§5. Interaction of Microwave with Synthetic Type-A Zeolite Containing Water

Tanaka, M., Takayama, S.,
Sano, S. (AIST)

Tritium is a radioactive hydrogen isotope that decays to ^3He by emitting a beta particle with a maximum energy of 18.6 keV, and the half-life of tritium is 12.32 years. Therefore, this radioactive material must be handled in a multi-confinement system. However, if tritium is released into the atmosphere accidentally, it must be rapidly removed from the atmosphere. The most widely used atmospheric tritium removal technique is to oxidize the tritium to water with catalytic oxidation reactors, and adsorb the water. This conventional tritium removal system is used in tritium facilities worldwide. In order to reuse the adsorbent, it must be periodically regenerated to remove the water. The conventional regeneration method is the temperature swing regeneration (TSR) method, in which the adsorbent is exposed to dry air heated to more than 500 K. The adsorbent is then cooled with a cold gas stream. These processes are lengthy and require large amounts of energy. Furthermore, high-temperature processing also shortens the life of the adsorbent when it is repeated frequently. However, water is a polar solvent which absorbs microwave energy efficiently; therefore, microwave heating has been used for adsorbent regeneration. Some advantages of microwave heating compared to conventional heating are rapid internal heating, high energy efficiency, high temperatures, and selective heating according to the absorption characteristics. Therefore, we focused on the interaction of microwaves with honeycomb synthetic type A zeolite containing water and then tested the microwave irradiation to regenerate the zeolite at the maximum electronic field point in the single-mode cavity.

Figure 1 shows the microwave heating apparatus. It consisted of a magnetron microwave generator with WRJ-2 rectangular waveguide, a dual directional coupler with crystal mount, three stub tuner, an iris, a single-mode resonance cavity, and a short plunger. The maximum power and frequency of the microwave generator were1 kW and 2.46 GHz, respectively. The temperature and the weight of the sample were measured by three infrared radiometers and a load cell. The sample was suspended using a glass fiber at the maximum electric field point in the single-mode cavity. The absorbent sample was prepared from synthetic type-5A zeolite and a clay binder. The sample had an inner diameter of 20 mm, a length of 50 mm, and a honeycomb structure with cell density of 200 CPSI. The dry sample weight was about 10 g. The test samples were incubated at 30 °C overnight under an atmosphere with a relative humidity of approximately 80% and the absorption capacity of the sample was saturated.

Figure 2 shows the results of the microwave irradiation and water desorption in the single-mode resonance cavity system with a matched impedance of 2.46 GHz for the corresponding microwave generator frequency. The change in the sample weight was about 1 g and the regeneration process was complete after 600 s. The microwave energy was absorbed effectively by the adsorbed water. Because the temperature measured by the top infrared radiometer was much higher than for the other infrared radiometers, this indicated that the microwave energy was absorbed in the center of the sample. Under these experimental conditions, the power consumption had peaks at 60 and 140 °C. Similarly, the deviation of the load cell signal had three peaks at 70, 120, and 160 °C.

The temperature of the hydrated synthetic zeolite was increased by the microwave irradiation. The microwave energy was consumed by desorption of the water in the sample, which increased the temperature. The adsorbed water acted as a heating agent during the initial period of microwave heating. After the regeneration process was complete, the zeolite itself played a key role in the microwave heating. Thus, the microwave assisted temperature swing regeneration for the hydrated synthetic zeolite was achieved by the synergistic effect of thermal and microwave desorption. This shows that microwave irradiation is an efficient method for regenerating zeolite because the heating period is shortened and the hydrated zeolite absorbs the microwave energy through the adsorbed water.

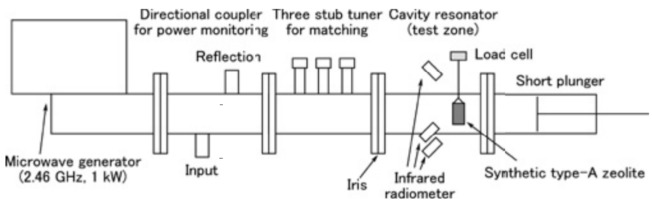

Fig. 1. Schematic diagram of the microwave heating apparatus.

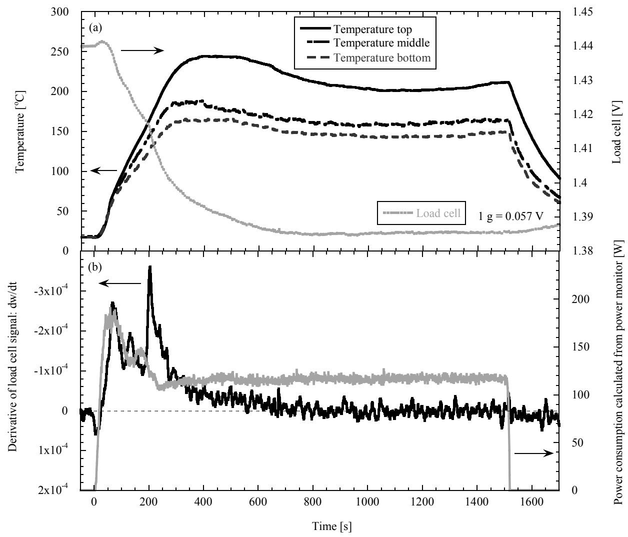

Fig. 2. The water desorption process in the single-mode resonance cavity system with a matched impedance at 2.46 GHz. (a) The change in the temperature and the load cell signal and (b) the power consumption calculated from the dual directional coupler and the derivative of the load cell signal.