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

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Introduction

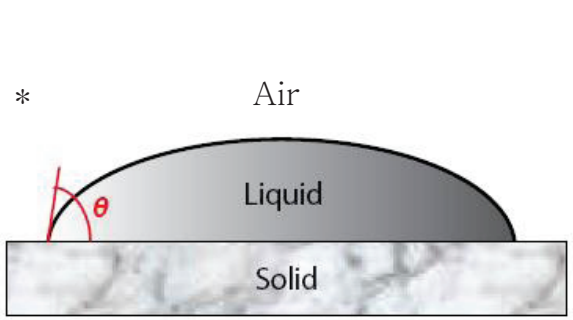
1. Wettability

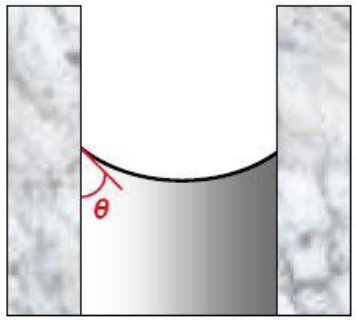
(1) Wetting : process of making contact between a solid and liquid

(adhesion, printing, cleaning, painting, lubrication.....)



(2) Contact angle (CA)





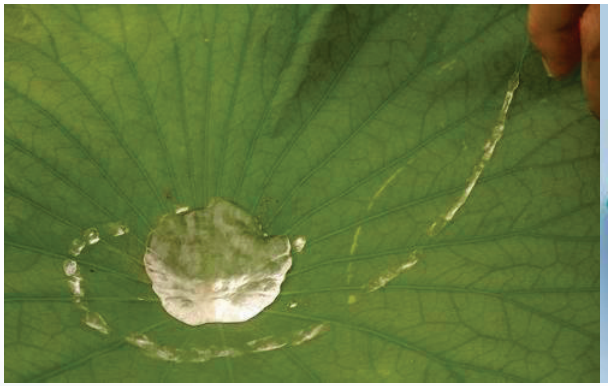
If $\theta < 90^{o}$, the surface is hydrophilic. If $\theta > 90^{o}$, the surface is hydrophobic.

* ***Annu. Rev. Mater. Res.* 2009, 39, 473.**

Introduction

※ Superhydrophobicity ($\theta \geq 150^{\circ}$)

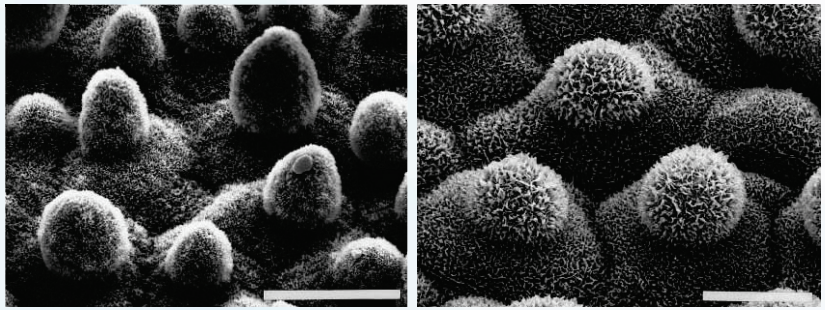
- Superhydrophobicity in nature



Lotus leaves

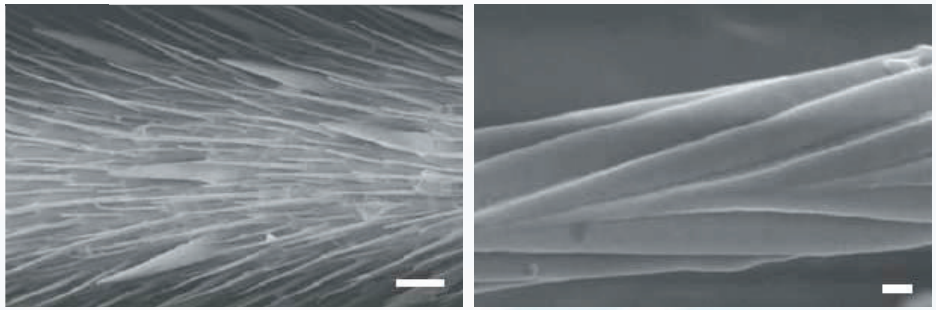
Legs of water strider

*



Scale bars are 20 μm.

**



Scale bars are 20 μm and 200 nm, respectively.

