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Wettability Conversion of Oxide Materials by High Energy Alpha Irradiation

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1. Introduction

When materials are irradiated by high-energy particles such as protons, alpha particles, and so on, nuclear reactions can be induced. In the case of alpha particle irradiation, those nuclear reactions usually happen near the surface of materials because of high linear energy transfer (LET) so that surface properties of materials can be changed.

Among various surface properties, wettability is regarded as one of the most important properties because it is closely related to various phenomena in people's daily lives 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 this research, we irradiated high-energy alpha particles onto oxide materials, which contains many oxygen atoms, and then examined their wettability. ^{19}F atoms were produced on the surface by $^{16}O(\alpha, n)^{19}Ne$ reaction and following β+ decay as well as by $^{16}O(\alpha, p)^{19}F$. These fluorine atoms resulted in the increase of oxide material's CA. In addition, color of surfaces could also be changed by the high-energy alpha irradiation.

2. Methods and Results

2.1 Target Materials

According to the proposed nuclear reactions, several oxide materials containing Oxygen atoms were chosen as targets for high energy alpha particle irradiation. Because the high energy charged particle irradiation usually causes the heating of target materials due to the energy deposition, high melting point of the material is preferred. In this experiment, aluminium oxide (Al_2O_3) and silicon oxide (SiO_2), of which melting point ranges from 1,700 to 2,000°C, were selected. One of them is shown in Fig. 1.

Fig. 1. Photo of a Al_2O_3 sheet (25 mm x 25 mm, thickness: 1.0 mm, Goodfellow).

2.2 Irradiation Condition

Target materials were installed and then irradiated with an alpha particle beam generated from a cyclotron (MC-50, Scanditronix) at Korea Institute of Radiological and Medical Sciences (KIRAMS). Beam energy was controlled considering the cross-sections of desired nuclear reactions (Fig 2). The irradiation process was carried out at room temperature in an ambient condition. Fluences of the alpha particle beam irradiating the samples were varied in the range from 1.0×10^{13} to 1.0×10^{15} α/cm^2.

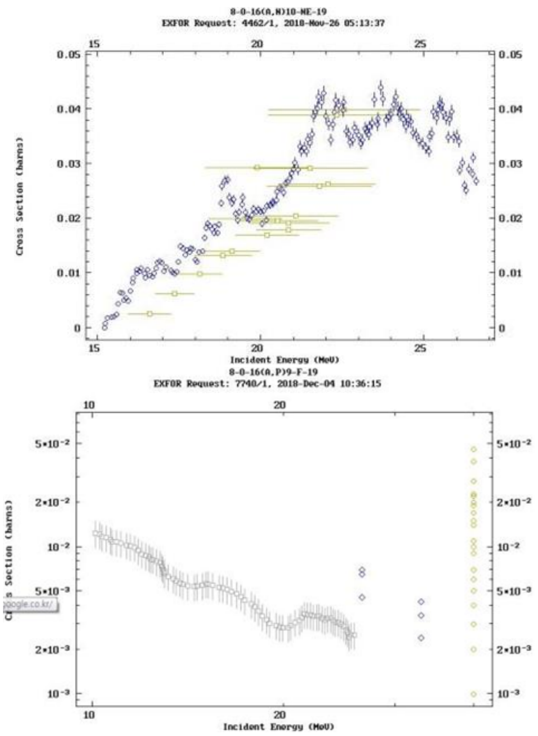

Fig. 2. Cross-section data of $^{16}O(\alpha, n)^{19}Ne$ and $^{16}O(\alpha, p)^{19}F$ nuclear reactions (from EXFOR library).

2.3 Wettability Change

Shapes of water droplets on the pristine and alpha-irradiated Al_2O_3 sheets are shown in Fig. 3. The surface of Al_2O_3 was originally hydrophilic with the CA of 37.3±1.2°. When it was alpha-irradiated with the fluence of 1 x 10^{14} cm^{-2}, the CA of the surface increased to 56.2±0.8°, but it was still hydrophilic. However, when the fluence was further increased to 1 x 10^{15} cm^{-2}, it finally became hydrophobic with the CA of 97.8±0.9°. Almost similar results were obtained in the case of SiO_2 surfaces.

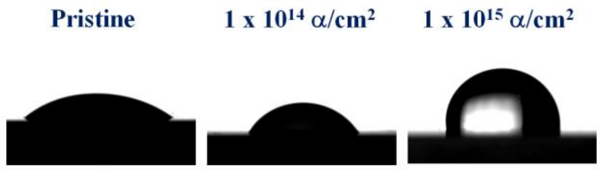

Fig. 3. Photo of water droplets on the pristine and alpha-irradiated Al_2O_3 sheets

2.4 Color Change

The alpha-irradiated Al_2O_3 surface exhibited orange color, while the pristine Al_2O_3 was originally white (Fig. 4). On the other hand, in the case of SiO_2, the surfaces showed almost no color change although they were alpha-irradiated with a fluence of up to 1 x 10^{15} cm^{-2}.

Fig. 4. Photo of an alpha-irradiated Al_2O_3 sheet

3. Conclusions

In this research, we performed the alpha irradiation of oxide materials in order to induce the wettability conversion via nuclear reactions. Hydrophilic surfaces of oxide materials could be transformed to hydrophobic surfaces by the alpha irradiation with sufficient fluence. We can conclude that the high-energy alpha irradiation is a novel method that can change the wettability and the color of oxide materials' surfaces simultaneously.

REFERENCES

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