Functional Nanoparticle-Augmented Surfactant Fluid for Enhanced Oil Recovery in Williston Basin

Quarterly Status Report
(for the period of August 1 through November 1, 2019)

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Summary of Current Progress

During the past quarter, the primary goals were to conduct the synthesis of silicon quantum dots and study its characteristics. In addition, preliminary study of the preparation of silicon nano-fluids were performed.

We mainly focused on the following tasks:

1) Synthesis of silicon quantum dots (SiQDs).
2) Fluorescence of SiQDs.
3) Size of SiQDs.
4) Selection of suitable surfactant to mix with SiQDs.
5) Preparation of SiQDs nano-fluid.

Below are the detailed results of these tasks.

1. Synthesis of silicon quantum dots (SiQDs)

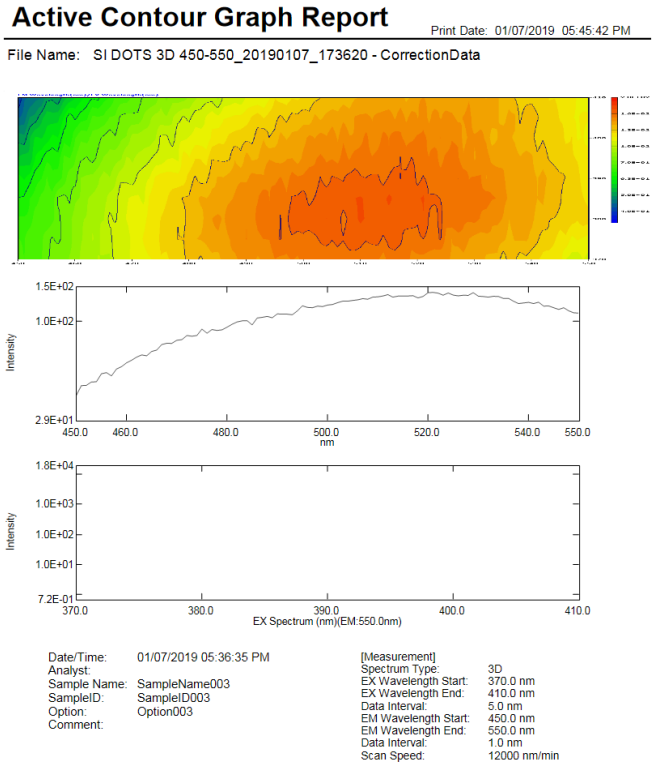
1 mL 3-aminopropyltriethoxysilane (APTES), 1.25 mL sodium ascorbate (SA) were mixed in 4 mL distilled water under vigorous stirring at 37°C for 4 hrs. Excess reagents like APTES molecules and SA were fully removed by ultrafiltration at 8000 rpm for 3 times with a centrifugal filter device (molecular weight cut-off MWCO = 3 kDa), and the SiQDs were obtained.

1.1 Fluorescence of SiQDs

The synthesized SiQDs have the fluorescence as shown in Figure 1. Under natural light, it is a little light red (Figure 1A), while there is a clearly green color under UV light (Figure 1B). At the excitation between 370-410 nm, the contour fluorescence graph was obtained in Figure 1C.

(A) Under natural light

(B) Under UV light



(C) 3-D contour fluorescence graph

Figure 1. Fluorescence of SiQDs.

1.2 Size of SiQDs

The size and the size distribution were characterized using a nanoparticle size analyzer. The dynamic light scattering (DLS) device Zetasizer Nano Series (Malvern, Westborough) was used to analyze the particle sizes. The obtained hydrodynamic diameter of the SiQDs and its distribution is shown in Figure 2 with an average size of 2.8 ± 0.4 nm.

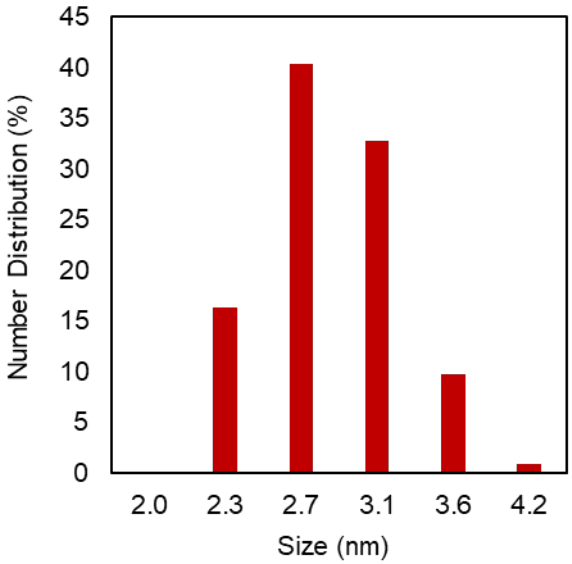


Figure 2. Particle size distribution based on the DLS method.

