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

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The lubricating and catalytic properties of two kinds of nano-MoS_2, 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, MoS_2 nano-platelets with a high BET area could well function as a powder lubricant. The high BET area also improved the catalytic activity of MoS_2 nano-platelets. The findings indicated MoS_2 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-MoS_2[1]. Spherical nano-MoS_2 (MoS_2 nano-sphere) usually reveals better tribological properties than platelet-like nano-MoS_2 (MoS_2 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 MoS_2 can be explained by the 'rim-edge site' model[5].

Though literatures reported the lubricating advantages of spherical nano-MoS_2 over platelet-like nano-MoS_2[1,2], the results in this work showed that MoS_2 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-MoS_2 samples in different shape were synthesized using chemical methods reported by Hu and Hu[6]. The characterization of nano-MoS_2 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 MoS_2 at 1.6 MPa and 0.4 m/s. Fig. 1 shows the schematic of the end-face powder-lubrication manner.

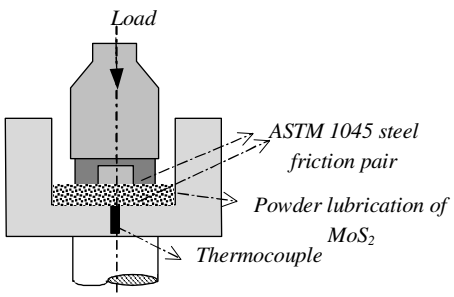

Fig. 1. Schematic diagram of the end-face tribological test

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-MoS_2: Fig. 2 provides micrographs of the two kinds of MoS_2 nanoparticles. As shown in Fig. 2a, nano-MoS_2 is in a hollow sphere-like shape with diameters of 100-200 nm and shells of about 15 nm. The other

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nano-MoS_2 in Fig. 2b comprises a platelet-like structure with thickness of about 8 nm and lengths of 20-40 nm.

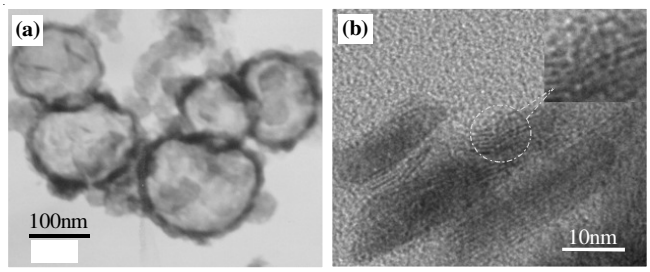

Fig. 2. Micrographs of (a) nano-spheres and (b) nano-platelets

Tribological properties of nano-MoS_2: 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.

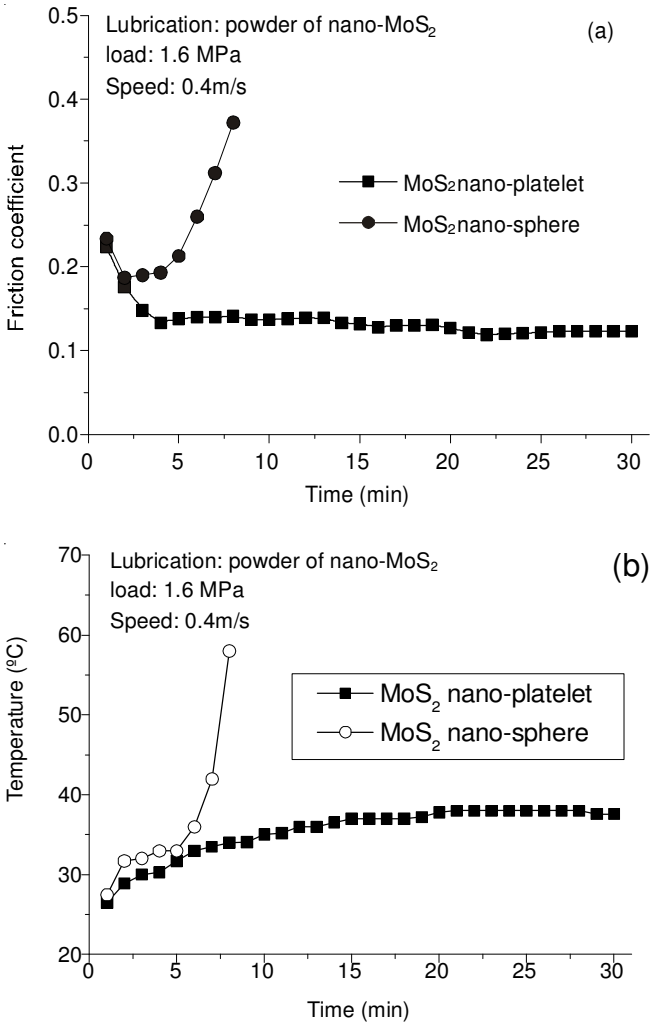

Fig. 3. Results of end-face tests: (a) friction coefficient and (b) friction temperature