* ***Planta*** **1997, 202, 1.** ** ***Nature*** **2004, 432, 36.**

Introduction

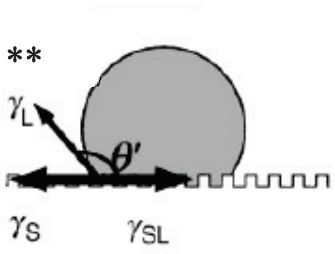
(3) Factors determining the wettability of a surface

① Chemical composition

- Functional groups such as NH_2, C=O, and OH : hydrophilic
- Functional groups such as CH_x and CF_x : hydrophobic

② Roughness

- Wenzel model *



$$\cos\theta' = \frac{r(\gamma_S - \gamma_{SL})}{\gamma_L} = r\cos\theta$$

$$r = \frac{\text{Real Surface area}}{\text{Apparent Surface area}}$$

If $\theta < 90^o$ (hydrophilic)
→ $\theta' < \theta$ (more hydrophilic)

If $\theta > 90^o$ (hydrophobic)
→ $\theta' > \theta$ (more hydrophobic)

r : surface roughness factor ≥ 1
θ′ : Contact angle of rough surface
θ : Contact angle of flat surface

* ***Ind. Eng. Chem.*** **1936, 28, 988.** ** ***Monatsh. Chem.*** **2001, 132, 31.**

Experimental

1. Materials

- Thermalox995^{TM} (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}

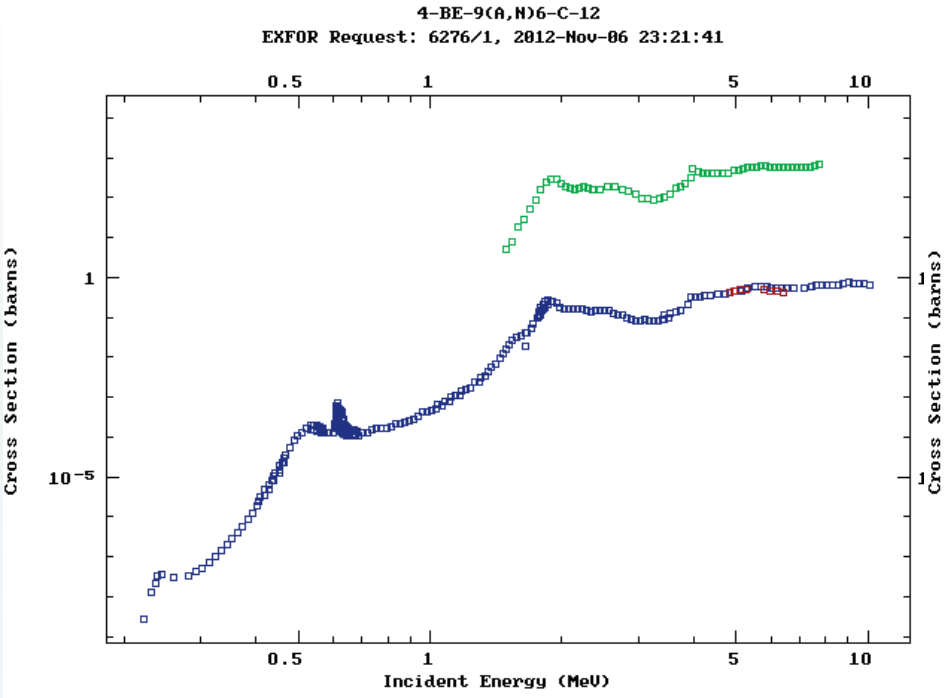
Experimental

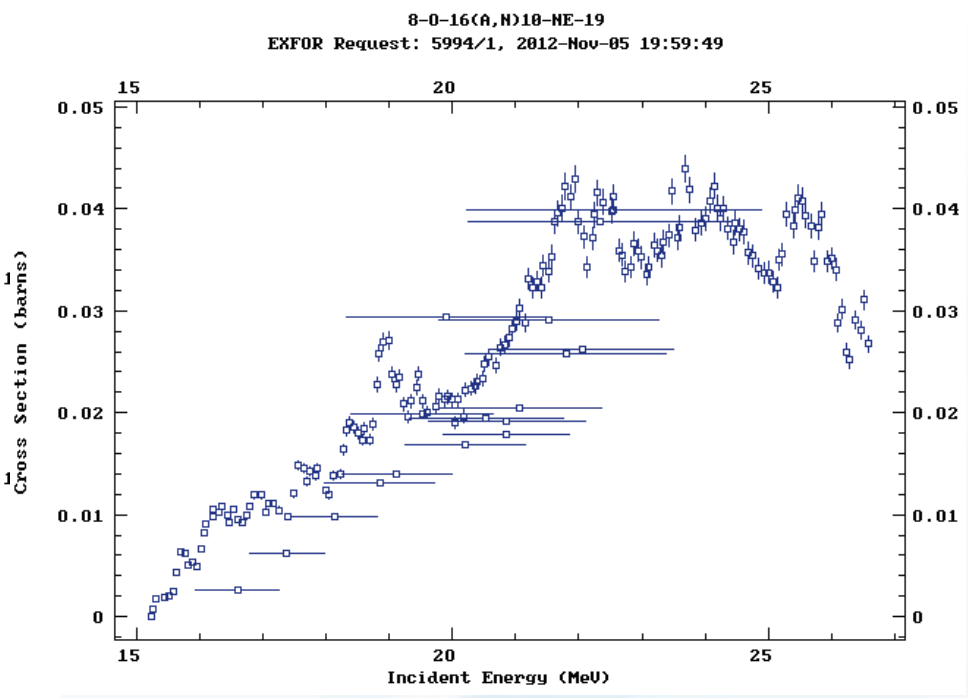
- Natural Abundance : ^{9}Be (100%), ^{16}O(99.757%)
- Main nuclear reactions probably induced by the alpha irradiation

