PROPERTIES OF ISOTROPIC PYROLYTIC CARBON: A MULTISCALE APPROACH

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Introduction

Pyrolytic carbon (PyC), due to its high mechanical properties and hemocompatibility is the main material used for mechanical heart valves (MHV) fabrication [1]. Mechanical characterization of the PyC used for biomedical application played a crucial role in the development of MHVs production. Here a multiscale approach was adopted, performing three points bending tests and nanoindentation tests.

Methods

Isotropic PyC was deposited on the graphite substrates following two different deposition processes. Three sizes of substrate were used. Obtained specimens were properly cut and polished to be tested through the three-point bending technique (figure 1a) and nanoindentation technique (figure 1b).

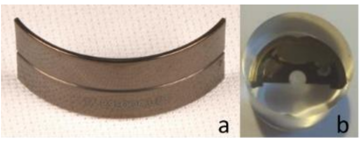

Figure 1. (a) Specimen used for three-point bending tests; (b) Specimen used for nanoindentation tests

A total of 78 specimens (13 for each size) were tested. Three-point bending tests were performed following the ASTM F 417 – 78. Due to arch geometry of the specimens, the maximum flexural stress was calculated according to eq. 1 [2]:

$$\sigma_{MAX} = P_{MAX}\frac{\tan\alpha}{2}\left[\frac{1}{A} - \frac{R}{I}y_e\right] \qquad (1)$$

The Young's modulus was calculated through the principle of the virtual work.

Indentation tests were performed with the Nanoindenter XP (MTS system Corporation, USA) equipped with a Berkovich indenter, previously calibrated on a standard silica specimen. For each specimen, a matrix of 30 indentations was generated. Specifically, the indentations were performed normally to the direction of the PyC deposition. Tests were performed in displacement control, setting the indentation depth to 800 nm. The Oliver & Pharr method [3] was applied to obtain the nanoindentation modulus and the nanoindentation hardness (data here not shown).

Results

Young's modulus and Fracture stress mean values obtained from three-point bending tests were reported respectively in figure 2a and figure 2b. Whereas fracture stress values were found to be slightly lower than that reported in literature [4], probably due to the different geometry of the specimens, measured Young's modulus were consistent with those reported in similar works [4].

The statistical analysis has revealed no significant difference ($p > 0.05$) between the two deposition processes at the macroscopic level.

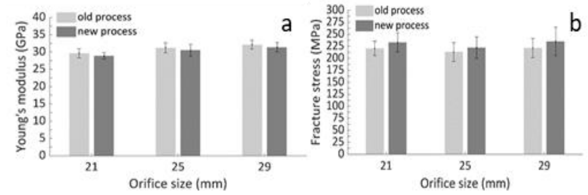

Figure 2. (a) Mean values of Young's Modulus; (b) Mean values of Fracture stress

The mean values of the Nanoindentation modulus (Figure 3) and of the Nanoindentation hardness also agree with those found in literature [5].

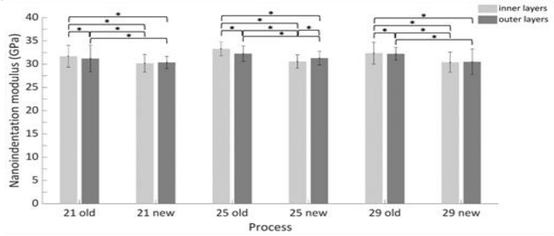

Figure 3. Mean values of nanoindentation modulus

In general, through the new deposition process, a significant reduction of the difference of the nanomechanical properties between the inner and outer layers was registered.

Discussion

Results obtained through three-point bending tests characterize the deposited PyC as bulk material. Since the bulk PyC is a layered material, possible changes due to a change in deposition process are difficult to detect at this scale. As matter of fact, the results of the three-point bending tests indicate that the two deposition processes lead to a PyC with comparable mechanical properties. On the other hands, the mechanical properties obtained at the microscale significatively change with the indentation site and the deposition process. It can be speculated, indeed, that through the nanoindentation approach is possible characterize a single layer of deposited PyC. Thus, information at the submicron scale reveals the effectiveness of settings variation of the deposition process on the layer's mechanical properties.

References

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