2. SiQDs mixed with different surfactants

Because nanoparticles are normally unstable in high salinity brine, nanoparticles are usually mixed with surfactants to improve their stability. Polyethylene glycol (PEG) and betaine were selected to improve the stability of SiQDs as shown in Figure 3. It is obvious that the particle size of SiQDs mixed with betaine is much smaller than it mixed with PEG, which indicates betaine is a suitable stabilizer to mix with SiQDs.

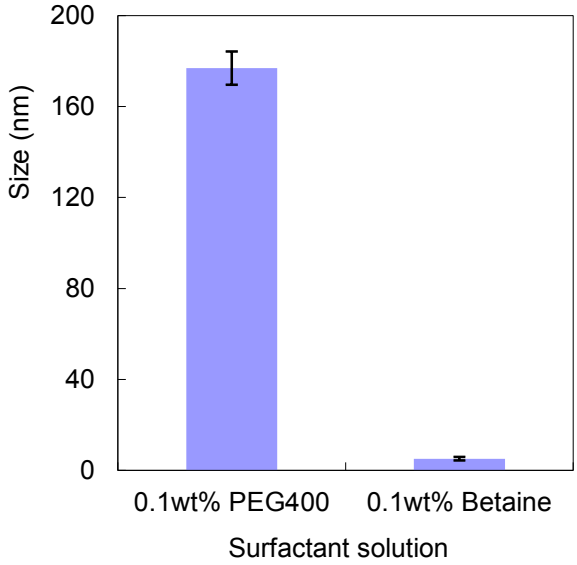


Figure 3. Particle size of SiQDs mixed with surfactants.

3. SiQDs nano-fluid in buffer solution

In order to further investigate the stability of the SiQDs nano-fluid, 2-hydroxyethyl (HEPES) buffer solution was applied to prepare it. Three kinds of nano-fluids were prepared, including SiQDs dissolved in HEPES (HEPES), the mixture of SiQDs and betaine dissolved in HEPES (Beta-Si HEPES), betaine added into HEPES containing SiQDs (HEPES Si-Beta), as shown in Figure 5. The size of the third type nano-fluid (HEPES Si-Beta) remained stable compared to the other two nanofluids whose particle sizes increased significantly. The main reason was that when SiQDs dissolved in HEPES the pH value of it is around 7, which made it positive. And the negative end of betaine would be absorbed onto the surface of it, which offered a space steric that enhanced the stability.

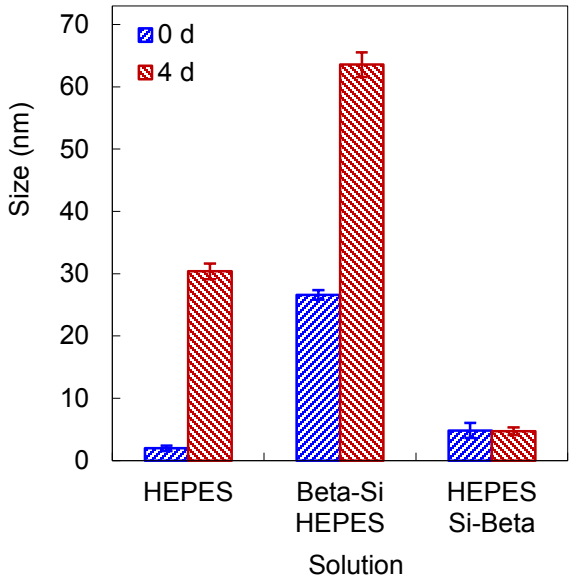


Figure 4. Particle size of SiQDs mixed with Betaine in buffer.

Future Work

1. Morphological representation of SiQDs.
2. SiQDs modified with surfactant.
3. SiQDs applied in oil recovery.