  a) $^{9}Be(\alpha,n)^{12}C$

  b) $^{16}O(\alpha,n)^{19}Ne \rightarrow {}^{19}F$ ($\beta+$, $T_{1/2}$=17.22 s),

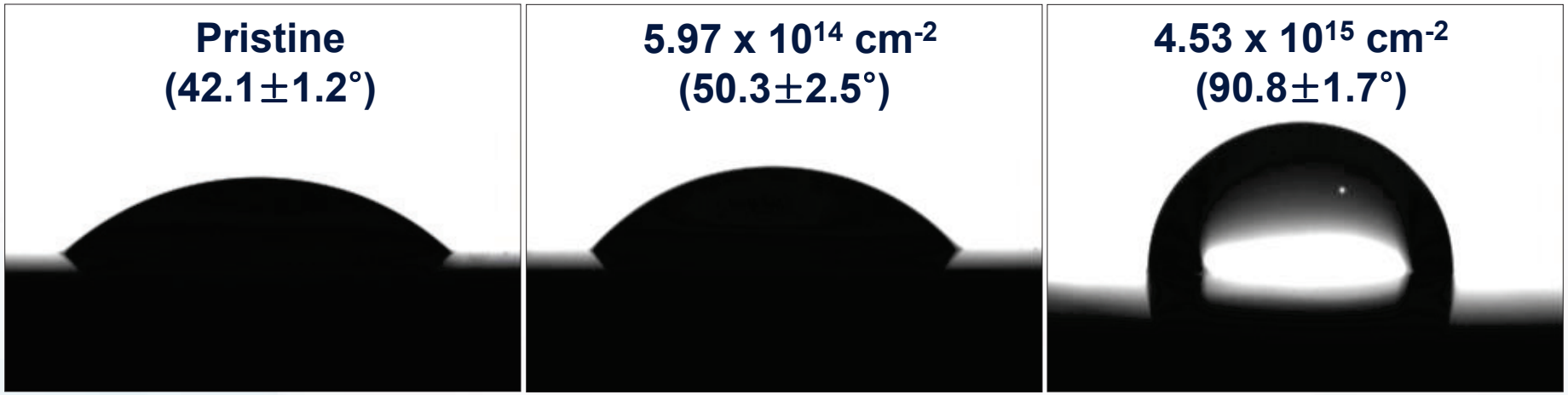
Cross-section data from EXFOR (http://www.nndc.bnl.gov/nndc/exfor)





