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Mechanical and Friction Behavior of Sputtered Mo-Cu-X-(N) Coatings under Various N_2 Gas Flow Using a Multicomponent Single Alloy Targets

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1. Introduction

Mo-Cu-N has been attractive due to its low friction coating having excellent high temperature stability and high hardness [1]. Since the Mo-Cu alloy system has little solubility with each other, even in liquid phase, it is relatively easy to form nanocomposite coating. In addition, it is possible to separate the phase with MoN-Cu under the nitrogen atmosphere, thereby forming a nano-coating layer having both a hard phase and a soft phase [2]. Especially, nanocomposite coating based on molybdenum nitride has been desirable for low friction coating due to lubricious oxide of MoO_3 (which was also known as Magneli oxides) and high hardness. Moreover, it was reported to have good adhesion to steel substrates due to good solubility of molybdenum in iron based materials [3]. Recently, studies done by Erdemir et al [4]. found that Mo-Cu-N coatings form carbon based tribofilm through the interaction with Cu element as metal catalyst while using olefin oil in the lubricating environment. The effects of ternary elemental addition such as (Cr, Ni, V, W) on Mo-Cu-N system and the optimum N content of Mo-Cu-N and Mo-Cu-X-N (X=Cr) based systems have been studied to find out their usefulness as the coating for automobile applications.

2. The advantages of alloying targets

Since Mo-Cu is almost immiscible in liquid and solid state, it is very difficult to prepare alloying targets in Mo-Cu binary system and thus, Mo-Cu-X-N coatings were generally prepared by using multiple targets [5]. At the case of using elemental targets, because the each element has its own sputtering yield, it is mostly difficult to get some objective composition and obtain a uniform composition over a large area specimens. This resulted in the complicated equipment and process conditions. Also even if we use the alloying targets, if there have some inhomogeneity, it is found that the coating layer has not the same composition with the target composition and the target has irregular surface erosion by the non-uniform sputtering [6]. In this study, powder metallurgy processes such as mechanical alloying and spark plasma sintering processes have been tried. The alloying target has the disc shape with the size of 7.5 cm in diameter and 0.7 cm in thickness.

To find out the advantage of the process using alloying target respect to the co-sputtering process with two elemental targets, the properties of the coatings prepared by single alloying target were compared with those prepared with two elemental targets [7]. As shown in the figure 5, the microstructure of the coating from two targets was columnar structure. But the coating by alloying target had the perfect featureless structure even the coating was prepared at room temperature. Interestingly, the coating layer by alloying target used only 300W as the power for a sputtering target was thicker than that of two targets with 300W for Mo target and 200W for Cu target, respectively. Also the surface roughness of the coating from alloying target was three times better than that of two targets. The finer microstructure of the coating from alloying target was resulted in 20 % higher hardness (28-29 GPa) compared with that (24-25 GPa) of the coating with the same composition and prepared from two targets. The coating from alloying target has almost the same composition with the target composition and moreover, it was easily prepared by just sputtering with proper power and without changing any other variables. But with two elemental targets, as mentioned previously, it was not easy to get the composition that would be intended to be obtained (10 at.% Cu) and the final composition was 8.9 at. % Cu.

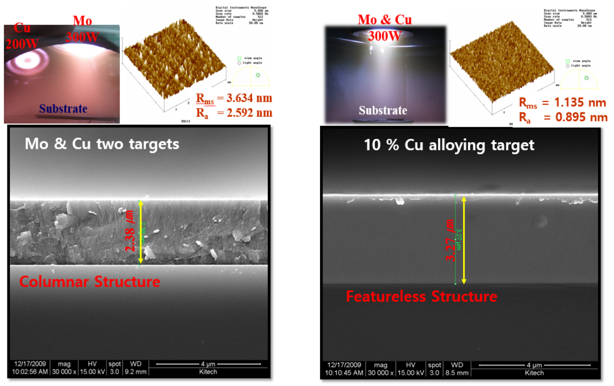

Fig. 1 Microstructures of coatings Prepared by two methods

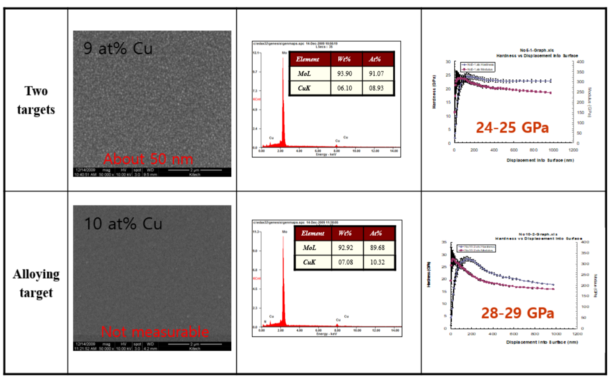

Fig. 2 Compositions of coatings prepared by two methods

3. Mechanical and Friction Behavior of Sputtered Mo-Cu-X-(N) Coatings

Mo-Cu-(N) coatings were fabricated successfully at various nitrogen flow rates using $Mo_{90}Cu_{10}$ single alloy target as a deposition source and using a DC Magnetron sputtering method [8]. It was confirmed that the Mo-10at% Cu-N coating deposited with Ar: N_2 gas ratio of 18: 6 show excellent wear resistance, friction and high mechanical properties, because a proper nanocomposite coating with Mo_xN phase with the smallest grain size of about 6.43 nm was formed. The mechanical properties were the highest with its hardness of 27.8 GPa and elastic modulus of 333.6 GPa.

