Deposition and characterization of hybrid DLC and Si-DLC films deposited on nitrile rubber

M. Lubwama, B. Corcoran, K. Sayers,

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Abstract

In this study a novel approach was used to increase the wear resistance of nitrile rubber piston seals. In this approach a hybrid diamond-like carbon (DLC) and silicon doped diamond-like carbon (Si-DLC), with and without Si-C interlayers, were deposited onto both nitrile rubber substrates and actual nitrile rubber piston seals. The deposition was done in a closed field unbalanced magnetron sputtering ion plating (CFUBMSIP) rig in Ar/C_4H_{10} plasma. Various characterization techniques were used to determine and quantify the properties of these films deposited on nitrile rubber including Raman spectroscopy, Scanning electron microscopy, surface profilometry, digital and optical microscopy, hydrophobicity analysis, adhesion and flexibility analysis, and tribological investigations under dry and wet conditions. A purposely designed and developed pump rig was used to test the wear resistance of the coated piston seals. The results show a dense, non-columnar microstructure with a dendritic morphology typical for such films. This dendritic crack-like structure promotes film flexibility. The Si-C interlayer enhanced adhesion of the films and altered the film bonding characteristics. The contact angle of water droplets showed that the films were hydrophobic. All of the films showed excellent tribological results for tribo-tests under dry and wet sliding with WC-Co and stainless steel counterpart materials. There was no penetration of the film for normal load of 1 N and 5 N under wet sliding and for normal load of 1 N under dry sliding with stainless steel used as the counterpart material in the tribo-tests. These results are interpreted in terms of hybridisation of carbon in the films. After over 100,000 strokes of operation of the reciprocating pump rig, extremely small changes in weight for the coated piston seals were observed with increased crack density of the films.