Proceedings of Asia International Conference on Tribology 2018, pp. 61-63, September 2018

Enhancement of tribological performance of hydroxylpropyl methylcellulose composite films with Cu and CuO nanoparticles

Shih-Chen Shi[1,*], Shia-Seng Pek[1]

Department of Mechanical Engineering, National Cheng Kung University,
No. 1 University Road, Tainan City, Tainan City 70101, Taiwan.

[*]Corresponding e-mail: scshi@mail.ncku.edu.tw

Keywords: Hydroxylpropyl methylcellulose; nanoparticle; tribology

ABSTRACT – Biopolymer nanocomposite films were prepared via the solvent evaporation method using hydroxypropyl methylcellulose as the substrate, with the addition of molybdenum disulfide and different nanoparticles. The effects of nanoparticles on the tribological performance of the composite film were measured using a ball-on-disc tribometer. The surface morphology and the wear surface of nanocomposite films, and the dispersibility of nanoparticles were observed using a scanning electron microscope and a 3D profiler. Experimental results show that the addition of Cu and CuO in an appropriate ratio to the MoS_2/HPMC bio-polymer film effectively reduces the wear rate of the film by 80% and provides excellent tribological performance. Enhancement mechanism by the addition of nanoparticles was also discussed.

1. INTRODUCTION

Hydroxypropyl methylcellulose (HPMC) is a biopolymer material with good biocompatibility and mechanical application characteristics. It can be easily detected and observed. Therefore, it has a high application value in the future, especially in the field of sustainable manufacturing. Previous studies have used oxides, sulfides, diamonds and other materials as additives to enhance the wearing resistance behavior of tribological materials. These particulate additives often result in issues such as aggregation and uneven distribution in practical application. The use of biocompatible HPMC can effectively solve the above issues. Furthermore, with the addition of MoS_2, HPMC can lead to more stable and better tribological performance [1-2]. As nanoparticles have high surface area to volume ratios, they can effectively enhance the bonding ability between additives and the substrate. Hence the addition of nanometal into polymers can achieve excellent anti-wearing effects [3].

2. METHODOLOGY

The nanocomposite film was prepared by heating a solution of 1.8 g deionized water and 7.2 g alcohol to 60 °C using an electromagnetic stirrer and subsequently adding 1 g HPMC powder. The solution was stirred until it was completely homogeneous. 0.5 g molybdenum disulfide powder was then added and the solution was shaken using an ultrasonic homogenizer for 20 minutes. When the preparation of MoS2/HPMC solution was completed, Cu or CuO nanoparticles dissolved in alcohol in an appropriate proportion were added into the composite material solution and stirred to form a completely homogeneous mixture. Micropipette was used to drop the solution on a glass substrate. It was then placed in a constant temperature and humidity machine (30°C, 40 RH%) for 6 h to prepare a nanocomposite composite film. The surface morphology, wearing trace and particle dispersibility of the nanocomposite film material will be detected by scanning electron microscopy (SEM). The wear test was carried out at room temperature and atmospheric conditions using a ball-on-disk tribometer, with a sliding speed of 0.03 m/s, a rotation radius of 6 mm, a load of 2 N and a stroke of 200 m. Chrome steel balls (AISI 521000) were used. The nanocomposite film on the glass substrate was placed on the disc at the bottom of the tribometer. The coefficient of friction was measured and recorded using a load element connected to the disc. The wearing loss was measured using a 3D scanner (Keyence VK9710, Osaka, Japan). The depth and width of the wearing traces were measured by laser scanning.

3. RESULTS AND DISCUSSION

Figure 1 (a) and (b) show the surface morphology of MoS2/HPMC composite films. It can be clearly observed that the layered MoS_2 is homogenously distributed in the HPMC polymer film. Figure 1 (c) and (d) are Cu/MoS_2/HPMC composite films. The dispersibility of copper nanoparticles can be observed, and there is no obvious aggregation effect observed. Figure 1 (e) and (f) are CuO/MoS_2/HPMC composite films, showing good particle dispersibility and homogeneity.

The effects of the addition of different nanoparticles on the coefficient of friction and wearing loss of the three HPMC composite films are compared in Figures 3 and 4. With the addition of MoS_2, the molecules are only bonded via the van der Waals forces due to the low shear stress of MoS_2. The bonds can be easily broken, so the coefficient of friction is reduced. However, the wearing loss becomes relatively large as the substrate can be easily stripped off. After adding Cu or CuO nanoparticles, the compressive strength of materials is enhanced. In addition, as the nanoparticles have relatively high surface energy and activity, they easily adhere to the abrasion balls, forming a barrier. The wearing of substrates due to abrasion balls can be avoided, substantially reducing the wearing loss and friction coefficient and achieving excellent anti-wearing effects. Among those films, CuO/MoS2/HPMC has the most optimized anti-wearing effect, with an average friction coefficient of 0.102.

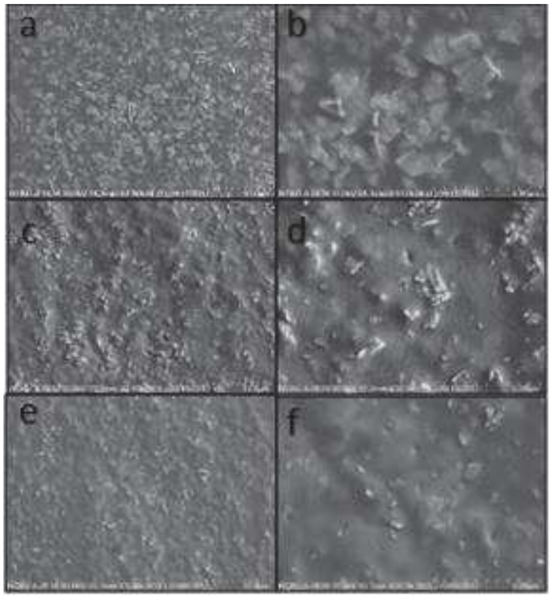

Figure 1 Surface morphology of different nanocomposite films: (a) and (b) are MoS_2/HPMC composite films, (c) and (d) are Cu/MoS_2/HPMC composite films, (e) and (f) are CuO/MoS_2/HPMC composite films.

