Synthesis, characterization and applications of functionally graded Cu-SiC coating

Swastika Banthia[a] and Karabi Das[a,b]

[a]School of Nano Science and Technology, Indian Institute of Technology Kharagpur, Kharagpur, India

[b]Department of Metallurgical and Materials Engineering, Indian Institute of Technology Kharagpur, India

Abstract

In the present investigation, Cu based functionally graded (FG) coatings are deposited by galvanostatic pulse reverse electrodeposition (PRED) route. A coating consisting of three layers of Cu (20 μm each) with a gradual reduction in the crystallite size towards the surface is deposited on an annealed Cu substrate by increasing the cathodic current density (C_{CD}) from 50 to 200 mA/cm^{2}and the resultant coating is definedas FG Cu coating. Two layers of Cu-SiC nanocomposite coating with an increment in the amount of incorporated SiC nanoparticles(from 2 to 7 vol%) are electrodeposited on FG Cucoating. This is done by introducing plating bath agitation (350 and 450 rpm) during deposition at$C_{CD}$of 200 mA/cm^2.The resultant coating consisting of three layers of Cu (12 μm each) and two layers of Cu-SiC (12 μm each) is defined as FG Cu-SiC coating. The FG Cu-SiC coating possesses higher hardness (~3.8 GPa), lower residual compressive stress (~291 MPa) and lower surface roughness (~0.9μm) as compared to single-layered (SL) Cu- 7 vol% SiC nanocomposite coating.

The corrosion and wear tests are done in 3.5 wt% NaCl aqueous solution and dry sliding wear conditions, respectively in order to evaluate the performance of Cu based SL and FG

coatings. It is observed that the FG Cu-SiC coating has higher corrosion resistance than the FG Cucoating. The sliding wear tests under the different loads (2, 5, 8 and 10 N) are carried-out for FG Cu, FG Cu-SiC, SL Cu (smallest crystallite size) and SL Cu- 7 vol% SiC coating. A drastic reduction in corrosion and wear rate is observed in the FG Cu and FG Cu-SiC coatings when compared with those of SL Cu and Cu-SiC nanocomposite coatings, respectively, although SL and FG coatings have comparable microstructure and hardness on the top surface. The FG Cu-SiC coating is found to be more wear-resistant than the FG Cu coating at high load, while the latter shows lower specific wear rate at low loads.

The reciprocating wear and electrical properties of FG Cu-SiC coating are studied in order to use it as an electrical contact material. The coefficient of friction (CoF), electrical resistivity and electrical contact resistance (ECR) of the SL Cu- 7 vol% SiC nanocomposite coating and FG Cu-SiC nanocomposite coatings are compared. The electrical resistivity of the FG Cu-SiC coating is measured by the four-wire resistance measurement method and the value is observed to be 50% less than SL Cu- 7 vol% SiC nanocomposite coating. The monitored value of CoF is significantly less for the FG Cu-SiC coatingthan the SL Cu- 7 vol% SiC nanocomposite coating at 2 and 5 N load and is nearly equal at 8 N load. The ECR value of FG Cu-SiC coating at 2 and 8 N load is recorded as 9.5 and 6 mΩ, respectively and after wear, it slightly increases to 10 mΩ at 2 N and drastically increases to 11 mΩ at 8 N. With such properties FG Cu-SiC coating on annealed Cu substrate can serve as a novel prospective electrical contact material.

Cu, its alloys and composites are also widely used in antibacterial application. In order to find the suitability of the SL and FG coatings as antimicrobial touch surface, they are tested against *Escherichia coli* NCIM 2931(Gram-negative) and *Bacillus subtilis* NCIM 2063(Gram-positive). After 24 hours of incubation, the bacterial survival rate is the least for

FG Cu-SiC coating among all the samples. The outer membrane permeabilization experiment and thiobarbituric acid reactive substances (TBARS) assay prove that the intake of excessive Cu ions leads to the damage of bacterial cell membrane and lipid degradation, respectively. The bacterial morphology is characterized by transmission electron microscopy and scanning electron microscopy while, the release of Cu ions is measured by atomic absorption spectroscopy. The anti-adhesive nature of the coatings is determined by the measuring the contact angle. The observed results of antibacterial and anti-adhesion properties show that the FG Cu-SiC coating is much better than the SL Cu coating and slightly better than the SL Cu-SiC nanocomposite coating.

Keywords: Antibacterial; Corrosion; Electrical contact material; Electrodeposition; Functionally graded coating; Wear