Designing Polymeric Cardiovascular Biomaterials for Hemocompatibility and Mechanical Performance

Mary Jialu Chen[1], Georgios Pappas[1], Daniele Massella[1], Arthur Schlothauer[1], Nikola Cesarovic[2,3], Volkmar Falk[2,3], and Paolo Ermanni[1]

[1]Laboratory of Composite Materials and Adaptive Structures, ETH Zürich, jichen@ethz.ch

[2]Translational Cardiovascular Technologies, ETH Zürich

[3]Klinik für Herz-, Thorax- und Gefäßchirurgie, Deutsches Herzzentrum Berlin

Introduction

Cardiovascular implantable devices increasingly use polymeric materials such as polyetheretherketone (PEEK) for higher durability and flexibility (Fig. 1).[1,2] Flexible thin ply carbon fiber/PEEK materials – with superior crystallinity (Fig. C1) - can be used as a transcatheter heart valve stent.[3,4]

How does the PEEK crystallinity affect hemocompatibility and mechanical performance?

Fig. 1: Top (left) and side (right) view of PEEK based heart valve prototype

Hypothesis

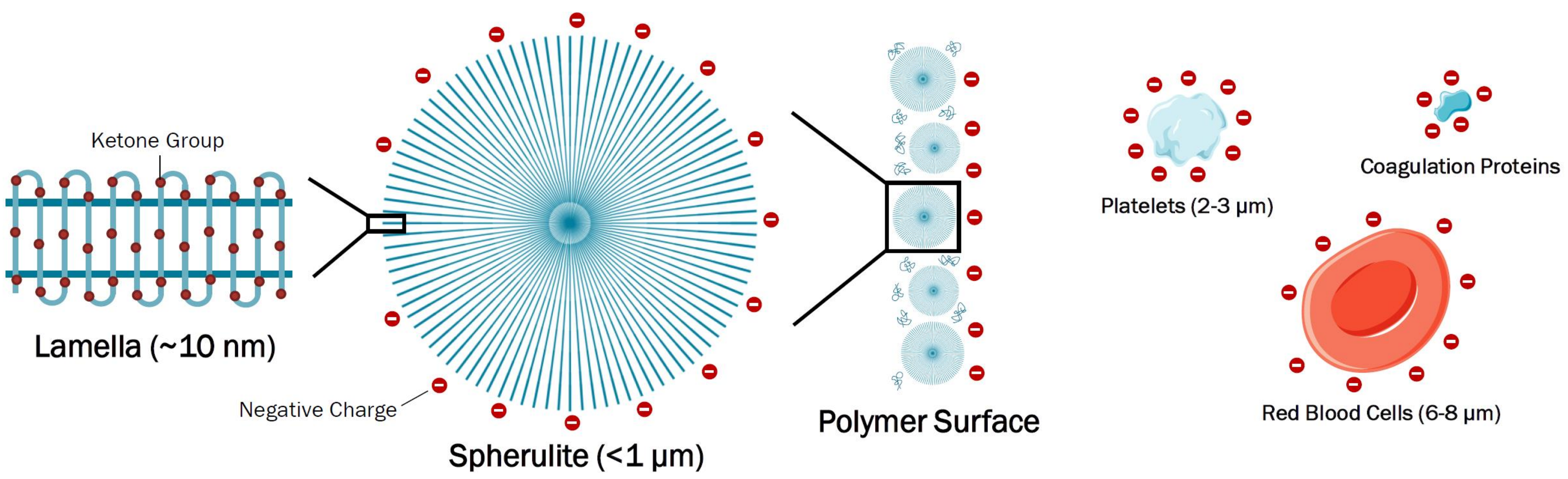

Fig 2: Schematic diagram depicting how higher crystallinity causes conformational changes and increased exposure of polar, oxygen-containing functional groups (Fig. C2) on lamellar edges. Negative surface charge on small, uniform spherulites results in a negatively charged polymer surface that repels similarly charged platelets, red blood cells, and coagulation proteins.

