The Growth and Characteristics of a Micro-textured Surface on Ti6Al4V

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Statement of Purpose: According to the American Academy of Orthopedic Surgeons, nearly 1 million total joint replacements (TJRs) were performed in 2006 [1]. Titanium (Ti) and CoCrMo alloys are the primary metallic materials for these prosthetic implants. Because of the superior wear performance, most TJRs include one or more cobalt-chromium alloy (CoCrMo) component. The release of solid material in the form of particles from component wear is a primary instigator of failure of total joint replacement (TJR) devices.

Wear is the loss of, or damage due to the displacement of, material on a surface. Adhesion, abrasion, fatigue, and corrosion wear affect the performance of all TJR materials [2]. Although Ti alloys possess great biocompatibility characteristics, they do not perform as well as CoCrMo alloys in wear conditions. A TJR system that contains a Ti component, such as an artificial hip stem, will typically use a CoCrMo component at a wear interface. If the Ti wear surface could be modified in such a way as to resist wear better than CoCrMo under articulating conditions, a wear resistant prosthesis made entirely of Ti may ultimately perform better than a multi-material system.

We have developed a novel method to create a micro-textured, hard carbide surface on CoCrMo implant alloys [3]. In this study, we investigated the potential to use similar methods to create a new micro-textured surface on Ti6Al4V. The overall goal is to engineer a new surface for the improved wear resistance of Ti implant materials. The purpose of the micro-textured surface is to improve wear performance, retain lubricating fluids, and entrap particles, keeping them away from the articulating surface. This research explored the creation and basic mechanical performance of an integrated micro-textured surface on a Ti alloy substrate.

Methods: A Microwave Plasma-assisted Chemical Vapor Deposition (MPCVD) protocol was applied to medical grade Ti6Al4V alloy specimens, using controlled parameters as described by VanDamme, et al [3], with the intention to create a micro-textured surface on the Ti substrate.

Titanium alloy specimens were cut from a 0.625 inch diameter wrought annealed Ti6Al4V ELI rod to a thickness of 7 mm. Both sides of each disk were polished to a mirror finish with an average surface roughness (Ra) of < 0.040μm by hand on a polishing table. Each specimen was then placed in an ultrasonic bath and cleaned for 10 minutes in DI water followed by 10 minutes in acetone, then allowed to air dry for a minimum of 2 hours.

Prior to MPCVD treatment, the diameter, thickness, weight and surface roughness was measured for each specimen. The surface roughness was measured and analyzed with a white light interference surface profilometer (WLISP, Zygo New View 100, Zygo, CT), Each specimen was subjected to MPCVD using controlled parameters for temperature, gas flow rate, and pressure.

Post processing weight and surface roughness was measured for each specimen using the same equipment as during pre-processing measurements. The morphology of processed Ti samples was observed via scanning electron microscopy (SEM). Micro-hardness indentation testing was performed on selected Ti samples using a minimum of 5 indentation locations on each. The width of each indent was extracted from WLISP depth profile images and the Vickers hardness (HV) value was calculated.

A total of 26 specimens were examined. Baseline specimens included one polished CoCrMo specimen, two polished Ti specimens and two Ti H_2 plasma-treated only (no CH_4) specimens processed at 776°C and 1006°C. Twenty one specimens were processed at a system pressure of 70 Torr, a gas flow rate of 100 sccm (99 sccm H_2 and 1sccm CH_4) and temperature settings ranging from 725°C to 1110°C for 1, 2, 4 or 6 hrs.

Results: Specimens processed at temperatures <1070°C did not exceed the polished, as-received CoCrMo HV, independent of processing time (2hr, 4hr, 6hr). Of the 21 MPCVD processed specimens, only the group of 3 specimens processed for 2hrs at temperatures > 1070°C exhibited a notable increase of HV over polished, as-received Ti6Al4V and CoCrMo. Specimens processed for only 1 hr in the same temperature range (T > 1070°C) exhibited an HV equal to, or slightly greater than, that of CoCrMo (Fig. 1). The Ti6Al4V specimen processed for 2 hrs at 1077°C exhibited an increase of over 150% of the HV of the CoCrMo.

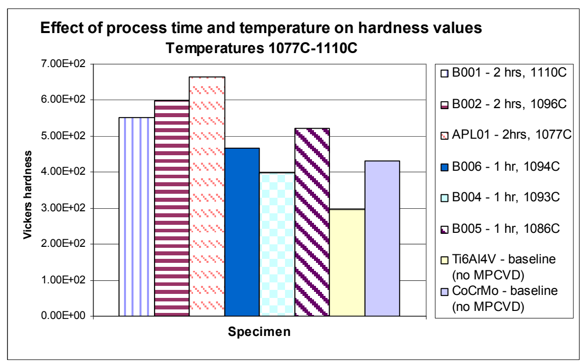

Figure 1.

Conclusions: A desirable micro-textured surface generated from a Ti6Al4V substrate may be achieved. Micro-hardness testing has indicated that a surface with the potential to possess improved wear properties over those of polished CoCrMo was generated from the Ti6Al4V bulk material. A processing time of 1hr at temperatures >1070°C produced a micro-textured surface, and showed a hardness increase to that of reference CoCrMo. Specimens from the 2hr processed time group showed substantial increases in hardness over CoCrMo. Further studies will be conducted to identify the constituents of the micro-textured surfaces and optimize the surface.

References:

1. AAOS. Facts on Hip Replacements. Dec 31, 2008
2. Hutchings, I.M., Friction, Lubrication, and Wear of Artificial Joints. 2003. 3. VanDamme, NS, et al. J of Matl Sci, 2005 (16): 647– 654

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