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Reduction of chemical reactivity of liquid sodium by Ti nanoparticles

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1. Introduction

SFR(Sodium Cooled fast Reactor) is one of the Generationⅳ nuclear reactor project to design a fast neutron reactor. SFR specially uses liquid sodium as its reactor coolant due to its higher thermal conductivity than water. However, liquid sodium has a critical disadvantage that it explosively reacts when it comes to contact with water because of strong chemical reactivity of sodium,. In the secondary part of SFR, liquid sodium coolant indirectly contacts with water. If any rupture occurs at the secondary part, tremendous explosion could be appeared. It is very important to guarantee the use of liquid sodium safely.

The current issues to guarantee the safety of using liquid sodium have been focused on reducing chemical reactivity of liquid sodium by nanoparticles [1]. Nano sized Titanium particles are dispersed in liquid sodium that makes the strong atomic bond between sodium and nanoparticles. This strong atomic bond disturbs the contact between sodium and water molecular and effectively reduces the chemical reactivity of liquid sodium at sodium-water vapor reaction. Nickel nanoparticles also have been shown the effect on reducing chemical reactivity of sodium [2].

This experimental study presents the more details about reducing chemical activity of sodium by Titanium nanoparticles (Ti NPs).

2. Experiments

In order to investigate the effect of titanium nanoparticles on SWR (Sodium Water Reaction), the distribution of nanoparticles in liquid sodium is carefully observed and the reactor has been installed.

2.1 Preparation of sodium nano fluid

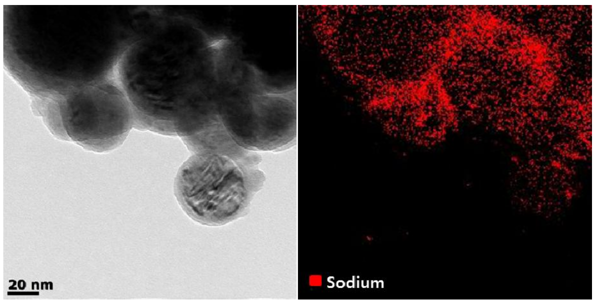
Ti NPs ($\leq$100nm) are employed in this research. Figure 1 shows Ti NPs are dispersed in 20g of liquid sodium with 0.1 weight % by stirring. Ultra sonication is also employed to avoid nanoparticle aggregation. All the experiment processes have been conducted under inert gas condition in a glove box to avoid surface oxidation of liquid sodium.

(a) (b)

Fig. 1. (a) Bare liquid sodium and (b) sodium nano fluid (sodium dispersed with Ti NPs) in quartz beaker.

2.2 Distribution of Ti NPs

Nanoparticle distribution is analyzed by TEM (Transmission Electron Microscope) and SIMS (Secondary Ion Mass Spectrometry). Ti NPs that dispersed in liquid sodium is observed by TEM and component analysis. As shown in figure 2 (b), red sports represent sodium and it is conformed that sodium is well attached on the surface of Ti NPs. However it is still unknown that how strong energy exists to grab sodium atoms on the surface of NPs.



(a) (b)

Fig. 2. TEM images of (a) titanium nanoparticles dispersed in liquid sodium. (b) Sodium component image mapping.

A sample of sodium nano fluid is solidified and observed by SIMS to validate the distribution of Ti NPs in liquid sodium. The analysis area is 100 $\mu m \times$ 100 μm and sodium and titanium ions are detected. At figure 3, the bright colour represents titanium and more NPs are detected as colour becomes from blue to red. It is observed that Ti NPs are well distributed in liquid sodium.

