Morphological Influence of Molybdenum Disulfide Nanoparticles on Powder Lubrication and Photocatalysis†

ZE-YIN XU¹, KUN-HONG HU^{2,*}, FEI HUANG¹, CHENG-LIANG HAN² and XIAN-GUO HU³

¹Department of Mechanical Engineering, Hefei University, Hefei 230601, P.R. China

²Department of Chemical and Materials Engineering, Hefei University, Hefei 230601, P.R. China

³Institute of Tribology, Hefei University of Technology, Hefei 230009, P.R. China

*Corresponding author: Email: hukunhong@gmail.com

AJC-13346

The lubricating and catalytic properties of two kinds of nano-MoS₂, namely nano-sphere and nano-platelet, were investigated. Results showed that the amount of nano-spheres with a low BET area in the contact area was not enough to lubricate the steel friction pair. However, MoS₂ nano-platelets with a high BET area could well function as a powder lubricant. The high BET area also improved the catalytic activity of MoS₂ nano-platelets. The findings indicated MoS₂ nano-platelets have potential applications in powder lubrication and photocatalysis.

Key Words: Molybdenum disulfide, Nanoparticles, Tribology, Lubrication, Photocatalysis.

INTRODUCTION

The shape remarkably affects the properties of nano-MoS₂¹. Spherical nano-MoS₂ (MoS₂ nano-sphere) usually reveals better tribological properties than platelet-like nano-MoS₂ (MoS₂ nano-platelet)² because of its particular lubricating mechanisms^{3,4}. However, the nano-platelet has higher catalytic activity than the nano-sphere. The catalytic mechanism of MoS₂ can be explained by the 'rim-edge site' model⁵.

Though literatures reported the lubricating advantages of spherical nano-MoS₂ over platelet-like nano-MoS₂^{1,2}, the results in this work showed that MoS₂ nano-spheres could not work in a powder-lubrication manner. Moreover, the nano-spheres also represent lower catalytic activity than the nano-platelets.

EXPERIMENTAL

Two nano-MoS₂ samples in different shape were synthesized using chemical methods reported by Hu and Hu⁶. The characterization of nano-MoS₂ was done on a Hitachi model H-800 transmission electron microscopy (TEM), a JEOL model JEM-2010 high-resolution transmission electron microscopy (HRTEM) and a micromeritics model ASAP 2020M+C physical and chemical adsorption analyzer.

Tribological tests: The tribological tests were completed on an MQ-800 end-face tribometer with an ASTM 1045 steel friction pair in a powder-lubrication manner of MoS₂ at 1.6

MPa and 0.4 m/s. Fig. 1 shows the schematic of the end-face powder-lubrication manner.

Fig. 1. Schematic diagram of the end-face tribological test

Catalytic tests: The catalytic properties were investigated using the degradation reaction of malachite green. The conversion rate (%) was evaluated by the absorbance (A) of malachite green solution that was measured on a 721 spectrophotometer.

RESULTS AND DISCUSSION

Characterization of nano-MoS₂: Fig. 2 provides micrographs of the two kinds of MoS₂ nanoparticles. As shown in Fig. 2a, nano-MoS₂ is in a hollow sphere-like shape with diameters of 100-200 nm and shells of about 15 nm. The other

†Presented to the 6th China-Korea International Conference on Multi-functional Materials and Application, 22-24 November 2012, Daejeon, Korea

nano-MoS₂ in Fig. 2b comprises a platelet-like structure with thickness of about 8 nm and lengths of 20-40 nm.

Fig. 2. Micrographs of (a) nano-spheres and (b) nano-platelets

Tribological properties of nano-MoS₂: The friction coefficients lubricated by nano-platelets at 0.4 m/s and 1.6 MPa were remarkably lower than these by nano-spheres (Fig. 3). The friction-time curve lubricated by nano-platelets was also more stable than that by nano-spheres. The friction temperature rapidly increased within 8 min to a very high value as lubricated by nano-spheres. Thus, the test was not completed. The result concerning nano-spheres is similar to that of a dry friction, indicating that the amount of nano-spheres in the contact area was not enough to lubricate the friction pair.

