

Effect of surface modification of silica nanoparticles on foam stability in decontamination foam

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1. Introduction

A large amount of liquid waste is generated from the decontamination that occurs when dismantling nuclear facilities. A process is needed to decrease the amounts of chemical reagents and secondary waste produced during the decontamination process. Decontamination foam is a non-stable, two-phase fluid with aqueous and gas phases representing not more than 10% and 90% of the total volume, respectively. This formulation can significantly decrease the amounts of chemical reagents and secondary waste [1].

The advantage of decontamination foam is its potentially wide application for metallic walls, overhead surfaces, and the elements of complex components and facilities. In addition, the application of foam allows for remote decontamination processing using only an injection nozzle and the equipment to generate the decontamination foam, which reduces operator exposure to high radioactivity [2].

Solid colloidal particles increase the foam stability in the foam formulation. These particles can be specifically hydrophobized for optimal adsorption at the liquid/gas interface, which creates armor for the bubbles and prevents coalescence by reducing the internal gas transfer [3-5]. Conversely, hydrophilic particles remain confined in the liquid phase, and to enhance the foam stability. In this study, we aimed to modify the surface of silica nanoparticles with dichlorodimethylsilane (DCDMS) reagents using methods proposed in previous literatures. We also investigated the foam stability with surface-modified silica nanoparticles to develop the new formulation of decontamination foam.

2. Methods and Results

Fumed silica (M-5) was purchased from Cabosil, and selected owing to their stability and in acid media and low cost. Various degree of hydrophobicity were obtained by silanization of the silica particle surface with DCDMS (+99.5%, Sigma-aldrich). In surface modification, 1.0 g fumed silica nanoparticles were modified with DCDMS/Si mole ratio as 0.005, 0.01, 0.025, 0.05, 0.1, 0.2 and 0.50 in toluene at 60 °C for 20 hrs and continuously injected by nitrogen gas. Then the samples were dried in furnace at 110 °C for 3 hrs.

A hydrophilic silica (M-5) was silylated by reaction with DCDMS. The silylation was performed with variable amounts of silane in order to control the DCDMS group (Fig. 1). The content of silanol groups was determined by titration with aqueous sodium hydroxide [6]. 1 g silica NPs modified with DCDMS/Si mole ratio as 0.005, 0.01, 0.025 were added to a 1% v/v ElotantTM Milcoside 100 (EM 100) surfactant solution to investigate the foam stability compared with unmodified silica nanoparticles.

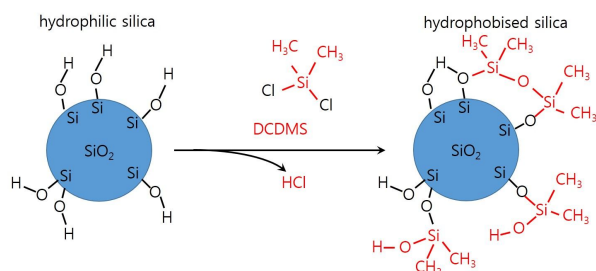


Fig. 1. Schematic diagram for surface modification of silica nanoparticles using DCDMS reagent.

The foam stability was measured using a Foamscan instrument. The foam is generated by blowing nitrogen gas at a flow rate of 200 ml/min through a porous glass filter at the bottom of a glass tube where 60 ml of the foaming aqueous solution at ambient temperature is placed. In all experiments, the foam was allowed to reach a volume of 200 ml. The bubbling was then stopped, and the evolution of the foam was analyzed using conductivity and optical measurements.

3. Results and Discussion

Fig. 2 shows the content of SiOH (%) group in DCDMS/Si mole ratio using NaOH titration. As shown in Fig. 2, the content of SiOH (%) was linearly decreased in the increase of DCDMS/Si mole ratio. About 60% for content of SiOH(%) was decreased in the addition of DCDMS/Si mole ratio as 0.5. To illustrate the properties for surface-modified silica nanoparticles, 1 g silica nanoparticles were added to 100 mL of 1% EM 100 at pH 2. In Fig 2 (inset), silica nanoparticles settle down the bottom, indicating that hydrophilic particles. In contrast, the surface-modified silica nanoparticles were floated on air-water surface.

This results showed that surface-modified silica nanoparticles was hydrophobic particles.

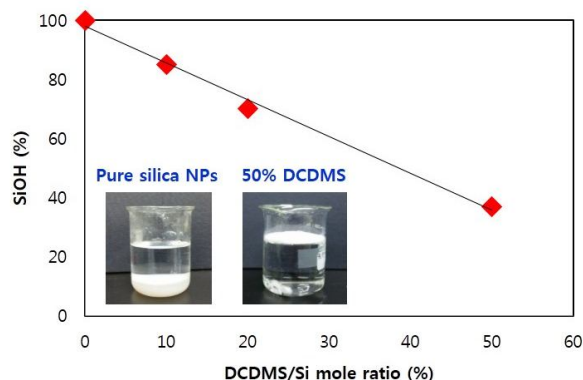


Fig.2. Content of SiOH (%) in DCDMS/Si mole ratio using NaOH titration

In Fig. 3, the foam volume remained at over 175 ml for 2 hours with surface-modified silica nanoparticles in DCDMS/Si mole ratio as 0.025. However, foam decreased and remained at 137 ml after 2 h with unmodified silica nanoparticles. In surface-modified silica nanoparticles in DCDMS/Si mole ratio as 0.005 and 0.01, foam volume was higher than that with unmodified silica nanoparticles. However, foam volume in DCDMS/Si mole ratio as 0.1 was continuously decreased and remained in 100 mL. This results showed that optimum DCDMS/Si mole ratio was 0.025. When partially hydrophobic silica nanoparticles and suitable surfactants are combined, synergistic effects can be found in terms of foamability and foam stability of the corresponding dispersions [7]. Previous studies reviewed the different concepts of foam stabilization mechanisms involving silica nanoparticles [8]. It has been found that silica particle layers can stabilize a fluid interface by forming a protective layer. These layers of silica nanoparticles decelerate the foam destruction.

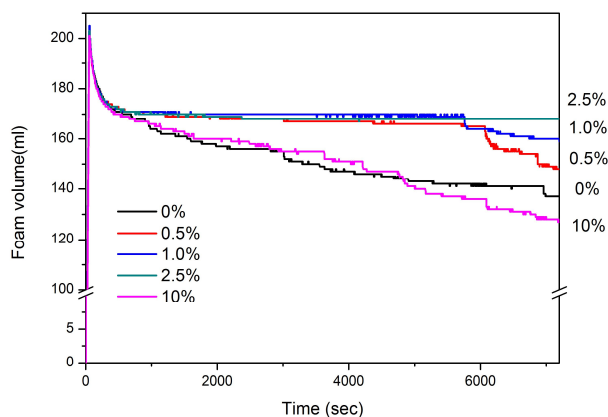


Fig.3. Foam volume containing silica nanoparticles containing surface-modified DCDMS.

4. Conclusions

Modified silica nanoparticles are effective stabilizer of decontamination foam by controlling their hydrophobicity, resulting that foam are stable to collapse. We plan to investigate further the influence pH and the concentration of chemical reagent in decontamination foam system. In future studies, decontamination tests will be conducted on a surface contaminated with radionuclides such as cesium and cobalt.

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