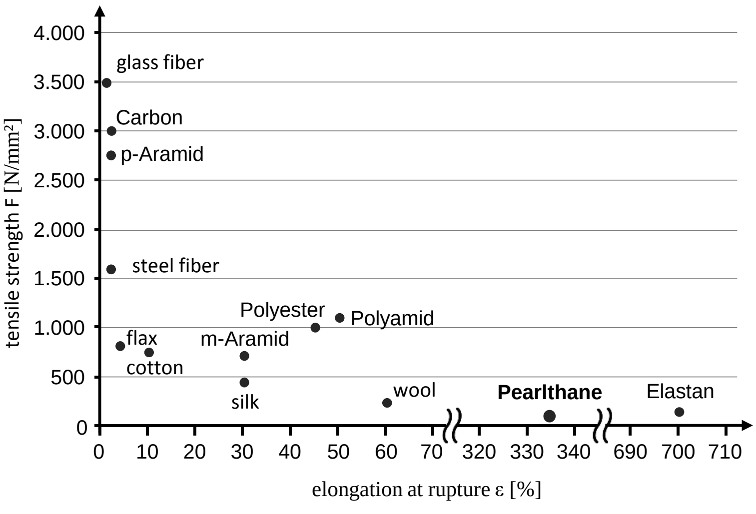

Figure 4: Comparison of tensile strength of Pearlthane® ECO D12T80 and other typical textile materials (based of [2])

Compared to GI-POF made from PMMA the light damping of GI-POF made from Pearlthane® is very high. The intensity of the injected light drops to 18 % after 10 cm. At the current state the material is only applicable for light transmission of short lengths.

3.4 Processing of fibers to textile fabrics

The general suitability of Pearlthane® ECO D12T80 for processing to knitted and weaved fabrics can be shown. The creation of a circular knitted fabric was successful. The in section 3.2 mentioned stickiness of the POF is responsible for very low production speed. Problems appear at the weaving process due to the stickiness of the material. This caused bad weaving results. Because of the high elasticity of the TPU a precise control of the weft tension is needed.

4. Conclusion

As materials for melt-spun GI-POF for lighting applications the two bio based thermoplastic polyurethanes Estane® ECO 62A NAT 021 TPU and Pearlthane® ECO D12T80 were investigated regarding their spinnability, their optical properties and their suitability for further processing to textile fabrics. While both materials can be melt-spun to GI-POF, only Pearlthane® offers the properties to be further processed to textile fabrics. The processing to circular knitted fabric was successful. Also weaving is possible, although problems regarding the fabric appearance occurred during the research.

The damping of the TPU-POF is considerably higher than the damping of typical GI-POF made from PMMA. Therefore, at the current state, GI-POF made from the thermoplastic polyurethanes can only be used at very short distances.

5. References

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