Tailoring the Steel/Amorphous Carbon Interfacial Shear Strength by Doping Amorphous Carbon with Rare-Earth Elements

Filippo Mangolini*[1], Camille Edwards[1], Hsu-Ming Lien[1], and Nicolas Molina[1]

[1]The University of Texas at Austin – United States

Abstract

Dopants and alloying elements are commonly introduced in amorphous carbon (a-C) materials to tailor their mechanical and tribological properties. While most published studies have focused on doping and/or alloying a-C coatings with metals or metalloids, doping a-C films with rare-earth elements has only recently been explored. Notably, our understanding of the shear-induced structural changes occurring in rare-earth element-containing a-C films is still elusive, even in the absence of any liquid lubricants. Here, the friction response of Eu- and Gd-containing a-C films with low hydrogen content was evaluated in open air and at room temperature. The normal pressure-dependent friction measurements indicated that the introduction of Gd ((2.3 $\pm$ 0.1) at.%) and Eu ((2.4 $\pm$ 0.1) at.%) into the a-C matrix results in a significant reduction of the shear strength of the sliding interfaces ((41 $\pm$ 2) MPa for a-C, (16 $\pm$ 1) MPa for a-C:Gd2.3 at.%, and (11 $\pm$ 2) MPa for a-C:Eu2.4 at.%.). Notably, these interfacial shear strength values for a-C films sliding against steel are favorably comparable with the values obtained from atomistic simulations of self-mated H-passivated a-C:H contacts, thus suggesting that the macroscale response of the sliding contact is determined by the shear response of colliding nanoscale asperities. NEXAFS spectromicroscopy experiments provided evidence that no stress-assisted sp3-to-sp2 rehybridization of carbon atoms was induced by the sliding process in the near-surface region of undoped a-C, while the amount of sp2-bonded carbon progressively increased in a-C:Gd2.3 at.% and a-C:Eu2.4 at.% upon increasing the applied normal load in tribological tests. The formation of an sp2-bonded carbon-rich surface layer in a-C:Gd2.3 at.% and a-C:Eu2.4 at.% films is postulated to induce shear localization within the sp2-carbon rich layer and the transfer film formed on the countersurface, thus decreasing the interfacial shear strength. These findings open the path for the use of Gd- and Eu-containing a-C even under critical conditions for nearly hydrogen-free a-C films (*i.e.*, humid air).

*Speaker