Hemocompatibility and Mechanical Characterization

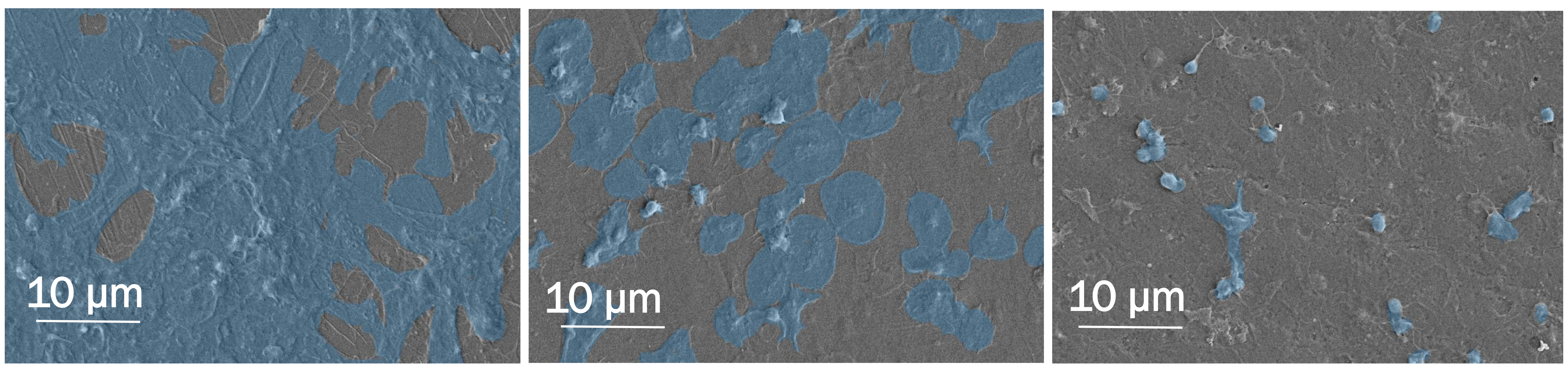

Fig 3: SEM images of maximum platelet adhesion on a) amorphous (4.2% crystallinity), b) crystalline (33.7% crystallinity), and c) carbon fiber/PEEK (41.2% crystallinity) composite samples, with platelets manually coloured in blue

Hemocompatibility: 95% reduction in platelet adhesion (Fig. 3), 50% reduction in hemolysis (Fig. C3a), and 75% reduction in thrombin generation rate (Fig. C3b) following crystallization.

Mechanical properties: 50% increase in Young's Modulus and 64% decrease in maximum elongation after annealing (Fig. C4). Higher crystallite order causes increased stiffness and decreased ductility.

Supplementary Information

Crystallinity Characterization

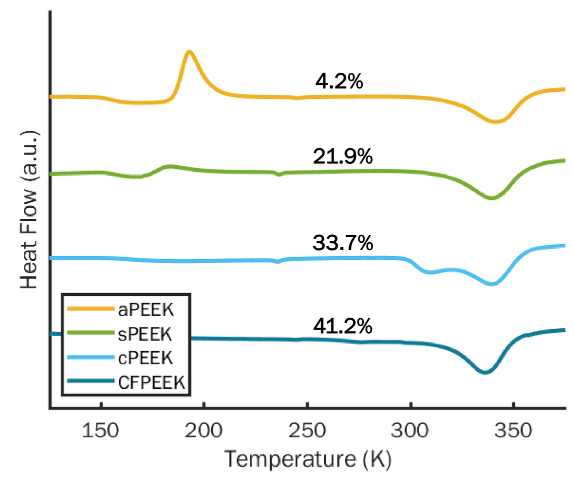

Fig C1: Differential scanning calorimetry melting curves obtained for amorphous (aPEEK), semi-crystalline (sPEEK), and crystalline (cPEEK) PEEK, as well as the carbon fiber/PEEK composite (CFPEEK)

