Material and Mechanical Characterization of the Micro-textured Carbide-CoCrMo Alloy Surface

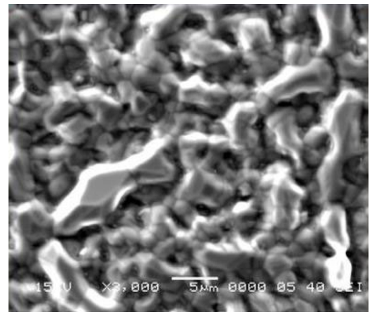
Geriel Ettienne-Modeste, L. D. Timmie Toploeski, Ph.D.
Department of Mechanical Engineering, University of Maryland Baltimore County, Baltimore, Maryland, USA

Statement of Purpose: A micro-textured carbide-CoCrMo alloy surface may be a successful alternative bearing material for artificial joints. Understanding the mechanical and material properties and surface morphology of the micro-textured carbide-CoCrMo alloy surface are important to designing wear resistant artificial joints. We previously described the formation and characterization of textured carbide surface layers created by a microwave plasma assisted chemical vapor deposition reaction (MPCVD) [1,2]. In this study, we determined the microstructural properties of the micro-textured CoCrMo alloy surfaces – hardness and elastic modulus by nanoindentation, and surface roughness parameters using white light interference surface profilometer (WLISP).

Materials and Methods: Test specimens were prepared from wrought CoCrMo alloy rod (ASTM F1537, Teledyne Allvac) machined to 16 mm diameter, 7 mm thick disk specimens. Fifty CoCrMo alloy disks were created, polished and prepared for film deposition. Prior to plasma processing, the top and bottom of all fifty CoCrMo alloy disks were sequentially polished to a mirror finish with #P500, #P800, #P1200, #P2400, #P4000 SiC abrasive paper and a final polish using 3μm diamond suspension, using a metallurgical polisher (Buehler LTD-Ecomet III, Model 850) and ultrasonically cleaned with D.I. water and acetone for 15 minutes (Cole-Parmer, Model 8849-00). The weight was measured for all disks using a digital balance with a precision of 0.0001 grams (Mettler Toledo, Model AX205). The carbide coated CoCrMo alloy disk surfaces were created using the MPCVD system in a mixture of methane (99.97% pure) and hydrogen (zerograde 99.99% pure) with a total gas pressure of 70 Torr and a total gas flow rate of 100 sccm (1 sccm CH_4, 99 sccm H_2) from 0.5 up to 6 hours, depending on film thickness. After deposition, the specimens for nano-indentation (n=10) were polished with a SiC abrasive paper #P2400 and #P4000 for 60-seconds each, followed by mirror finishing with a 3-μm diamond suspension for two 45-second sessions. The remaining 40 specimens were not polished after MPCVD processing. Six nano-indentation measurements were made along the diameter to compare the effect of processing time (2hr vs 4hr) on the measured properties (hardness and elastic modulus). SEM images were produced at five random locations using standard procedures (n=20).

Results: The MPCVD processing resulted in two carbide caoting thicknesses (3 μm and 10 μm), depending on processing time. The surface roughness decreased as the processing time, and hence carbide coating thickness, increased. The initial R_a values agreed with previous studies [1-3]. The profilometer results suggested that the brain coral morphology at 4hr deposition is more mature than the 2hr coating deposition as evidenced from the crystal growth structure shown in the SEM images (Figure 1). The average surface roughness (R_a) of the mirror polished non-coated Co-Cr-Mo disks was 0.037 μm, and for the micro-textured coated CoCrMo alloy disk at 2hr and 4hr deposition, the average R_a's were 0.310 μm, and 0.385 μm, respectively. The nanoindentation results (Table 1) showed substantial increases in the hardness (~45% or more), but no significant change in modulus.

2 hr



4hr

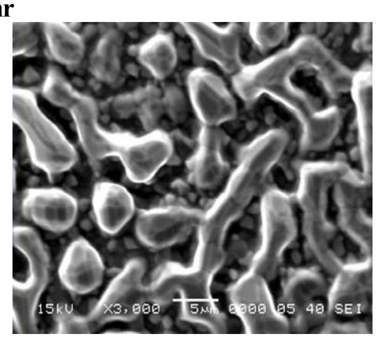


Figure 1. *SEM images of the micro-textured CoCrMo alloy specimens (2hr vs. 4hr deposition time)*

	CoCrMo (control)	Carbide-CoCrMo (2h)	Carbide-CoCrMo (4h)
Hardness (GPa)	8.82 ± 0.55	12.8 ± 1.3	12.9 ± 1.3
Modulus (GPa)	214 ± 5.31	216 ± 5.73	217 ± 6.23

Table 1. *Hardness and modulus of elasticity measured by nano-indentation (average ± standard deviation).*

Conclusions: The data shows that the micro-textured, carbide coated CoCrMo alloy has a greater hardness than the CoCrMo base metal. The micro-textured CoCrMo alloy specimens may have the potential to retain lubricating fluid because of their textured morphology created during the coating process. Thus, the micro-textured carbide coated CoCrMo has the potential to provide high wear resistance in a severe wear environment. The next steps of this research are to optimize the surface parameters for the carbide-CoCrMo to minimize wear of both the carbide surfaces and their potential counter surfaces (UHMWPE or metal).

References: [1] Vandamme, NS; Que, L; Topoleski, LDT, *J Mater Sci*, **v 34, n 14,** 1999, p. 3525-353.
[2] Vandamme, NS; Topoleski, LDT, *J Mater Sci: Materials in Medicine*, **v 16, n 7,** 2005, p 647-654.
[3] Vandamme, NS; Wayman, BH; Topoleski, LDT, *J Mater Sci: Materials in Medicine*, **v 14, n 1**, 2003, p. 47-53.

Acknowledgements: The authors wish to thank the Arthritis Foundation, a GAANN Fellowship (US Dept. of Education), the UMBC Graduate Meyerhoff Fellowship (NIGMS-R25-GM55036), and an NSF MRI grant (CBET 0521467) for the support of this research.