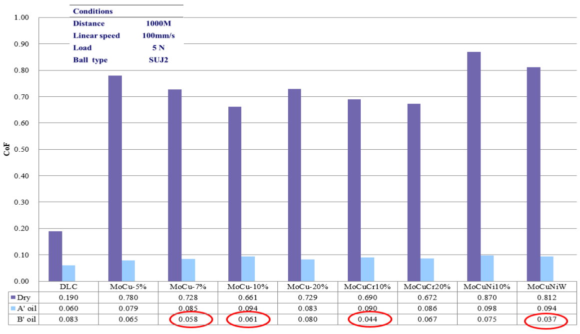

Fig 3. Friction coefficients of various Mo-Cu-X-N systems

Among the various ternary element addition systems, 10 at.% Cr added Mo-Cu-N systems showed the better friction coefficient as shown in Fig. 3, Mo-Cu-(N) coatings were also fabricated at various nitrogen flow rates using $Mo_{80}Cu_{10}Cr_{10}$ single alloy target as a deposition source and using a DC Magnetron sputtering method [9]. The Mo-Cu-Cr-N coating containing some specific nitrogen content had a nanocomposite structure comprising transition metal nitride phases (Mo-N/Cr-N) and metal phase (Cu) having high mechanical properties and corrosion resistance while retaining the excellent tribological properties of binary Mo-Cu-N coatings as shown in Fig 4 & 5.

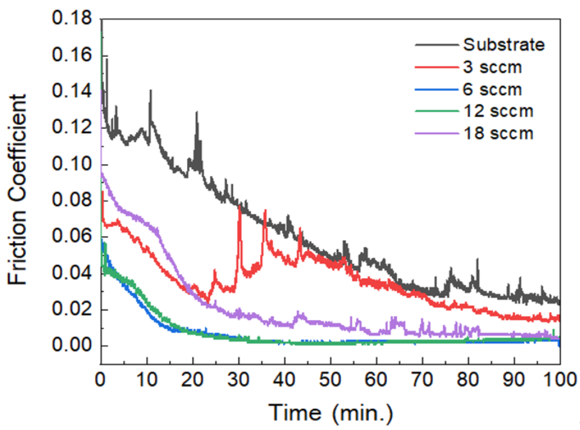

Fig. 1 Friction coefficients of the Mo-Cu-(X)-(N) coatings

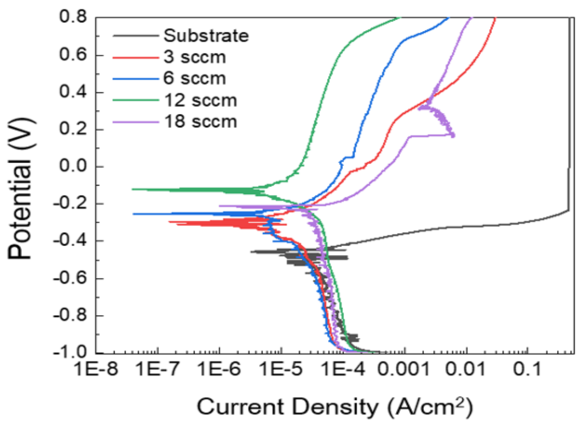

Fig. 2 Potentiodynamic polarization curves of Mo-Cu-Cr-N coating

4. Conclusions

In this study, the coatings prepared by sputtering with an alloying target were compared with those prepared with two elemental targets. By using alloying targets, nanocomposite coatings that have the same compositions with the targets and nano-sized microstructure could be obtained easily by reactive sputtering process at room temperature. This coating has the better properties compared with those prepared by co sputtering process with two and more elemental targets. The microstructure and the surface roughness of the coatings from the single alloying target were finer compared with those of the coatings prepared by co sputtering process. Among the ternary elemental addition in Mo-Cu-N systems, mechanical and tribological properties were much improved in Cr added systems and the better properties could be obtained by a proper nitrogen content. As reported by Erdemir et al, it is found also that Cu within Mo-Cu-(N) and Mo-Cu-Cr-(N) systems could act as the metal catalyst, reacting with the Olefin component of PAO to form a carbon-based tribofilm on the surface

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