Smart Lubricity of BN-Containing $CaCO_3$-SiO_2 Hybrid Shell Colloidal Capsules under Hot Metal Forming Conditions

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The smart responsive BN-containing $CaCO_3$-SiO_2 hybrid shell colloidal capsule has been developed as a multifunctional additive for hot metal forming lubrication. This colloidal capsule works synergistically with sodium borate melt to deliver superior anti-oxidation (~93.3% reduction), ultralow friction (0.07), and excellent wear alleviation (~80% reduction) compared to the dry sliding test at 880°C. Such outstanding performances are attributed to the smart responsiveness of the colloidal capsule under sodium borate melt at elevated temperatures that *in-situ* generate sodium-calcium borosilicate melt and release the h-BN nanosheets. This study sheds a new light to an application of smart microcapsule in high-temperature manufacturing lubrication.

Keywords: smart material, friction, wear, colloidal capsule

1. Introduction

Microencapsulation technique is a powerful tool to design a functional additive. Such technique has recently been applied in lubricant science to control the release of the core active ingredients (anti-wear agents, friction modifiers…) [1]. The benefit of this technique centers around the porosity and permeability of the polymeric shell that limit the additive dosage and hinder the competitive interactions between the core and other additives [2]. Utilizing this technique to formulate a multifunctional additive for hot metal forming is of great interest but the original concept of the control-release may not be suitable at harsh heating conditions. Instead, we utilize the smart thermo-responsive characteristics concept to design the colloidal capsule which shows an excellent lubrication enhancement by the synergistic effect between the shell materials, core active ingredients, and melt base lubricant.

2. Methods

2.1. Friction and wear evaluation

Tribological performances of different lubricant (Table 1) are evaluated by UMT Tribolab with reciprocating module. The testing conditions are 10 N applied load (equal to 1.04 GPa Hertzian pressure), 1 Hz, 880°C. The tested disc is stainless steel while the tested ball is GCr15 bearing steel. The colloidal capsule is added to the borate aqueous lubricant at room temperature with a weigth ratio of borate/capsule = 1:1 before applied on the disc surface as a coating prior to the hot friction test.

Table 1: Name of the tested lubricant

Test	Name
Dry sliding	D-L
Borate lubrication	B-L
Borate + capsule without h-BN	C-B (1:1)
Borate + capsule with h-BN	BN@C-B (1:1)

2.2. Tribofilm characterization

SEM/FIB/TEM/EDS/EELS is applied to study the structure and composition of the colloidal capsule and tribofilm. Raman microscope is utilized to detect the possible h-BN presenting in the colloidal capsules and the lubricant film before and after the hot friction test.

3. Results

h-BN-containing $CaCO_3$-SiO_2 hybrid shell colloidal capsule is synthesized that shows an outstanding performances in improving oxidation resistance, friction reduction, and wear alleviation of sodium borate melt.

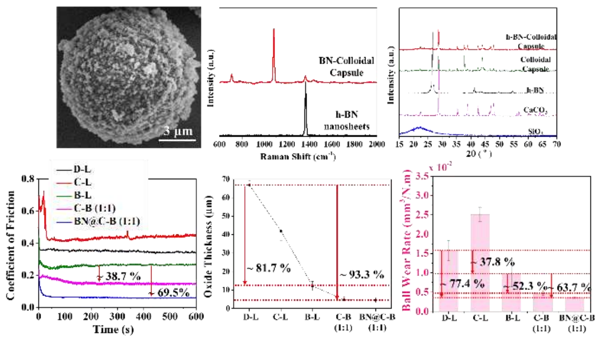

Figure 1: Designed colloidal capsule as a smart multifunctional lubricant additive for sodium borate melt lubricant at elevated temperatures.

4. Discussion

The colloidal capsule contains different solid lubricant additive that can be function at elevated temperatures including h-BN nanosheets, $CaCO_3$ nanoparticles, SiO_2 glass. Under heating at 880°C, the $CaCO_3$-SiO_2 hybrid shell thermally reacts to sodium borate melt that form the sodium-calcium borosilicate melt. The melting of the shell release the encapsulated h-BN nanosheets. During sliding, both the melt and h-BN nanosheets function synergistically to significantly reduce friction and wear while the borosilicate melt plays a main role in reducing oxidation process of steel substrate.

5. References

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