Laser Processed CoCrMo-Calcium Phosphate Composites for Articulating Surfaces

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Statement of Purpose: CoCrMo is well known and widely used material for bio implants. This material is hard and shows good wear and corrosion resistance. However, over long periods, the wear that they undergo is still significant [1]. Various attempts have been made to reduce the wear damage of CoCrMo. In this research we use Laser Engineered Net Shaping (LENS™), a powder additive manufacturing technology, to form meal-ceramic composites by the addition of tricalcium phosphate (TCP) to CoCrMo. **The objective** is to study the effect of TCP on the tribological properties of CoCrMo. **Our hypothesis** is that TCP will act as a solid lubricant to reduce metal ion release due to wear induced surface damage of CoCrMo. Addition of TCP will also reduce the metallic ion release from CoCrMo during wear.

Methods: A mixture of CoCrMo powder and 1% and 3% (by weight) TCP powder (particle size range 44-149µm for both) in was processed using Laser Engineered Net Shaping (LENS™ 750, Optomec, Albuquerque, NM.) setup in our laboratory on SS316 substrate. LENS™ uses a high power laser to melt metallic powder and deposit in a layer by layer three dimensional pattern. The process takes place inside a glovebox where oxygen is maintained below 10ppm. The part to be fabricated is designed using CAD software. The LENS™ technology offers advantages like high solidification rates, controlled processing environments, alloy forming capability and reproducibility. Square shaped samples of sides 14.5mm and thickness of ~6-8mm were fabricated using laser power of 400W. Mechanical testing done on these samples included micro hardness test and tribology in DI (at room temperature) and in DMEM (at 37˚C) medium. The samples were tested for wear for a distance of 1km in each media.

Results: The hardness of LENS™ processed CoCrMo was found to be 494±31 $HV_{0.1}$ and the hardness of CoCrMo with 3% TCP added composite was 534±98 $HV_{0.1}$. Thus, contrary to the expectation, the addition of TCP did not increase the hardness of CoCrMo significantly.

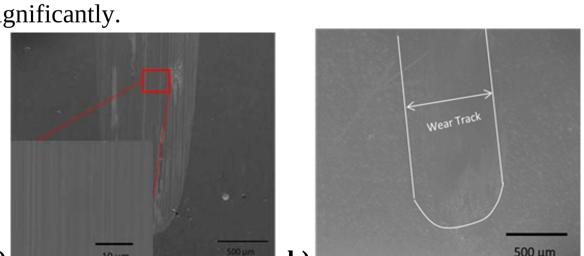
a) b)


Figure 1: Wear track in 1km DI wear (a) CoCrMo-0% TCP (b) CoCrMo-3%TCP

However addition of TCP had a significant effect on the wear behavior of CoCrMo. Figure 1 shows the wear track of CoCrMo-0% TCP and CoCrMo-3% TCP processed by LENS™. LENS™ processed CoCrMo with no TCP addition had a wear track width of 926±123 µm and this width decreased to 670±78µm with the addition of 3%TCP. Calculating the wear volumes revealed that the addition of 1%TCP decreased the wear volume by half. Similarly, wear volume of CoCrMo-3% composite was one third compared to the sample with no TCP addition. The results are tabulated below.

Sample	Wear track Width (µm)	Wear Volume (mm^3)	Wear Rate (mm^3/Nm)
Co-Cr-Mo-0%	926±123	22.3×10^{-2}	4.46×10^{-5}
Co-Cr-Mo-1%	719±63	10.68×10^{-2}	2.13×10^{-5}
Co-Cr-Mo-3%	670±78	8.5×10^{-2}	1.7×10^{-5}

Table 1: Wear volume in DI wear test

Low wear on the surface of the CoCrMo-3% sample is also clearly visible from the SEM images in Figure 1. More detailed SEM of the wear tracks revealed the formation of a TCP tribofilm.

Figure 2: Formation of tribofilm in CoCrMo-TCP Composite

Careful inspection of the entire wear track revealed that most of the wear took place along the sides and ends of the wear track where the wear media is relatively 'static' and contact is maximum. These were also the regions where the TCP tribofilm was not as extensive as in the central region of the sample. Thus, towards the center of the wear track, we observe little wear and a clear and continuous tribofilm and towards the ends and edges, we see more wear but also a discontinuous TCP tribofilm. Observations were similar in wear in DMEM at 37˚C.Thus addition of TCP increases the wear resistance of CoCrMo by forming a lubricating tribofilm.

Conclusion: Addition of TCP to traditional CoCrMo has improved the tribological performance. A distinct tribofilm has been found to develop that reduced the wear induced surface degradation. Further data analysis show the influence of this tribofilm on the coefficient of friction. AAS analysis of the wear media will be analyzed to measure the change in metal ion release.

References: 1. R. Pourzal *et al*., Wear(2011), 271-9-10, pp 1658-1666.
2. S.A. Dittrick *et al.*, MSE 'C'(2011), 31-4, pp 809-814.