However, previous researches found that spherical MoS_2 nanoparticles usually have lubricating advantages over platelet-like MoS_2 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-MoS_2: Two kinds of nano-MoS_2 represented good activity for the degradation of malachite green at 20 ºC (Fig. 4a). As compared with nano-sphere, nano-platelet revealed higher catalytic activity. The catalytic activity of nano-MoS_2 was weakened as repeatedly used for 4 cycles (Fig. 4b). However, the weakening of activity was not very remarkable, indicating nano-MoS_2 catalysts have a good regeneration performance.

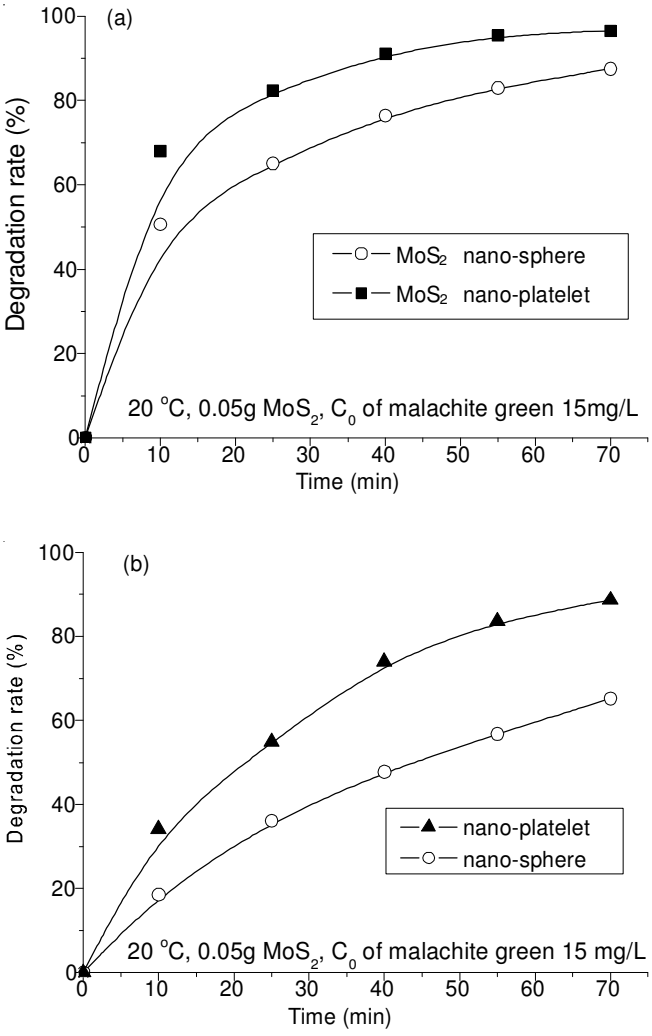

Fig. 4. Catalytic activity of 0.1 g MoS_2 used for (a) the 1st cycle and (b) the 4th cycle

MoS_2 contains three kinds of surface (or site), *i.e.* basal surface, rim site and edge site[5]. The catalytic active sites are located at the rim-edge surface. MoS_2 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 MoS_2 layers[7]. Thus, nano-spheres still represented good activity in the degradation reaction.

Adsorption behaviour of nano-MoS_2: Results given in Figs. 5 and 6 indicate the two kinds of nano-MoS_2 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 m^2/g, whereas the BET area of nano-spheres is only at 19 m^2/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.

