# Effect of $SiO_2$ Nanoparticles on Wax Crystallization and Flow Behavior of Model Crude Oil

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## 1. Additional results

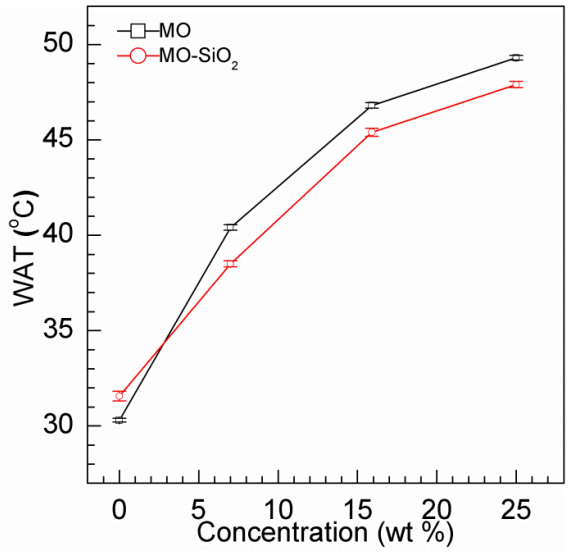


**Figure S1.** Wax appearance temperature of model oils with and without $SiO_2$ nanoparticles.

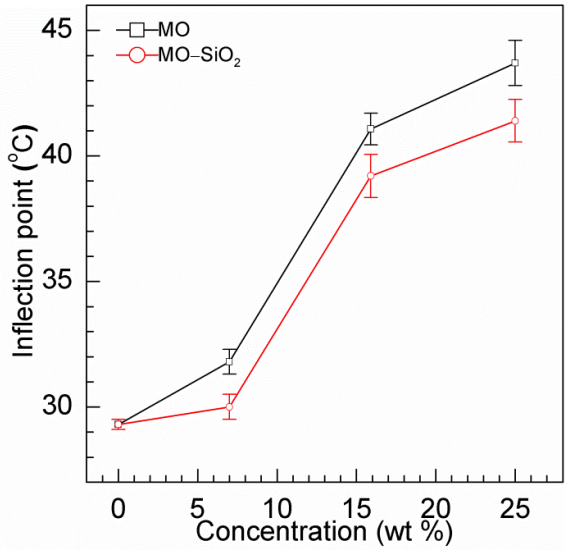


**Figure S2.** Inflection point of model oils treated and untreated with $SiO_2$ nanofluid.

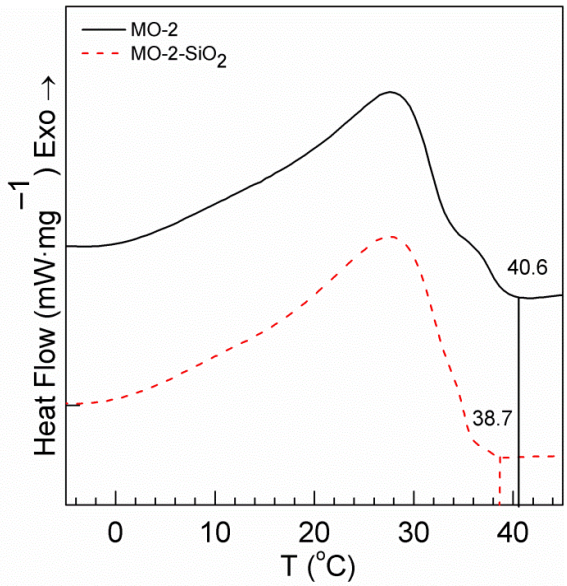


**Figure S3.** DSC cooling curves of MO-2 in the presence of absence of $SiO_2$ nanoparticles.

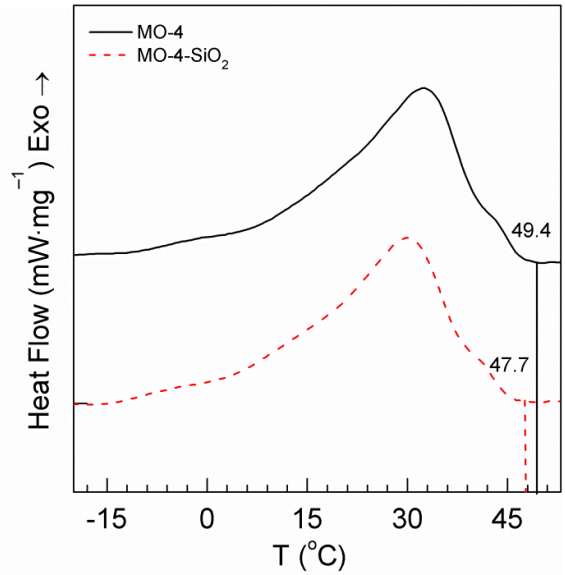


**Figure S4.** DSC cooling curves of MO-4 with and without $SiO_2$ nanoparticles.

## 2. Reliability and repeatability of experimental data

In order to make sure the experimental data is reliable, each sample was tested three times, and the results are shown in Figure