

Objective

- To improve the performance of Co-Cr-Mo implant material used in an artificial joint by surface modification to reduce wear.

Introduction

- The most common causes of joint dysfunction are osteoarthritis and rheumatoid arthritis.
- The replacement of diseased natural joints with total artificial joints is one of the most successful treatments for arthritis.
- The materials currently used for the frictional surfaces of artificial joints are a combination of metal (Co-Cr-Mo) or ceramic (Aluminum Oxide) with UHMWPE (Ultra High Molecular Weight Polyethylene).
- However, many recent researchers have demonstrated that the release of wear debris due to severe wear of UHMWPE leads to loosening and osteolysis. Therefore, a study to reduce the wear of these implant surfaces is very important for the long-term clinical use of artificial joints.
- Some important approaches, such as developing alternative materials for bearing surfaces and surface modification methods for existing bearing surfaces, have been recommended to improve wear resistance.
- In this study, we prepared a surface carbide coating on Co-Cr-Mo implant alloy using MPCVD (Microwave Plasma-Assisted Chemical Vapor deposition) System. We studied the wear behavior of the UHMWPE sliding on carbide coated Co-Cr-Mo implant alloy using a pin on disc uni-directional sliding Wear testing Machine (NIST).

Materials and Methods

Sample Preparation: Discs (0.625 inch in diameter and 7 mm thick) were machined from a wrought Co-Cr-Mo alloy rod (ASTM F1537, Teledyne Allvac).

Cleaning Procedure: The top, bottom and edge surfaces of the discs were polished to a "mirror finish" with #P220, #400C, #P1200 SiC abrasive paper and 3- μ m diamond suspension. The discs were then ultrasonically cleaned with D.I water and acetone for 15 minutes and 10 minutes respectively.

MPCVD System

The surface carbide layers are created by the reaction between the alloy surface and a mixed gas of methane and hydrogen by a microwave Plasma-assisted reaction.

The microwave generator (Toshiba corp., Tokyo)

Power: 0.1 to 1.5 KW

Frequency: 2.45 GHz.

Total gas pressure: 70 Torr

Total gas flow rate: 100 sccm

Methane: 1 sccm

Hydrogen: 99 sccm.

Plasma chamber

Inner diameter: 34 mm

Temperature Measurement:

Infrared thermometer (M90H, Mikron instrument Co., NJ)

Plasma Processing Parameters: Chamber pressure, Anode voltage, Reflected current, Processing Temperature and Processing time.

Surface Profilometry: The surface roughness parameters such as Average Roughness R_a , Core roughness depth R_k , Reduced peak height R_{pk} , Reduced valley depth R_{vk} are measured with a white light interference surface Profilometer (WLISP), (New View 100, Zygo Inc., CT) using Advanced Texture application with 40X magnification lens.

Initial average roughness (R_a):

Mirror polished Co-Cr-Mo ~ 0.01 μ m

Carbide coated Co-Cr-Mo ~ 0.16-0.50 μ m

UHMWPE ~ 0.01-0.1 μ m

Wear Tests

The wear tests were carried out using an uni-directional rotational pin-on-disc wear testing machine equipped with three stations consisting of three specimen holders and three load and pin assemblies.

Wear testing Machine (NIST)

Testing conditions:

Contact stress: 2.04 Mpa

Dead load : 14.4(\pm 1) N

Pin Diameter: 3mm

Sliding speed: 26 rpm

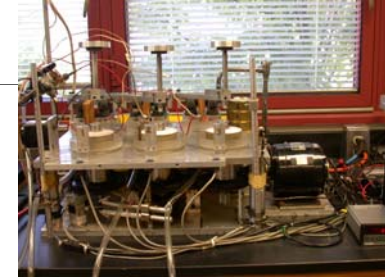
Sliding distance: 4382m

Sliding time~ 75hrs

Lubricant: D.I water

Temperature: 37(\pm 2) $^{\circ}$ C

Alignment: Eccentric

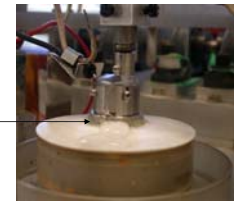


Wear testing station

Pin: UHMWPE

Disc: Carbide coated Co-Cr-Mo

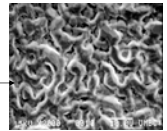
Control: Uncoated / Mirror polished Co-Cr-Mo



Results and Discussions

Brain-coral Surface morphology:

The Scanning Electron Micrograph (SEM) of surface carbide layers on Co-Cr-Mo shows "brain-coral" like surface morphology.



Control of surface Morphology:

The surface roughness parameters such as Average Roughness R_a , Core roughness depth R_k , Reduced peak height R_{pk} , Reduced valley depth R_{vk} increased with Plasma processing time and temperature as shown in Figure.1.

Processing temperature, time and coating thickness:

Fine group: ~ 940 $^{\circ}$ C, 2 hrs, 5 μ m

Medium: ~ 965 $^{\circ}$ C, 2hrs, 5.6 μ m

Coarse : ~ 1000 $^{\circ}$ C, 4hrs, 10.5 μ m

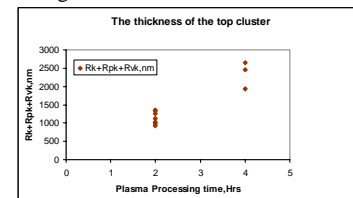


Figure.1.

Wear behavior:

Accumulated weight change:

All the specimens underwent two Phases as shown in Figure.2.

1. Water Absorption phase:

Weight gain in first 15–30 Hrs

2. Wear phase: Although it has

rough surface morphology,

weight change in Carbide coated Co-Cr-Mo is same as control.

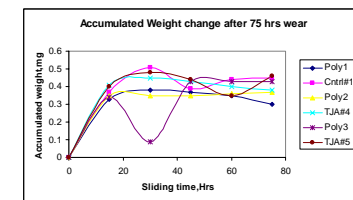


Figure.2.

Future Work:

- Continue wear testing to understand the wear mechanism of UHMWPE on carbide coatings.

Acknowledgements



References

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