Plasma Spray Deposition of Titanium and Hydroxyapatite on PEEK and Carbon Fiber-Reinforced PEEK

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Purpose: The use of PEEK and Carbon Fiber-Reinforced PEEK (CFR-PEEK) is notably increasing in the biomedical field, especially in spine applications, due to its biocompatibility, radiolucency and favourable stiffness values. In order to improve the bone-implant interface, PEEK implants may be coated with Titanium (Ti) or Hydroxyapatite (HA) via Plasma Spray (PS) processes[1]. Although microstructural analysis showed good interlocking between deposited particles and PEEK substrate[2] few details are reported on the mechanical properties of the coated substrates. This work aims at investigating the influence of the PS process on tensile and flexural properties of PEEK and CFR-PEEK. In order to distinguish the effects induced by sandblasting, representing the first step of PS coating process, a mechanical characterization has been carried out also on a set of sandblasted PEEK and CFR-PEEK specimens. Scanning electron microscope (SEM) analysis and adhesion measurements of the coatings were carried out in order to characterize the coatings.

Materials and methods: PEEK and CFR-PEEK OPTIMA® (Invibio Ltd, UK), loaded with 30% carbon fibers, were used as substrate. HA and Ti coatings were applied via PS (Eurocoating S.p.A). Mechanical testing were performed on as delivered, sandblasted, HA-coated and Ti-coated specimens. Tensile and flexural tests were carried out according to ISO 527-1 and ISO 178 standards respectively, using an INSTRON 8516 testing machine. Tensile elastic modulus (EM), tensile strength (TS) and flexural strength (FS) were recorded.
Adhesion tests were performed according to ASTM F1147. SEM inspections were carried out using a Jeol Inc. JSM-5500 instrument.

Results and discussion: Tensile and flexural strength values as well as elastic moduli for coated PEEK and CFR-PEEK are shown in Tables 1 and 2. These data suggest that the coating process slightly reduces specimens tensile and flexural strength, although, if we compare data normalised to polymeric section, PEEK strength values are substantially equivalent (here not shown). An increase of specimens elastic modulus seems to be induced by the Ti-coating application.

PEEK	TS [MPa]	FS [MPa]	EM [GPa]
As delivered	90.8± 1.5	158±3	3.9± 0.2
Sandblasted	89.8± 0.4	160±2	3.9± 0.1
HA-coated	85.2± 0.4	149±4	3.9± 0.2
Ti-coated	86.6± 0.6	147±3	4.6± 0.3

Tab.1: PEEK tensile and flexural properties.

A limited reduction of both tensile strength and elastic modulus is produced by HA deposition onto CFR-PEEK. Flexural strength values show a similar behaviour for HA coated material.

CFR-PEEK	TS [MPa]	FS [MPa]	EM [GPa]
As delivered	231± 1	192±15	26.6±1.2
Sandblasted	221± 1	176±7	24.9±0.2
HA-coated	212±5	180±35	22.3±0.5
Ti-coated	217±1	261±25	24.2±0.4

Tab.2: CFR-PEEK tensile and flexural properties.

The relatively high value for Ti-coated CFR-PEEK specimens could be attributed to an influence of Ti-particles on the compression side, which increase the stiffness of the flexural specimens (not shown).
Coating-substrate adhesion values are reported in Table 3 for both coatings.

Substrate	Coating	Adhesion value [MPa]
PEEK	HA	17.1±2.7
	Ti	22.0±3.0
CFR-PEEK	HA	21.6±4.7
	Ti	26.2±5.0

Tab.3: adhesion values of coating

Both materials show partial cohesive and partial adhesive coating failures.
SEM analysis performed on the two coatings revealed complete and homogeneous coverage of surfaces for both materials and thicker coatings have also been found to be porous. (Figg.1-2).

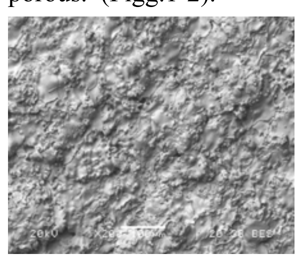
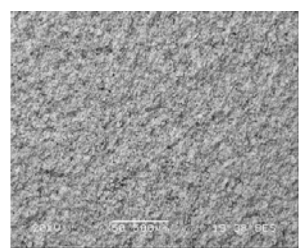

Fig.1-2: Ti coating onto CFR-PEEK (L) - HA coating onto PEEK (R)

Conclusions: A properly designed and applied plasma spray process may potentially improve the osseoconductivity of PEEK or CFR-PEEK components while modestly varying the tensile and flexural properties. Coatings were homogeneous with adhesion properties satisfying standard specifications.

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