Fig. 3. Results of end-face tests: (a) friction coefficient and (b) friction temperature

However, previous researches found that spherical MoS₂ nanoparticles usually have lubricating advantages over platelet-like MoS₂ because of the particular lubricating mechanisms of spherical structures^{3,4}. The bad performance of nano-spheres in powder lubrication does not negate the lubricating advantages of spherical structures. This is because the amount of nano-spheres with a low BET area in the contact area was not enough to lubricate the friction pair.

Catalytic properties of nano-MoS₂: Two kinds of nano-MoS₂ represented good activity for the degradation of malachite green at 20 °C (Fig. 4a). As compared with nano-sphere, nano-platelet revealed higher catalytic activity. The catalytic activity of nano-MoS₂ was weakened as repeatedly used for 4 cycles (Fig. 4b). However, the weakening of activity was not very remarkable, indicating nano-MoS₂ catalysts have a good regeneration performance.

Fig. 4. Catalytic activity of 0.1 g MoS₂ used for (a) the 1st cycle and (b) the 4th cycle

MoS₂ contains three kinds of surface (or site), *i.e.* basal surface, rim site and edge site⁵. The catalytic active sites are located at the rim-edge surface. MoS₂ nano-platelet provided the active rim-edge surface and showed high activity for the degradation of malachite green. However, nano-sphere can only offered basal surfaces. Thus, it should reveal a low activity

in the degradation reaction. However, the activity of basal surfaces on nano-spheres was improved by the incurvation of MoS₂ layers⁷. Thus, nano-spheres still represented good activity in the degradation reaction.

Adsorption behaviour of nano-MoS₂: Results given in Figs. 5 and 6 indicate the two kinds of nano-MoS₂ have a similar adsorption behaviour. However, the adsorbed quantity on nano-platelets is remarkably higher than on nano-sphere. The two liner correlation coefficients exceed 0.9999, indicating the BET results are reasonable. The nano-platelets have a BET area of 42 m²/g, whereas the BET area of nano-spheres is only at 19 m²/g. The low surface area decreased the adsorption of nano-sphere on the friction surface. The amount of nano-spheres in the contact area was not enough to lubricate the friction pairs. The relatively high surface area of nano-platelets increased the adsorption on the friction surfaces, leading to a stable lubrication and also offered more active sites for the degradation of malachite green.

Fig. 5. Adsorption isotherm plot of MoS₂: (a) nano-spheres and (b) nano-platelets

Fig. 6. BET surface area plot of MoS₂: (a) nano-spheres and (b) nano-platelets

Conclusion

MoS₂ nano-spheres cannot work in the powder-lubrication manner, whereas MoS₂ nano-platelets represent a stable lubricating performance. As compared to MoS₂ nano-spheres, MoS₂ nano-platelets have better catalytic activity for the degradation of malachite green.

ACKNOWLEDGEMENTS

This work was supported by the National Natural Science Foundation of China (grant no. 50905054 and 51275143) and the China Postdoctoral Science Foundation funded project (Grant No. 2011M500110).

REFERENCES

1. J.V. Lauritsen, J. Kibsgaard, S. Helveg, H. Topsøe, B.S. Clausen, E. Lægsgaard and F. Besenbacher, *Nat. Nanotechnol.*, **2**, 53 (2007).
2. K.H. Hu, X.G. Hu and X.J. Sun, *Appl. Surf. Sci.*, **256**, 2517 (2010).
3. J. Tannous, F. Dassenoy, I. Lahouij, T. Le Mogne, B. Vacher, A. Bruhács and W. Tremel, *Tribol. Lett.*, **41**, 55 (2011).
4. I. Lahouij, F. Dassenoy, B. Vacher and J.M. Martin, *Tribol. Lett.*, **45**, 131 (2012).
5. M. Daage and R.R. Chianelli, *J. Catal.*, **149**, 414 (1994).
6. K.H. Hu and X.G. Hu, *Mater. Sci. Technol.*, **25**, 407 (2009).
7. K.H. Hu, X.G. Hu, Y.F. Xu and X.Z. Pan, *React. Kinet. Mech. Catal.*, **100**, 153 (2010).