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Abstract

Recent Progress toward the Development of TMD-Based Industrial Dry Lubricants for Multi-Environment Sliding †

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Transition metal dichalcogenides (TMDs) sputtered coatings are promising dry lubricants for dry and vacuum environments. To fulfill the needs of aerospace and automotive industries, past few decades mark considerable research on the enhancement of the applicability of TMD coatings in diverse sliding environments. C-alloyed TMDs were recently optimized by our group for multi-environment sliding but, in this case, it is mandatory to use separate TMD and C targets. This multiple target deposition approach might not be favorable for some industries. Thus, considering the low-cost manufacturing demands, an effort was dedicated towards the development of alloyed TMD coatings via DC reactive sputtering. For this purpose, it was decided to explore and optimize N-alloyed WS2 and MoSe2 coatings.

The W-S-N coatings were deposited with N-content in the range of 0 to 26 at. %. All coatings were sub-stoichiometric with respect to WS2 compound but displayed compact morphologies as compared to the literature. The (100) preferential orientation of 0 at. % N coating shifted to a strong (002) preferential orientation with increasing N content. A maximum hardness of 8.0 GPa was achieved for the coating with ~23 at. % of the N-content. For the first time, the sliding efficiency of the W-S-N coatings was analyzed in three atmospheres, i.e., room temperature, 200 °C and dry nitrogen. The aim of this tribological analysis was to not only perform an organized tribological property investigation of W-S-N coatings in multi-environments, but also to compare the results with C-alloyed WS2 coatings. Without this comparison, it is not possible to know whether industries can opt TMD-N coatings over TMD-C or not. The W-S-N coatings displayed friction coefficients vs. specific wear rates of 0.09 vs. 7.2×10^{-8} mm^3/Nm, 0.02 vs. 7.1×10^{-8} mm^3/Nm and 0.03 vs. 9.3×10^{-9} mm^3/Nm in room temperature, 200 °C and dry N2, respectively. These tribological results of the W-S-N coatings are almost similar to the W-S-C coatings tested in similar conditions. This means that the W-S-N coatings possess excellent capability to replace W-S-C coatings in industries that do not prefer to use multi-target deposition setup/approach.

In the next phase, the DC reactive sputtered Mo-Se-N coatings were investigated. This is the first time that these coatings were deposited with DC sputtering. The Mo-Se-N coatings were synthesized with N-content in the range of 0 to 40 at. %. Although, the coatings were sub-stoichiometric with respect to MoSe2, the degree of sub-stoichiometry was less as compared to the W-S-N coatings. This better Se/Mo ratio than S/W resulted in porous morphology of pure MoSe2 coating when compared with the WS2. Similar to the W-S-N system, increasing the N-content enhanced the compactness of the coatings. The structural analysis of Mo-Se-N coatings displayed different results than the W-S-N coatings. The pure MoSe2 coating showed (002) preferential orientation while all other coatings were X-ray amorphous. A maximum hardness of 5.0 GPa was measured, a value slightly lower than the upper cap of the former system. The tribological analysis was only performed in room temperature until now. Minimum friction coefficient of and specific wear rate of 0.055 and 4×10^{-7} mm^3/Nm, respectively, were achieved. The achieved friction results are slightly better than the W-S-N system. Overall, the results of this Mo-Se-N system are quite interesting and novel, i.e., for the first time ever, it was observed that irrespective of the chemical compositional variations, a coating system displays constant frictional properties. The variations in composition in sputter deposition are a common problem. Thus, this can be a very important and valuable result for industries that have to deposit coatings on complex 3D parts where they face compositional variation issues. This phase of the Mo-Se-N coatings exploration is still ongoing and, in future, multi-environment tribological testing will be carried out.

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