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# Tailoring Nanostructures of Injection-Molded Polymers

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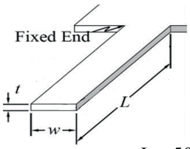
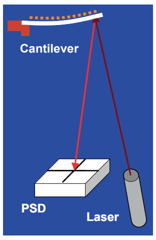
## INTRODUCTION

Understanding and controlling the structural anisotropies of injection-molded polymers is vital for designing products such as cantilever-based sensors [1]. Synchrotron radiation-based scanning small angle X-ray scattering (SAXS) techniques were used to quantify crystallinity and anisotropy in polymer micro-cantilevers. We demonstrate that micro-cantilevers (µCs) made of semi-crystalline polymers such as polyvinylideneflouride (PVDF), polyoxymethylene (POM) and polypropylene (PP) show the expected strong degree of anisotropy along the injection direction.

## CANTILEVER SENSORS

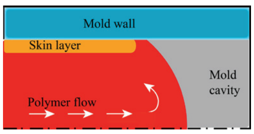



$L = 500$ µm
$w = 100$ µm
$t = 35$ µm



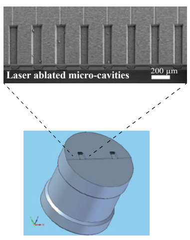

Cantilever sensing involves detection of cantilever bending. Adsorption of analytes onto the functionalised cantilever surface produces a differential stress between the two surfaces and induces bending.

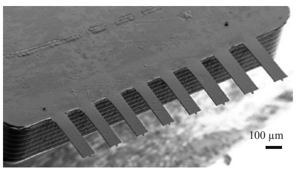
## MICRO-INJECTION MOLDING




Filling of cavities is explained by fountain flow: solidification of melts at mold walls leading to skin layers.

Micro-injection molding using a laser machined high-quality steel mold was applied for the fabrication of µCs [2]. Keeping the injection speed at 9 cm³/s the µCs were molded with 2 sets of mold temperature: PVDF 80°C, 120°C; POM 120°C, 150°C; PP 40°C, 80°C.

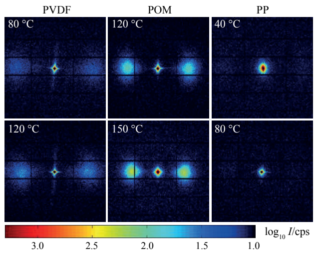


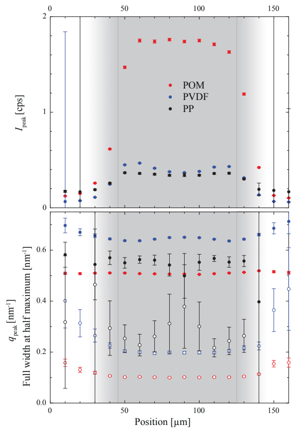

SEM of injection molded PP µC array

## X-RAY SCATTERING RESULTS

Background-corrected SAXS patterterns for the center of the µCs show two diffraction spots in the flow (horizontal) direction.

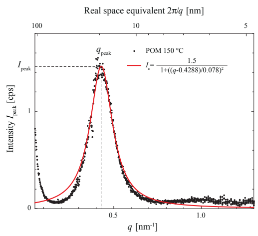


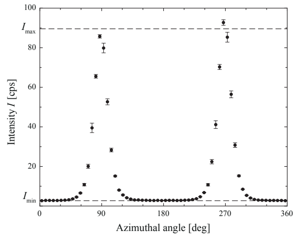

The distance of the spots from the beam stop is material dependent and decreases with the mold temperature [3].




Variation of $I_{peak}$, $q_{peak}$, and FWHM$_{peak}$ across the central part (µC width in gray). The low intensity variations in the central part of the µC indicate a homogeneous semi-crystalline structure.

The radial integration of the SAXS patterns allows characterization of the lamellar periodicity using a Lorentzian fit. The decrease of $q_{peak}$ with mold temperature is significant.




The degree of anisotropy is defined as $(I_{max} - I_{min}) / (I_{max} + I_{min})$ which can be derived from the azimuthal intensity distribution. A strong orientation of the semi-crystalline lamellae stacks within the µC is observed for PVDF, POM and PP µCs.

## CONCLUSIONS

- ✓ The micro-cantilevers are homogenous in the scanning direction perpendicular to the beam.
- ✓ By increasing the mold temperature, larger nanostructures can be formed
- ✓ The anisotropy at the nanometer level can be controlled using the process parameters.
- ✓ The strong anisotropic crystalline structure can be controlled by changing the mold temperature but not the injection speed.

## REFERENCE

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[3] P. Urwyler, H. Deyhle, O. Bunk, P.M. Kristiansen, B. Müller (2012 in press) *J. Appl. Phys.*

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