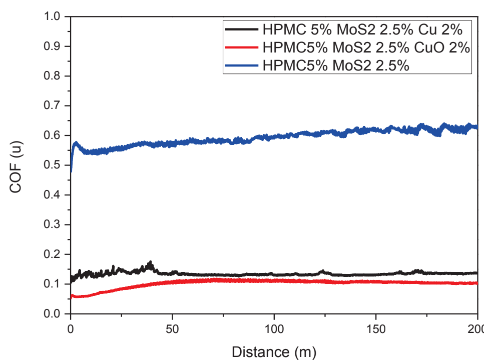

Figure 2 Coefficient of friction (COF) of different nanocomposite films.

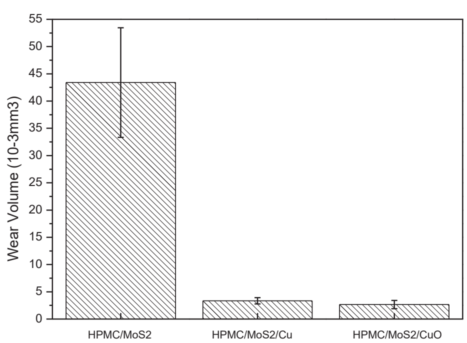

Figure 3 Wear losses of different nanocomposite film materials.

Results for the abrasion test of the composite films were obtained by observing the wearing surfaces by SEM. As shown in fig. 4 (a) and (b), the MoS_2/HPMC film shows obvious ploughing and stripping effects after the abrasion test. Obvious debris can be observed at the edge of wear trace. Fig. 4 (c) and (d) show that adhering wearing and slight scratches are found on the Cu/MoS_2/HPMC composite film. However, grinded traces were observed on only some substrates of the CuO/MoS_2/HPMC film, with no wearing debris found in the traces, as shown in Fig. 4 (d) and (e).

When Cu and CuO nanoparticles were added, the ploughing and stripping phenomena were not observed, mainly due to changes in the wearing mechanisms. With the addition of Cu nanoparticles, the compression strength of composite films is enhanced, with a wearing mechanism dominated by plastic deformation of Cu nanoparticles. The plastically deformed Cu nanoparticles can effectively protect the composite film substrates from direct wearing by counter balls. CuO particles are relatively hard and they are not easily flattened with loading. The enhanced anti-loading capability leads to better anti-wearing properties of the films. Hence, CuO/MoS_2/HPMC composite film materials can achieve the lowest wearing loss and coefficient of friction.

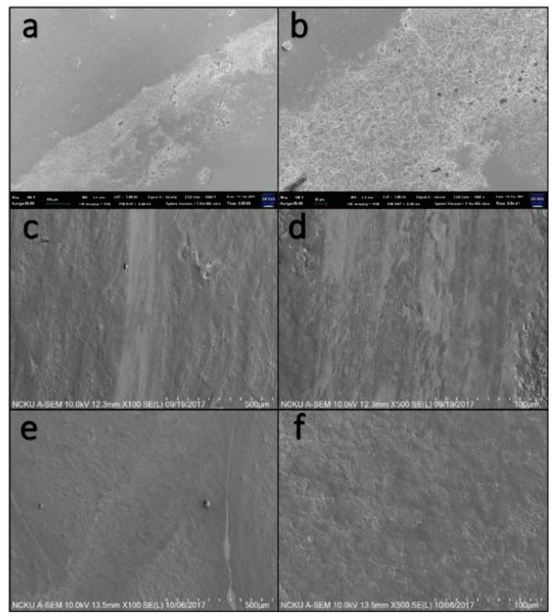

Figure 4 Analysis of wear traces: (a) and (b) for MoS_2/HPMC; (c) and (d) for Cu/MoS_2/HPMC; (e) and (f) for CuO/MoS_2/HPMC.

4. SUMMARY

Nanoparticle additives/MoS_2/HPMC composite film materials with good dispersibility were successfully produced by the solvent evaporation method.

The addition of nanoparticles can effectively reduce the wear rate of MoS_2/HPMC films by 80%.

After adding nanoparticles, composite materials show no ploughing effects but effective anti-wear effects.

The addition of metal and metal oxides shows different wearing mechanisms. Cu nanoparticles protect the substrates to achieve anti-wearing effects through plastic deformation, whereas CuO nanoparticles provide excellent load capacity for soft films due to their higher hardness.

REFERENCES

[1] Shi, S. C., & Huang, T. F. (2017). Self-healing materials for ecotribology. *Materials*, *10*(1), 91.
[2] Shi, S. C. (2016). Tribological performance of green lubricant enhanced by sulfidation IF-MoS2. *Materials*, *9*(10), 856.
[3] Cho, M. H., & Bahadur, S. (2005). Study of the tribological synergistic effects in nano CuO-filled and fiber-reinforced polyphenylene sulfide composites. *Wear*, *258*(5-6), 835-845.