PULSED PLASMA DEPOSITION OF ZIRCONIA THIN FILMS ON UHMWPE: PROOF OF CONCEPT OF A NOVEL APPROACH FOR JOINT PROSTHETIC IMPLANTS

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Introduction

Currently, the mean survival rate for Total Joint Arthroplasty is ~ 90% after 10 years; then, a revision surgery is generally required, due to osteolysis and aseptic loosening of the implant, which are strongly correlated with the formation of wear debris from the UHMWPE insert [Ingham, 2005]. Here, a new approach to overcome this detrimental issue is presented: hard, well-adhered and tough zirconia (ZrO_2) thin films directly deposited onto the surface of UHMWPE by the novel Pulsed Plasma Deposition (PPD) technique in order to strongly limit the elasto-plastic deformation of the UHMWPE substrate especially under high local loads [Bianchi, 2013].

Methods

3% yttria-stabilized zirconia films were deposited by PPD technique. PPD is based on the ablation of a target material by a high-energy pulsed electron beam; the ablated material forms a plasma plume directed toward the substrate where it is deposited. Thank to the possibility to work efficiently even at room temperature, PPD is suitable for coating plastic materials. Films were characterized by SEM-EDX, X-ray diffraction, nanoindentation, adhesion and tribological tests. Moreover, the capability of the ZrO_2–UHMWPE system of carrying local loads – i.e. an estimation of the resistance to a third-body abrasion – was investigated.

Results

Deposited zirconia films exhibited a fully cubic structure and a smooth nanostructured surface. Mechanical tests showed that hard, tough and well-adherent films were deposited. In particular, nanoindentation tests revealed rather high hardness and Young's modulus values (17 GPa and 154 GPa respectively), while critical fracture tests revealed that, even under loads as high as 500 mN (equivalent to ~ 8 times the maximum pressure exercised on a femoral head during normal walking activity) no radial cracks, spalling or pile-up phenomena were observable, revealing a high fracture toughness and a very high adhesion degree of the ceramic film to the plastic substrate. Moreover, preliminary tribological tests carried out in air against an alumina ball counterpart showed wear rate as low as $3.2*10^{-6}$ $mm^3N^{-1}m^{-1}$ after 500.000 cycles.

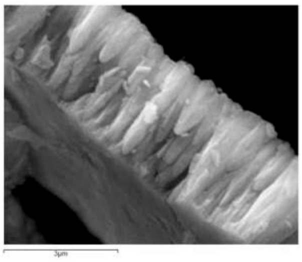

Figure 1: SEM image of a ZrO_2 film deposited by PPD (side view).

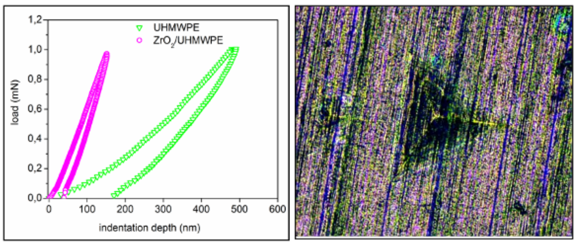

Figure 2: Nanoindentation curves for coated and uncoated UHMWPE (left) and optical image of nanoindenter footprint for a load of 500mN (right).

Discussion

The results showed in this work suggested the feasibility of pursuing this alternative and completely new route to improve UHMPWE performances while preserving its well-established mechanical properties.

References

Bianchi *et al*, J Mater Chem, 1:310-318, 2013.
Ingham *et al*, , Biomater, 26:1271-1286, 2005.