CrN-Ag Nanocomposite Coatings: Control of Lubricant Transport by Diffusion Barriers

by

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ABSTRACT

1-µm-thick self-lubricating CrN-Ag composite coatings containing 16 at.% Ag were deposited on Si substrates by reactive co-sputtering at T_s = 400°C, and were covered with CrN cap layers with a columnar microstructure and a thickness d = 0–1000 nm. Vacuum annealing at T_a = 500 and 600°C for one hour causes Ag transport to the sample surface and the formation of Ag surface grains. Quantitative scanning electron microscopy and energy dispersive spectroscopy analyses show that increasing d from 0 to 10 to 100 nm for T_a = 500°C leads to a decrease in the areal density of Ag surface grains from 0.86 to 0.45 to 0.04 μm^{-2}, while their lateral size remains constant at 360±60 nm. However, increasing T_a to 600°C causes a doubling of the Ag grain size, and a 4-30 times larger overall Ag transport. These results are explained by kinetic barriers for Ag diffusion through the porous cap layer with a porosity that decreases with increasing d. This leads to an effective activation barrier for Ag transport that increases from 0.78 eV in the absence of a cap layer to 0.89 eV for d = 10 nm and 1.07 eV for d = 30 nm. Auger Electron Spectroscopy depth profile analyses of annealed layers reveal no detectable Ag within the CrN cap layer and a uniform depletion of the Ag reservoir throughout the composite coating thickness, indicating unhindered Ag transport within the composite. The overall results show that a CrN diffusion barrier cap layer is an effective approach to control Ag lubricant transport to the surface of CrN-Ag composite coatings.