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Surface modification of CFR-PEEK by sulfonation and plasma immersion ion implantation for enhanced osseointegration

Ang Gao[1,2], Huaiyu Wang[2], Paul Chu[1]

1 Department of Physics & Materials Science, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong, PR China
2 Institute of Biomedicine & Biotechnology, Shenzhen Institutes of Advanced Technology, Shenzhen, Guangdong, PR China

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Introduction: Carbon-fiber-reinforced polyetheretherketone (CFR-PEEK) is the most promising candidate to replace metallic implants in orthopedics and trauma, as its elastic modulus closely match cortical bone thus avoiding the stress shielding effect [1]. However, its chemical and biological inertness that impedes osseointegration after implantation still limit its wide clinical adoption [2]. Surfaces with favorable morphologies and chemical cues is highly desirable for orthopedics implants [3], and thus surface modification is an effective way to enhance the biomedical performance without affecting the excellent attributes of the bulk CFR-PEEK [4,5].

Materials and Methods: CFR-PEEK was firstly subjected to sulfonation treatment by being immersed in concentrated sulfuric acid (95-98 wt.%) followed by in 95% ethanol (labeled as SPEEK). After rinsed with distilled water and dried, SPEEK samples were further treated by oxygen or nitrogen plasma immersion ion implantation (PIII) (labeled as SPEEK-O2 and SPEEK-N2, respectively). The modified surfaces were characterized by various techniques, including scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS), and water contact angle. The biological performance of the treated surface was assessed by *in vitro* studies such as osteoblasts adhesion, proliferation, and osteogenic abilities.

Results and Discussion: The results demonstrated that the sulfonation treatment followed by ethanol immersion gave rise to the three dimensional (3D) porous surface (Figure 1B). After O_2 PIII treatment, the porous surface was further eroded to be cluster-like (Figure 1C), whereas N_2 PIII rarely change the surface morphology (Figure 1D). The CCK assay results at day 3 indicated that the cell viability was impaired by sulfonation treatment, and even further suppressed by the followed O_2 PIII treatment. However, cell proliferation was enhanced if the O_2 PIII was replaced by N_2 PIII.

Conclusion: Surface modification techniques including sulfonation and PIII were utilized to treat CFR-PEEK and the surface morphologies, chemical composition, and thus the biological performance can be easily tailored. The surface of CFR-PEEK modified by solfnoation followed by N_2 PIII treatment shows the ability to accelerate osseointegration.

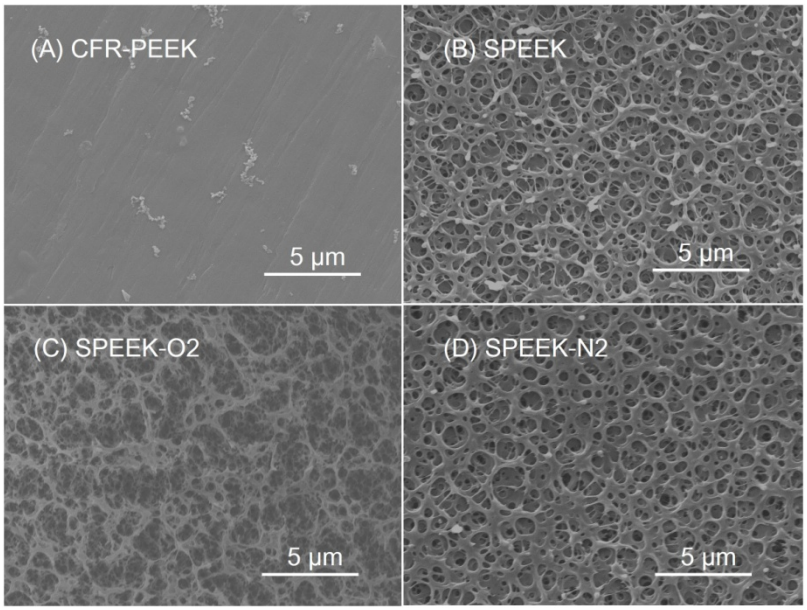

Figure 1 SEM top-view images of the (A) pristine CFR-PEEK control; (B) CFR-PEEK after sulfonation treatment followed by ethanol immersion (labeled as SPEEK); (C) SPEEK after O_2 PIII treatment; (D) SPEEK after N_2 PIII treatment.

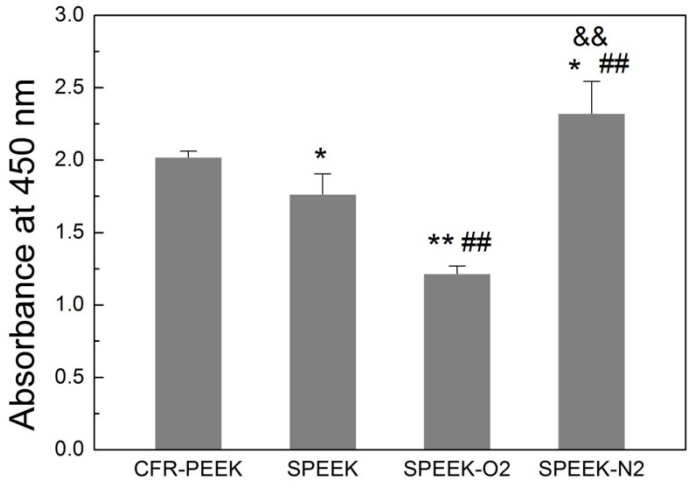

Figure 2 Proliferation of MC3T3-E1 cells on samples measured by CCK assay after 3 days of culture. *, $^{**}p < 0.05$ or 0.01 vs CFR-PEEK, $^{\#\#}p < 0.05$ or 0.01 vs SPEEK, and $^{\&\&}p < 0.05$ or 0.01 vs SPEEK-O2.

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Corresponding:

Email: paul.chu@cityu.edu.hk
Tel: +852-34427724
Fax: +852-34420538