Results

1. CA

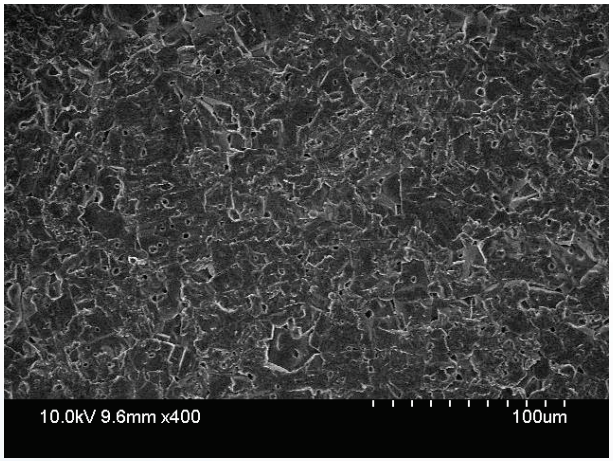
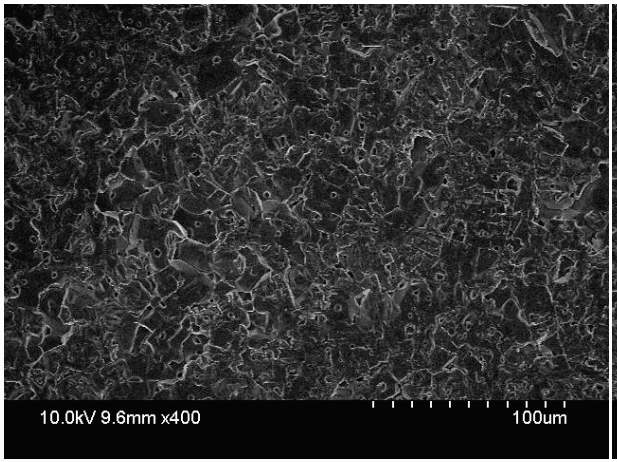
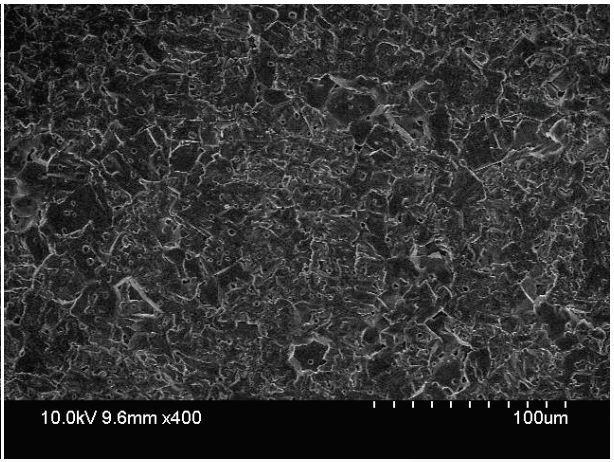
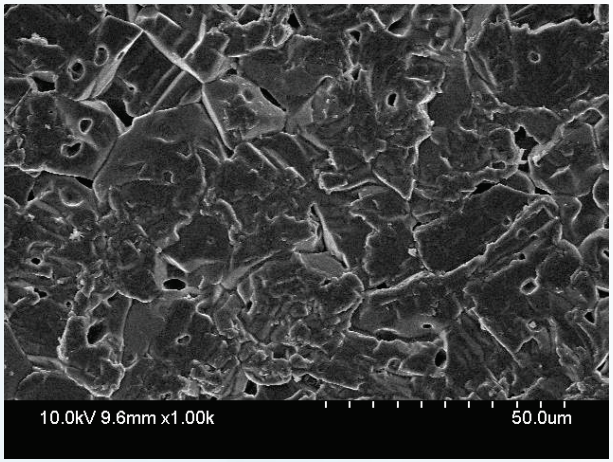
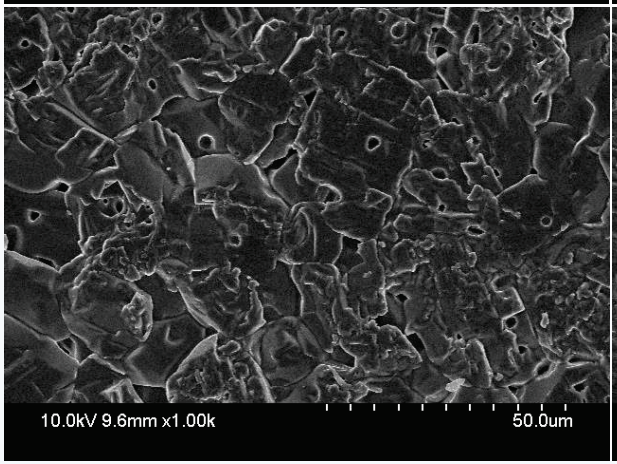
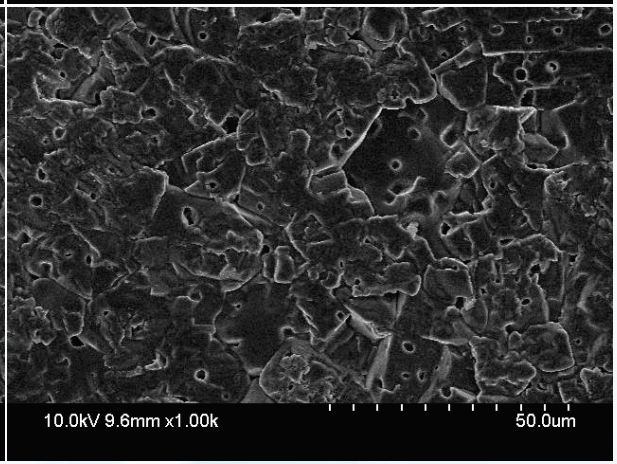