S5 and Figure S6. As can be seen in the figures, the standard deviations of WAT and inflection point are less than 0.3 °C and 0.9 °C, respectively. They are all smaller than the minimum difference between the results before and after treated with $SiO_2$ nanoparticles. It means that repeatability meets the requirements of this study.

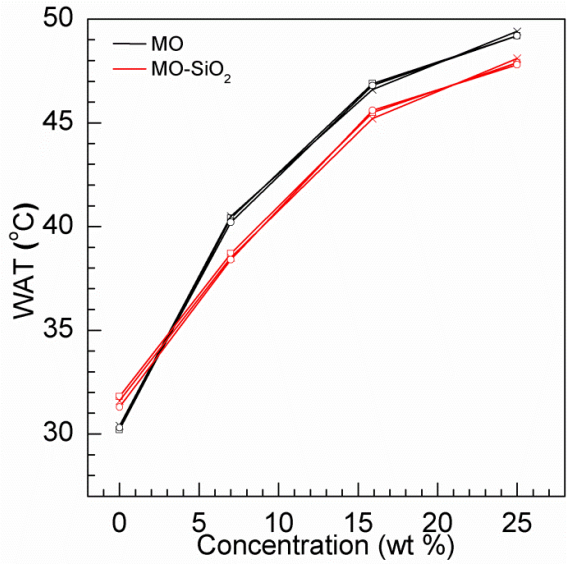


**Figure S5.** Repeatability of WAT. (□) 1st test, (×) 2nd test, (○) 3rd test.

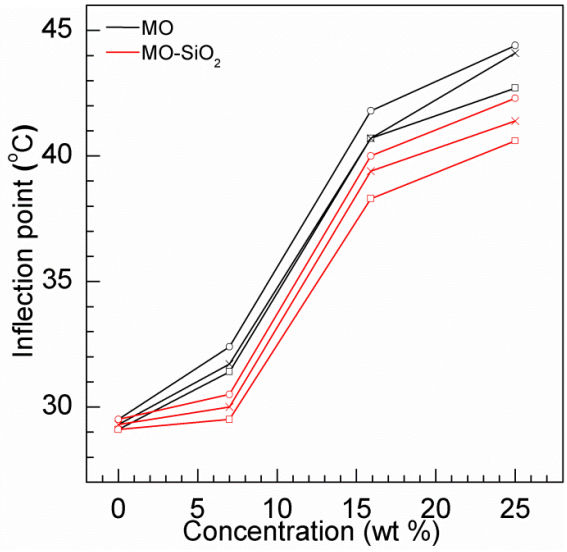


**Figure S6.** Repeatability of inflection temperature. (□) 1st test, (×) 2nd test, (○) 3rd test.

### 3. The effect of $SiO_2$ nanoparticles on crystallization and rheological properties in crude oil

To study the effect of $SiO_2$ nanoparticles on the crystallization and rheological properties in crude oil, 0.2 g $SiO_2$ nanofluid was added to 20 g crude oil, and then stirred at 80 °C for 3 h.

