Fabrication of Hydrophobic Surfaces from Hydrophilic BeO by Alpha-Irradiation-Induced Nuclear Transmutation

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1. Wettability

(1) Wetting: process of making contact between a solid and liquid
(adhesion, printing, cleaning, painting, lubrication......)

(2) Contact angle (CA)

If $\theta < 90^\circ$, the surface is hydrophilic. If $\theta > 90^\circ$, the surface is hydrophobic.

Introduction

※ Superhydrophobicity (θ ≥ 150°)

- Superhydrophobicity in nature

(3) Factors determining the wettability of a surface

1. Chemical composition

- Functional groups such as \( \text{NH}_2, \text{C}=\text{O}, \) and \( \text{OH} : \text{hydrophilic} \)
- Functional groups such as \( \text{CH}_x \) and \( \text{CF}_x : \text{hydrophobic} \)

2. Roughness

- Wenzel model *

\[
\cos \theta' = \frac{r(\gamma_L - \gamma_{SL})}{\gamma_L} = r \cos \theta
\]

\( r \) : surface roughness factor \( \geq 1 \)
\( \theta' \) : Contact angle of rough surface
\( \theta \) : Contact angle of flat surface

If \( \theta < 90^\circ \) (hydrophilic)
- \( \theta' < \theta \) (more hydrophilic)

If \( \theta > 90^\circ \) (hydrophobic)
- \( \theta' > \theta \) (more hydrophobic)

1. Materials

- Thermalox995™ (standard BeO), Materion
- diameter = 35 mm, thickness = 2 mm, BeO > 99.5%

2. Irradiation condition

- Alpha (α) particle beam generated from a cyclotron (MC-50, Scanditronix) installed at Korea Institute of Radiological & Medical Sciences (KIRAMS)
- Beam energy = ~25 MeV, average beam current = ~315 nA
- Fluence = 0, 5.97 x 10^{14}, 4.53 x 10^{15} cm^{-2}
Experimental

- Natural Abundance: $^9\text{Be}$ (100%), $^{16}\text{O}$ (99.757%)
- Main nuclear reactions probably induced by the alpha irradiation
  a) $^9\text{Be}(\alpha, n)^{12}\text{C}$
  b) $^{16}\text{O}(\alpha, n)^{19}\text{Ne} \rightarrow ^{19}\text{F}$ ($\beta^+$, $T_{1/2}=17.22$ s),

Results

1. CA

- Hydrophilic BeO surfaces could be converted to hydrophobic surfaces by sufficient alpha irradiation.
Results

2. Surface morphology

- Microstructure of BeO surfaces was not so much influenced by the alpha irradiation.
Results

Pristine

RMS roughness: $1.083 \pm 0.046 \mu m$

5.97 x 10^{14} \text{ cm}^{-2}

RMS roughness: $1.065 \pm 0.034 \mu m$

4.53 x 10^{15} \text{ cm}^{-2}

RMS roughness: $1.090 \pm 0.014 \mu m$
Results

3. XPS

<table>
<thead>
<tr>
<th></th>
<th>Be (At. %)</th>
<th>O (At. %)</th>
<th>C (At. %)</th>
<th>F (At. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pristine</td>
<td>43.12</td>
<td>48.43</td>
<td>8.45</td>
<td>0</td>
</tr>
<tr>
<td>$5.97 \times 10^{14}$ cm$^{-2}$</td>
<td>39.62</td>
<td>47.94</td>
<td>12.33</td>
<td>0.11</td>
</tr>
<tr>
<td>$4.53 \times 10^{15}$ cm$^{-2}$</td>
<td>35.86</td>
<td>47.51</td>
<td>16.36</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Intensity (a. u.)

Binding Energy (eV)

688.9 eV: CF$_2$ molecular bonds
Summary

1. A facile route to fabricate hydrophobic surfaces from hydrophilic BeO was presented on the base of the alpha irradiation.

2. When Be and O atoms were irradiated with alpha particle beam, C and F atoms were successfully created.

3. CF₂ functional groups, providing hydrophobic property, were formed by the combination of produced C and F atoms.

Thank you for attention!