Chemical Characterization

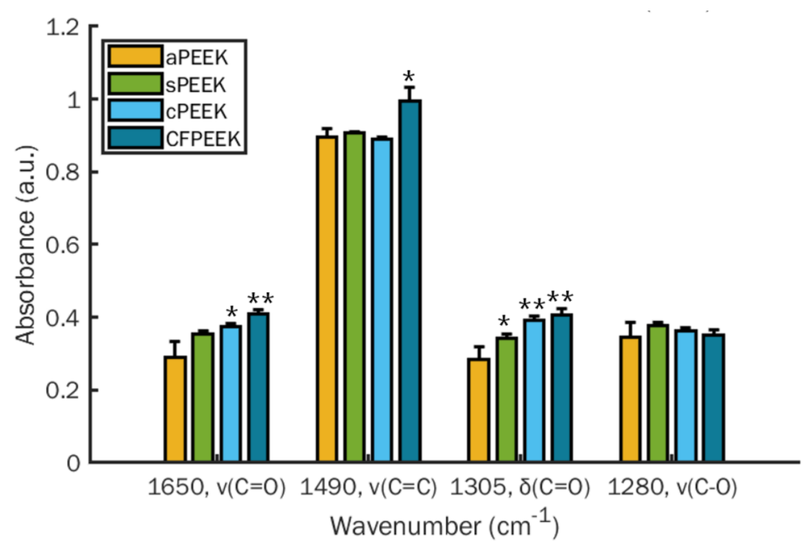

Fig C2: Absorbance values of the characteristic absorption bands obtained from ATR-FTIR analysis. Error bars are mean ± SD ($n = 3$). All significance comparisons were made to aPEEK: * $p < 0.05$, ** $p < 0.01$

Effect of Crystallinity on Hemocompatibility

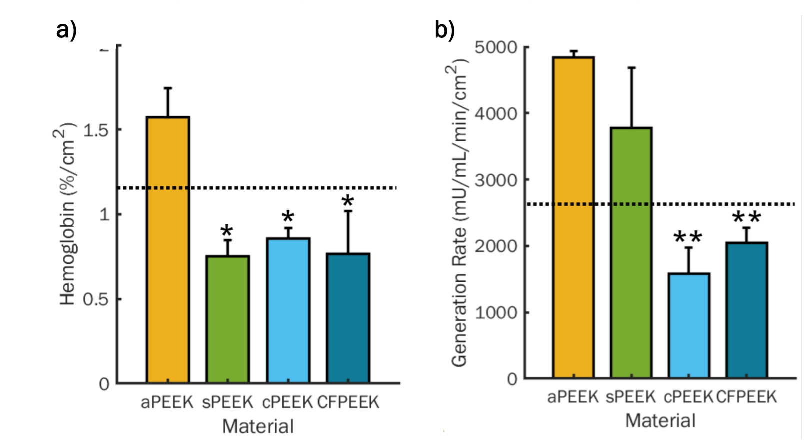

Fig C3: a) Percent hemoglobin released for PEEK samples after incubation in erythrocytes for 24 hours. b) Maximum thrombin generation rate determined for PEEK samples incubated in thrombin for 30 minutes. Error bars are mean ± SD ($n = 3$). All significance comparisons were made to aPEEK: * $p < 0.05$, ** $p < 0.01$, unpaired t-test (two-tailed), black dotted lines indicate average value of negative control.

Effect of Crystallinity on Stress-Strain Behavior

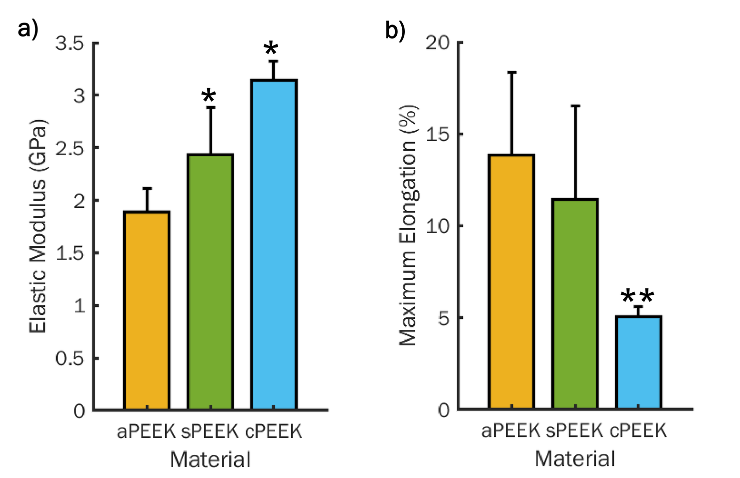

Fig C4: Stress-strain curves obtained for a) amorphous, b) semi-crystalline, and c) crystalline PEEK films through tensile testing. Error bars are mean ± SD ($n = 5$). All significance comparisons were made to aPEEK: * $p < 0.05$, ** $p < 0.05$, unpaired t-test (two-tailed).

References

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[4] A. Schlothauer, et al., Compos. Sci. Technol. 199 (2020).

Molecular reorientation during polymer crystallization results in generally improved hemocompatibility and mechanical performance

Laboratory of Composite Materials and Adaptive Structures

ETH zürich

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