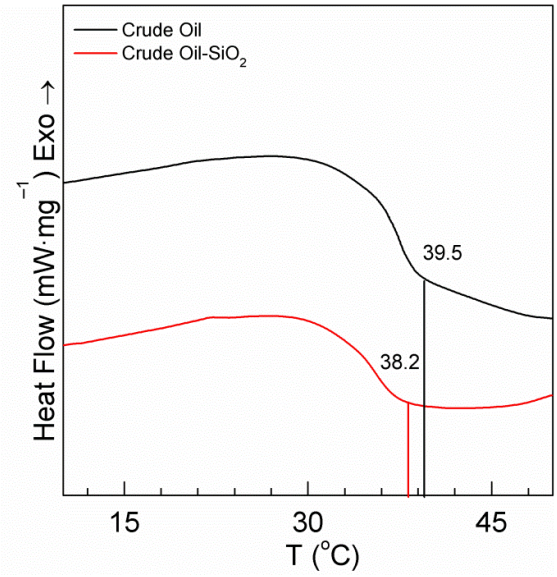


**Figure S7.** DSC cooling curves of crude oil untreated and treated with $SiO_2$ nanoparticles.

The thermal response of model oils before and after addition of $SiO_2$ nanoparticles is shown in Figure S7. The images of crude oil in the absence and presence of $SiO_2$ nanoparticles are shown in Figure S8. The viscosity-temperature Semi-logarithmic curves of crude oil with and without $SiO_2$ nanoparticles are shown in Figure S9. The corresponding

WAT and inflection point are shown in Table S1. As can be seen in these figures and table, after introducing $SiO_2$ nanoparticles, both WAT and inflection point of crude oil are reduced, the amount of wax crystals decreased and the wax crystals were sparse. These phenomenon are consistent with the result of model oils which contain asphaltene and resin.

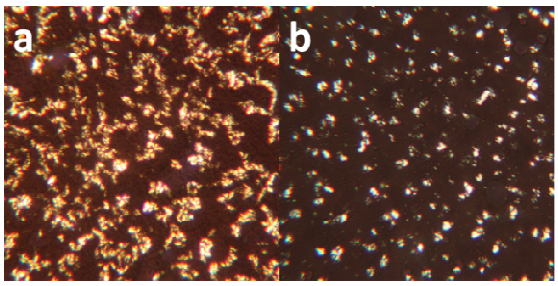


**Figure S8.** Polarized optical microscopy images of crude oil in the absence (a) and presence (b) of $SiO_2$ at 25 $^oC$.

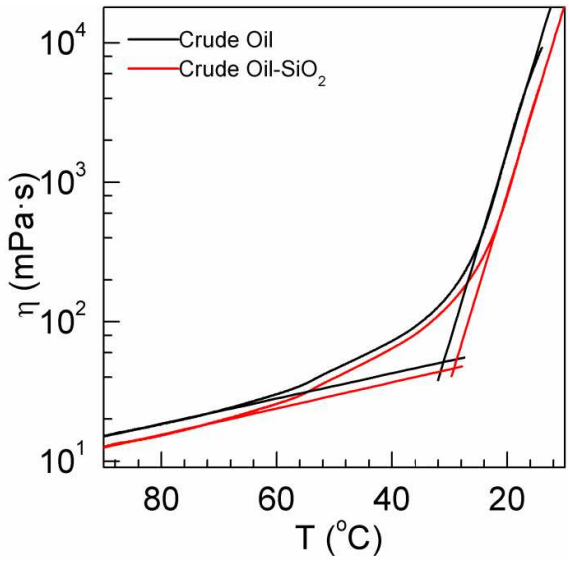


**Figure S9.** Semi-logarithmic curve of viscosity versus temperature for the crude oil untreated and treated with $SiO_2$ nanofluid.

**Table S1.** Wax appearance temperature and inflection temperature for crude oil, untreated and treated with $SiO_2$ nanoparticles.

| WAT ($^oC$) | | Inflection temperature ($^oC$) | |
|---|---|---|---|
| untreated | treated | untreated | treated |
| 39.5 | 38.2 | 31.1 | 29.2 |