Can oxygen be beneficial for tribological performance of MoS_2 coatings?

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The MoS_2-based coatings have been widely used in tribological applications where low friction coefficient is highly desirable. Meanwhile, two main drawbacks of the MoS_2 materials that are ascribable to their low load-bearing capacity and fast degradation in terrestrial atmosphere became a driving force for the extensive research for the tribological community. Regarding degradation in terrestrial air, published results indicate that still there are splits in over leading factor affects degradation of TMDs lubricity, is it ambient moisture-MoS_2 bonding or oxidation process. Existing data are quite contradictive, on the one hand, it is widely stated oxidation and, as result, formation of the Mo oxide cause the degradation of tribological properties of MoS_2-based materials, on the other hand some data claim that the co-existence the MoS2 + MoO3 allows to achieve advanced performance. To shed the light on the performance of O-doped MoS_2 coatings, the $Mo_{32}S_{66}O_2$, $Mo_{33}S_{58}O_9$, $Mo_{24}S_{38}O_{38}$ and $Mo_{24}S_5O_{71}$ coatings were fabricated by unbalanced magnetron sputtering. The increase of oxygen concentration in the Mo-O-S system from 2 to 38 at.% displace sulfur, and changes the structure from columnar crystalline to dense amorphous Mo-O-S. Hardness and Young modulus rise with an increase of O concentration from 2 to 38 at.%. These changes are accompanied by enhancement of the tribological performance both under vacuum and humid air. The triboactivated formation of the crystalline MoS_2 tribolayer from amorphous Mo-O-S occurs in the tribocontact area. In the case of the $Mo_{24}S_5O_{71}$ coating with low S content, the lubricious MoS_2 tribolayer is not formed and the coatings fail the all tribotests. Under vacuum, the lowest CoF of 0.02 is observed for the $Mo_{33}S_{58}O_9$ coating and associated with interfacial sliding between MoS2 transfer film and wear track. For the $Mo_{32}S_{66}O_2$ and $Mo_{24}S_{38}O_{38}$ coatings, CoF values of 0.05 and 0.04 are recorded, this slightly higher CoF is associated with mixed interfacial sliding/transfer film shearing mode of friction. In humid air the CoF values of the coatings were 0.27, 0.29, and 0.18 for the $Mo_{32}S_{66}O_2$, $Mo_{33}S_{58}O_9$, and $Mo_{24}S_{38}O_{38}$ coatings, respectively. Probably, the friction is controlled by physisorbed water between the MoS_2 tribolayers that forms hydrogen bonds with S atoms which increases the interlayer binding energy, and CoF, respectively. Wear resistance under vacuum is governed by the ability of the coatings to form continuous and stable MoS2 tribolayer and their mechanical properties. Wear resistance in humid air is governed by cohesive wear that probably takes a place because of increased interlayer binding energy. Important, that in the case of a moderate concentration of O in the coatings composition ($Mo_{33}S_{58}O_9$) the water physisorption can be suppressed, and that improves wear resistance.

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