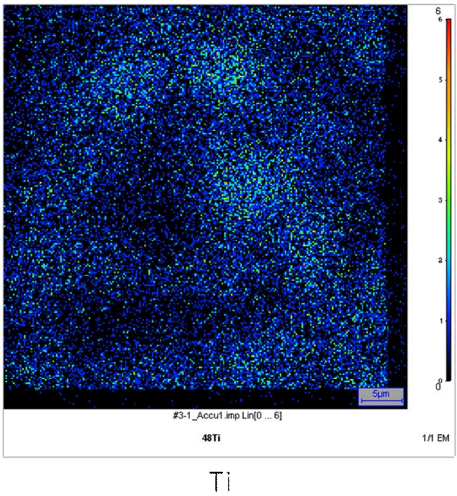


Fig. 3. SIMS image of titanium nanoparticles in sodium nano fluid

2.3 Experimental apparatus

The reactor is installed for sodium-water reaction experiment. A cylindrical stainless steel reactor vessel contains a small amount of sodium and is heated up to 150°c to make liquid sodium. Temperature of reactor inside is measured by k-type thermocouple. When the temperature is reached to a certain temperature, the reactor is vacuumed by vacuum pump. The temperature of reactor inside is maintained above melting point of sodium during vacuuming. When a solenoid valve on the top of the reactor is opened, water is sucked into the reactor, then sodium reacts with water. Increase of absolute pressure inside of reactor is measured in real time due to hydrogen generation as reaction product.
In this experiment, 2.5ml of pure water has been produced to react with 0.3g of liquid sodium. The amount of water is enough to react with all amount of sodium.

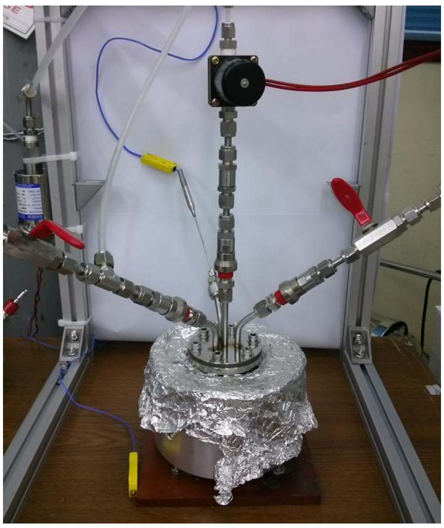


Fig. 4. The reactor covered by heater and measurement lines

3. Result

As shown in figure 5, the pressure initiated by hydrogen generation between bare sodium and sodium nano fluid present different tendency. Maximum pressure of bare sodium (blue points) is 2.21bar at 3.5 sec after reaction triggered, but 1.78bar at 4.9 sec in sodium nanofluid case (red points). The rate of pressure change in sodium nano fluid case is much slower than bare sodium case during initial reaction (1~5sec in figure 5).

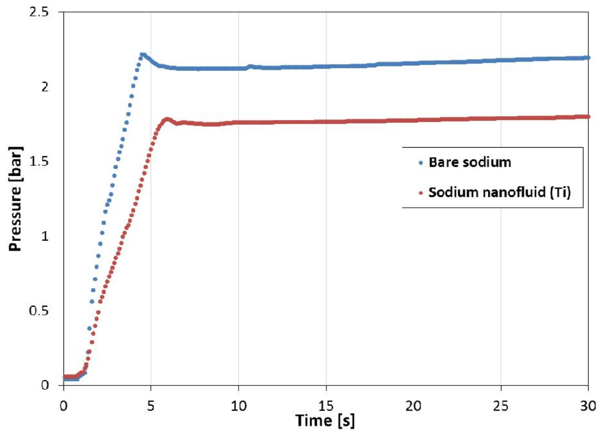


Fig. 5. Pressure change vs reaction time

4. Conclusions

Titanium nanoparticles are dispersed in liquid sodium and Ti NPs are well distributed among liquid sodium. Moreover, Ti NPs attract sodium atoms on the NP surface around by unknown forces. As a result, the rate of reaction between sodium and water is suppressed by addition of NPs. However, deep analysis of the interaction between sodium and the surface of NPs is required.

ACKNOWLEDEGEMENT

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