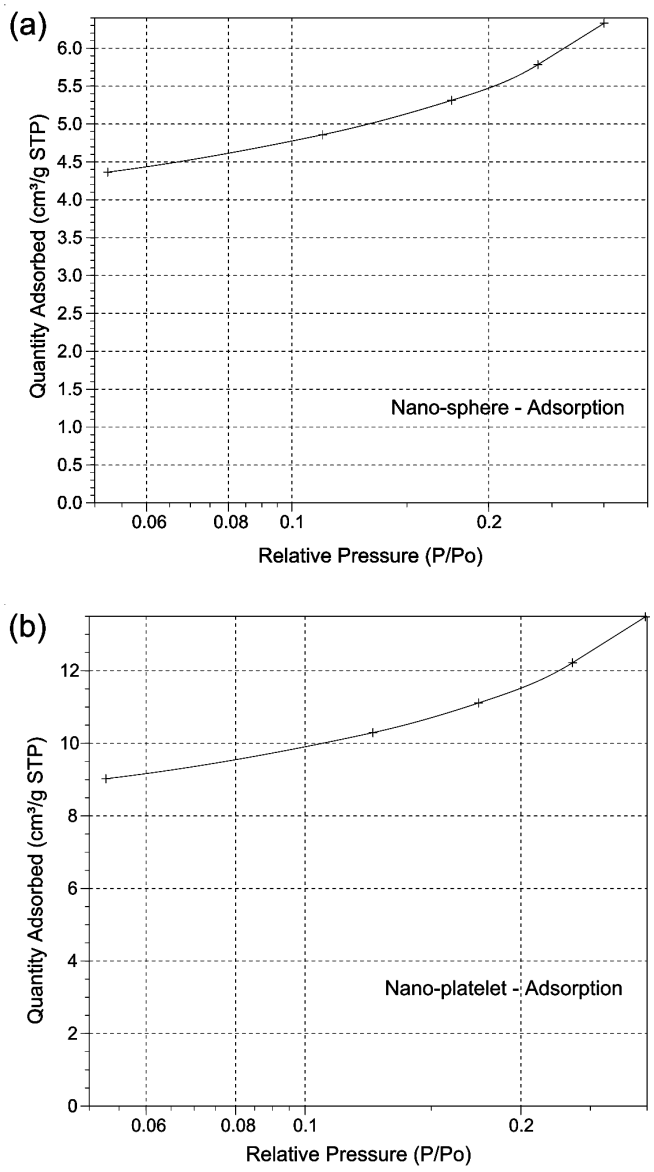

Fig. 5. Adsorption isotherm plot of MoS_2: (a) nano-spheres and (b) nano-platelets

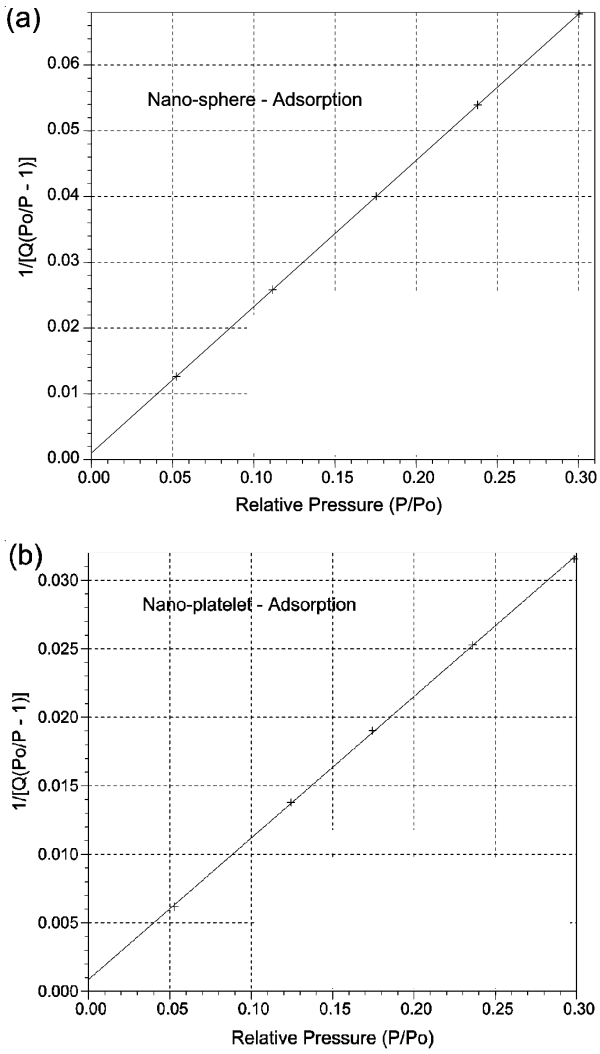

Fig. 6. BET surface area plot of MoS_2: (a) nano-spheres and (b) nano-platelets

Conclusion

MoS_2 nano-spheres cannot work in the powder-lubrication manner, whereas MoS_2 nano-platelets represent a stable lubricating performance. As compared to MoS_2 nano-spheres, MoS_2 nano-platelets have better catalytic activity for the degradation of malachite green.

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