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Anisotropic Properties of PEEK Foils

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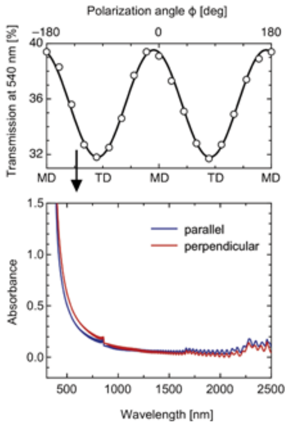
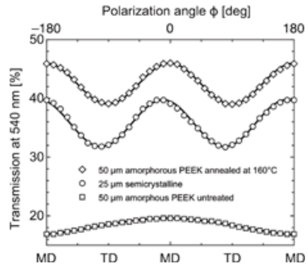
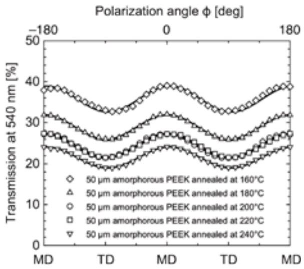
INTRODUCTION

During the last three decades, poly-etheretherketone (PEEK) has been increasingly employed as biomaterial for trauma, orthopaedic and spinal implants, etc. PEEK is biocompatible, chemically inert and exerts excellent mechanical properties compared to other thermoplastic polymer materials. Moreover, due to it's rigid backbone, PEEK tends to align anisotropically upon action of shear forces. Commercially available amorphous PEEK foils (APTIV TM) have been converted by cold crystallization into an anisotropic state. As anisotropy is common in human tissues, this phenomenon is promising to realize biomimetic implants.

LINEAR DICHROISM/OPTICAL MEASUREMENTS





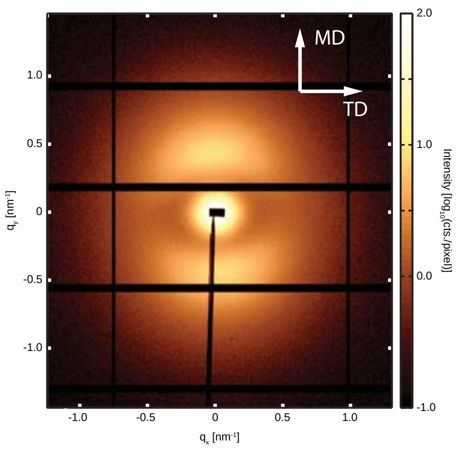


The semicrystalline PEEK foils exhibit an anisotropy according to the extrusion - machine direction (MD) and transverse direction (TD).

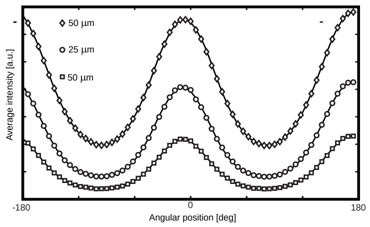
Upon annealing at 160 °C applying 12.3 MPa, amorphous PEEK foils become anisotropic to a comparable extent than the semicrystalline foils. Changing the annealing temperature from 160 to 240 °C, the specimen are more and more opaque, while the anisotropy stays almost constant.

Annealing [°C]	Const [T%]	Amplitude [T%]	MD [T%]	TD [T%]	MD/TD	2* Amplitude [T%]
160	35,7	3,2	38,9	32,6	1,19	6,32
180	28,9	3,0	31,8	25,9	1,23	5,99
200	24,3	2,9	27,2	21,5	1,27	5,75
220	24,4	2,8	27,2	21,6	1,26	5,70
240	21,5	2,6	24,1	19,0	1,27	5,14

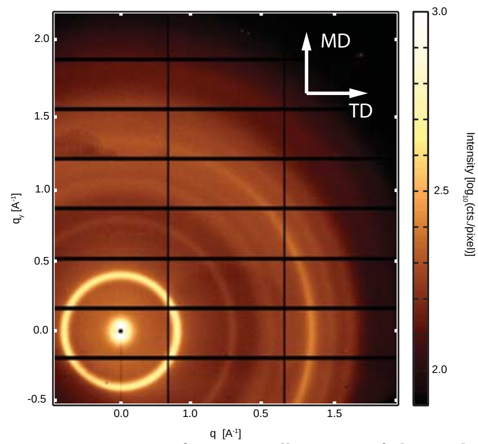
SMALL ANGLE X-RAY SCATTERING



The 146.6 Å feature investigated with scanning SAXS, shows a thickness-dependence which indicates that the anisotropy originates from the bulk and is not a surface phenomenon.

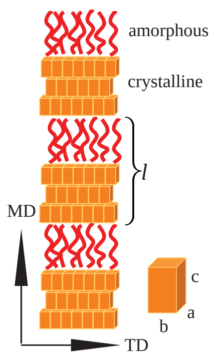


WIDE ANGLE X-RAY SCATTERING



Scanning WAXS of semicrystalline PEEK foils reveals rings corresponding to 146.6 Å, 15.6 Å, 7.92 Å, 5.94 Å, 5.37 Å and 4.69 Å. The 146.6 Å and 5.94 Å features are found to be anisotropic and perpendicular to each other, associated with c-axis orientation in MD- and a- and b-axes orientation in TD-direction.

PEEK POLYMER MODEL



The X-ray data was interpreted by the common two-phase model. The observed long range order of 146.6 Å (l) can be described by a two-phase model wherein the sample is composed of stacks of thin lamellae alternating between thicker amorphorous interlayers. The crystalline part is arranged in an orthoromic lattice. Differential Scanning Calorimetry (DSC) of amorphous PEEK foils shows the glas transition temperature around 143 °C and the melting temperature around 338 °C. In slowly crystallizing polymers, cold crystallization is often observed upon heating of amorphous foils, seen as an exothermic peak at 171 °C in DSC measurements.

CONCLUSIONS

While amorphous PEEK foils are isotropic, semicrystalline and post-processed amorphous foils exhibit an anisotropic nanostructure, which is essential for the development of biomimetic implants. Transmission measurements and X-ray scattering techniques demonstrate the relation between the machine direction and the molecular ordering within the semicrystalline PEEK.

ACKNOWLEDGEMENTS

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