Transactions of the Korean Nuclear Society Autumn Meeting
Yeosu, Korea, October 25-26, 2018

Study on Mechanism of Wettability Change from Hydrophilicity to Hydrophobicity Induced by Nuclear Reaction

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1. Introduction

Wettability is regarded as one of the most important properties because it is closely related to various phenomena such as lubrication, adhesion, cleaning, painting, printing, and so on [1]. Wettability is usually described by water contact angle (CA) on a material's surface. When the surface shows CA less than 90°, it is considered as hydrophilic, to which water can easily attached. On the other hand, if the surface exhibits CA higher than 90°, it is called as hydrophobic, to which water hardly adhere.

It has been revealed that the wettability is determined mainly by two factors, surface roughness and surface energy [2]. In the view point of the surface energy, if we produce amine ($-NH_2$) or carboxyl (-COOH) functional groups on a surface, the surface can become hydrophilic. In addition, hydrocarbon ($-CH_n$) or fluorocarbon ($-CF_n$) functional groups can make a surface hydrophobic. In previous work, we presented hydrophilic beryllium oxide (BeO) surface could be transformed to hydrophobic surface by high energy alpha particle irradiation [3]. However, the mechanism of wettability change was not fully proved and discussed.

Here, we measured the gamma spectra of samples irradiated with high energy charged particle beams, which are direct evidences that show what kind of isotopes are produced by nuclear reactions and following decays. In addition, the mechanism of wettability change from hydrophilicity to hydrophobicity was further discussed.

2. Methods and Results

2.1 Proposed Nuclear reactions

As mentioned above, hydrocarbon ($-CH_n$) or fluorocarbon ($-CF_n$) functional groups should be formed on a surface in order to induce the hydrophobicity. Therefore, several nuclear reactions which can produce carbon and fluorine atoms are suggested as listed below.

1) $^{9}Be(\alpha, n)^{12}C$
2) $^{10}B(\alpha, n)^{13}N \rightarrow {}^{13}C$
3) $^{14}N(p, 2n)^{13}O \rightarrow {}^{13}N \rightarrow {}^{13}C$
4) $^{16}O(\alpha, n)^{19}Ne \rightarrow {}^{19}F$

2.2 Target Materials

According to the proposed nuclear reactions, several materials containing Be, B, N, and O atoms were chosen as target materials for high energy charged particle beam irradiation. Because the high energy charged particle beam irradiation always causes the heating of target materials when the target materials are thicker than the penetration depth (range), high melting point of the material is preferred. In this experiment, ceramic materials including Al_2O_3, SiO_2, BeO, MgO, and BN as well as B, of which melting point is ranged from 1,600 to 3,000°C, were selected. One of them is shown in Fig. 1.

Fig. 1. Photo of BeO disk (diameter: 35 mm, thickness: 2 mm, Thermalox995^{TM}, Materion).

2.3 Irradiation Condition

For the nuclear reactions induced by high energy alpha particles, target materials were installed and then irradiated with an alpha particle beam generated from a cyclotron (MC-50, Scanditronix, Sweden) at Korea Institute of Radiological and Medical Sciences (KIRAMS). For the nuclear reactions induced by high energy proton, target materials were installed and then irradiated with a proton beam generated from RFT-30 cyclotron of Korea Atomic Energy Research Institute (KAERI) (Fig. 2).

Beam energy was controlled considering the cross-sections of desired and unwanted nuclear reactions. The irradiation process was carried out at room temperature in an ambient condition. Fluences of the alpha and proton beam irradiating the samples were varied in the range from 1.0×10^{13} to 1.0×10^{15} particles/cm^2.

Fig. 2. Photo of RFT-30 cyclotron.

2.4 Gamma spectra measurement

Using a high purity Ge (HPGe) detector (GEM20P4, ORTEC) and multichannel analyzer (MCA) system (ORTEC), the gamma spectra of irradiated samples were measured. Fig. 3 is the typical decay mode and gamma spectrum of ^{19}Ne [4].

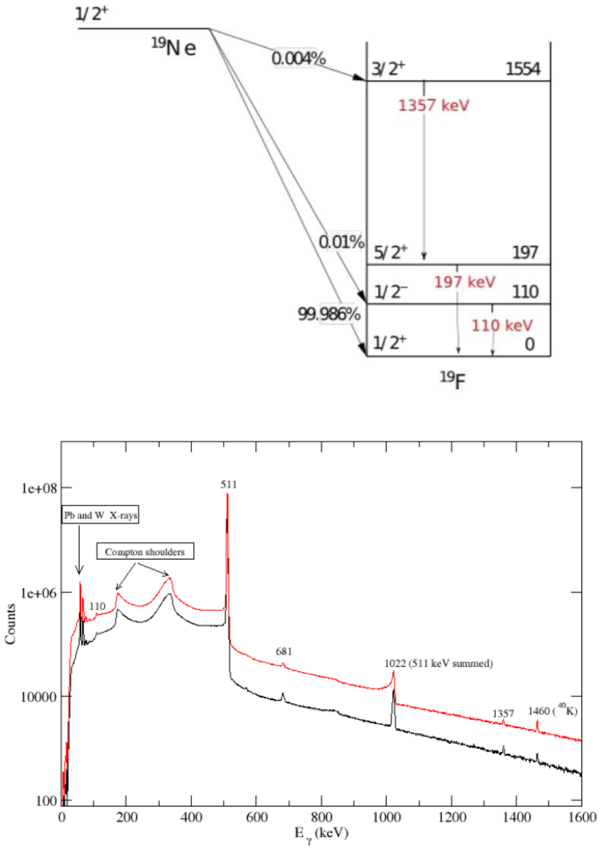

Fig. 4. Typical decay mode and gamma spectrum of ^{19}Ne [4].

3. Conclusions

In this research, we measured gamma spectra from alpha or proton irradiated samples. Gamma spectra revealed that carbon and fluorine atoms were produced after the irradiation and following decays. This measurement can be a direct evidence of the formation of carbon and fluorine which can form fluorocarbon functional groups on a surface and therefore induce the hydrophobicity.

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