ASIATRIB 2002 International Conference
JEJU ISLAND, KOREA

Research and Application of Nano-particles as Oil Additives

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Nano materials have great potential for development of advanced lubricating and protecting materials. Nano-particles capped by organic compound such as organic acid, dialkyldithiophosphate (DDP) are capable to disperse stably in lubricating oils, and are able to reduce wear and to increase load-carrying capacity.

Keywords: organic compounds capped nanoparticles, oil additives, friction and wear

A series of DDP capped LaF_3, CeF_3, PbS, ZnS, Cu and Ag nanoparticles, 2-ethyl hexoic acid (EHA) capped TiO_2, stearic acid (SA) capped ZrO_2, and oleic acid (OA) capped PbS and ZnS nanoparticles were chemically synthesized in ethanol–H_2O mixture solvent. The structure of all the prepared nanoparticles were characterized by transmission electron microscopy (TEM), high resolution electron microscopy (HREM), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FT-IR), X-ray photoelectron spectroscopy (XPS). TEM,

HREM and XRD examination have shown that the diameter of the prepared particles are fairly uniformly distributed with an average size of about 2~15 nm, the results also indicate that the existence of surface modification layer of DDP, EHA, SA and OA could prevent the agglomeration of nanoparticles effectively. FT-IR analyses have found that the DDP or aliphatic acid was conjugated to the surfaces of nanoparticles. XPS analyses indicated that the modification layer could effectively prevent nanoparticles from oxidation.

The tribological behaviour as shown in Table 1 of steel-on-steel system with the lubrication of the prepared nanoparticles as oil additives was evaluated on a four-ball wear tester, under a rotating speed of 1450 r/min at room temperature for 30 min. Liquid paraffin (LP) was used as the base oil.

Table 1 Tribological behaviour of capped nanoparticles as oil additive in LP

		300 N		400 N		600 N		800 N		1200 N		1500 N	
Sample	wt.%	*WSD mm*	*μ*	*WSD mm*	*μ*	*WSD mm*	*μ*	*WSD mm*	*μ*	*WSD mm*	*μ*	*WSD mm*	*μ*
LP	100	0.68	0.090	--	--	--	--	--	--	--	--	--	--
DDP-LaF_3	1	0.39	0.088	0.42	0.080	0.45	0.077	0.48	0.078	0.65	0.064	0.90	0.066
DDP-CeF_3	1	0.39	0.084	0.43	0.088	0.50	0.083	0.78	0.082	1.00	0.068	--	--
DDP-Cu	4	0.40	0.093	0.45	0.080	--	--	--	--	1.02	0.065	0.94	0.048
DDP-Ag	1	0.40	0.088	0.48	0.081	0.79	0.080	1.03	0.086	2.31	0.095	2.72	0.10
DDP-PbS	0.05	0.44	0.10	0.50	0.097	--	--	--	--	--	--	--	--
DDP-ZnS	0.1	0.38	0.090	0.55	0.10	--	--	--	--	--	--	--	--
EHA-TiO_2	0.5	0.51	0.094	0.64		--	--	--	--	--	--	--	--
SA-ZrO_2	0.1	0.39		0.43		--	--	--	--	--	--	--	--
OA-PbS	0.2	0.47	0.064	0.50	0.061	--	--	--	--	--	--	--	--
OA-ZnS	0.05	0.50	0.076	0.55	0.067	--	--	--	--	--	--	--	--

'--' lubrication failure.

It is seen that DDP capped LaF_3 and CeF_3 nanoparticles used as oil additives show similar tribological behaviour at the load range from 300 N to 600 N. With the addition of 1 wt.% of capped LaF_3 and CeF_3 nanoparticles, the wear scar diameter can be reduced by 43 % as compared to lubrication with LP alone at 300 N, and even can lubricate the system at 1500 N and 1200 N, respectively, much higher than use LP alone (no higher than 300 N). The results indicate that DDP capped LaF_3 and CeF_3 nanoparticles used as oil additives exhibit good antiwear ability, much higher load-carrying capacity. They even can reduce friction coefficient at higher load (nanocore play the main role), but the friction coefficient didn't change much as compared to lubrication with LP alone at 300 N.

DDP capped PbS, ZnS nanoparticles, EHA capped TiO_2 and SA capped ZrO_2 nanoparticles as additives in LP are effectively for increasing the antiwear ability (the wear scar diameter can be reduced by 35~45 % as compared to lubricate with LP alone at the load of 300 N) even at a extremely low concentration, and can lubricate the system at 400 N. The friction coefficient has only little change as compared to lubrication with LP alone [1-2].

The tribological behaviour of DDP capped metal nanoparticles, such as Cu and Ag nanoparticles as oil additives are apparently different at higher load (>500 N). Cu-DDP nanoparticles as oil additives in LP can't protect the system at the load range from 500 to 900 N. The most interesting phenomena is that it regain lubrication again at even higher load (1000~1500 N) with lower friction coefficient than lubrication at lower load. We suppose that at the lower load, the organic modification layers play the main role to lubricate the system; while at the high load (higher than 900 N), under the high pressure and temperature, Cu nanoparticles can form alloy with Fe substance, the high combination strength lead to the good tribological property. At the medium load, they fail to protect the system because the organic layer decomposed and the Cu-Fe alloy can't form under such a low load. Wear scar diameter increased abruptly with the lubrication of Ag-DDP as oil additives at the load higher than 800 N, indicating that they fail to protect the system at such a high load. The reason that two metal nanoparticles show such different tribological behaviour is because that Ag is very difficult to form alloy with Fe substance.

OA-capped PbS and ZnS nanoparticles as oil additives can both improve the antiwear and friction-reduction ability. The wear scar diameter can be reduced by 31 % and 25 %, and the friction coefficient can be reduced by 29 % and 16 %, respectively as compared to lubrication with LP alone at 300 N.

The results shown above leading to the conclusion that all the capped nanoparticles used as oil additives can effectively improve the antiwear ability and load-carrying capacity to some extent. OA capped nanoparticles as oil additives can effectively reduce friction coefficient of the system to a great extent, while DDP capped nanoparticles as modification agent can not, indicating that the modification agent have much influence to the friction coefficient.

The morphologies of the worn surfaces after four-ball teste were examined with a JSM-5600 LV scanning electron microscope (SEM), the element distribution on the worn surface was measured by a KEVEX energy dispersion spectroscopy (EDS). The boundary film on the worn surface was investigated by XPS. Results indicate that there are large plough groove on the wear surface lubricated with LP alone, while with the lubrication of capped nanoparticles, the worn surface were much smoother and rich of elemental distribution. The formation of a deposited boundary film of the materials same to the nano-core and a tribo-chemistry reaction film contributed to the good tribological behaviour. With the application of nano-materials in lubricating oil, it is hope to develop better performance lubricant which are able to work at higher load with lower wear and friction coefficient.

ACKNOMLEDGEMENTS
The authors are grateful to the National Natural Science Foundation of China and Chinese Academy of Sciences for the financial support.

REFERENCES

[1] Xue, Q., Liu, W. and Zhang Z., "Friction and wear properties of a surface-modified TiO_2 nanoparticle as an additive in liquid paraffin", **Wear**, Vol. 213, pp. 29-32, 1997.

[2] Chen, S., Liu, W., "Preparation and Characterization of Surface-Coated ZnS Nanioparticles", **Langmuir**, Vol. 15, pp. 8100-8104, 1999.