hydrophilic hydrophilic hydrophobic

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

Results

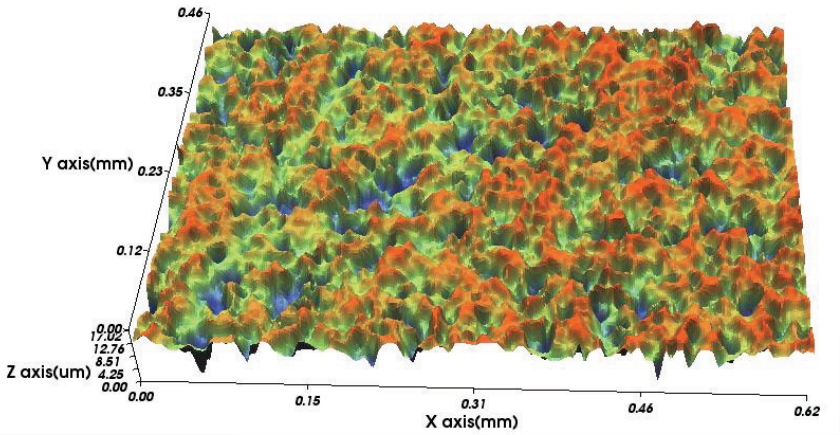
2. Surface morphology

Pristine	5.97 x 10^{14} cm^{-2}	4.53 x 10^{15} cm^{-2}
		
		

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

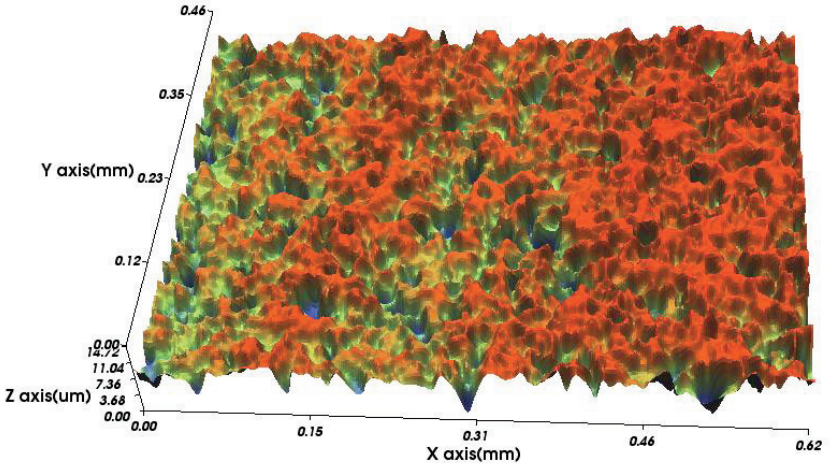
Results

Pristine



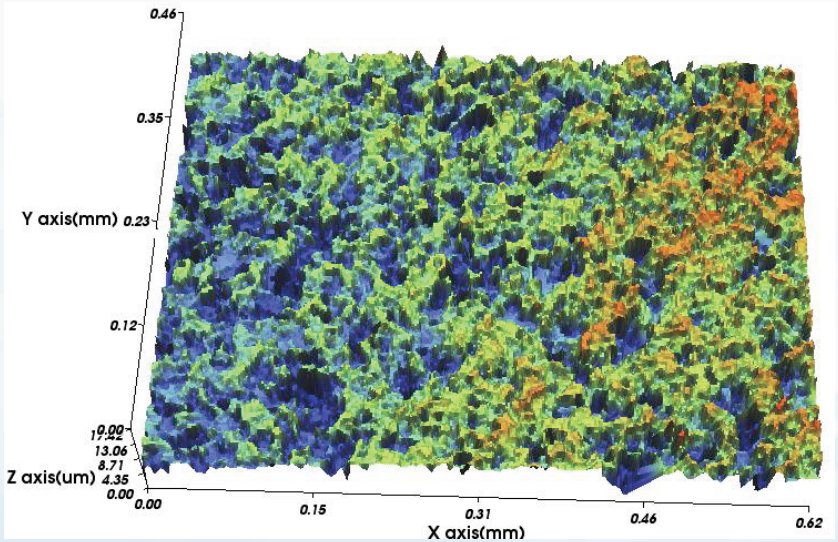
RMS roughness: 1.083±0.046 μm

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



RMS roughness: 1.065±0.034 μm

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



RMS roughness: 1.090±0.014 μm

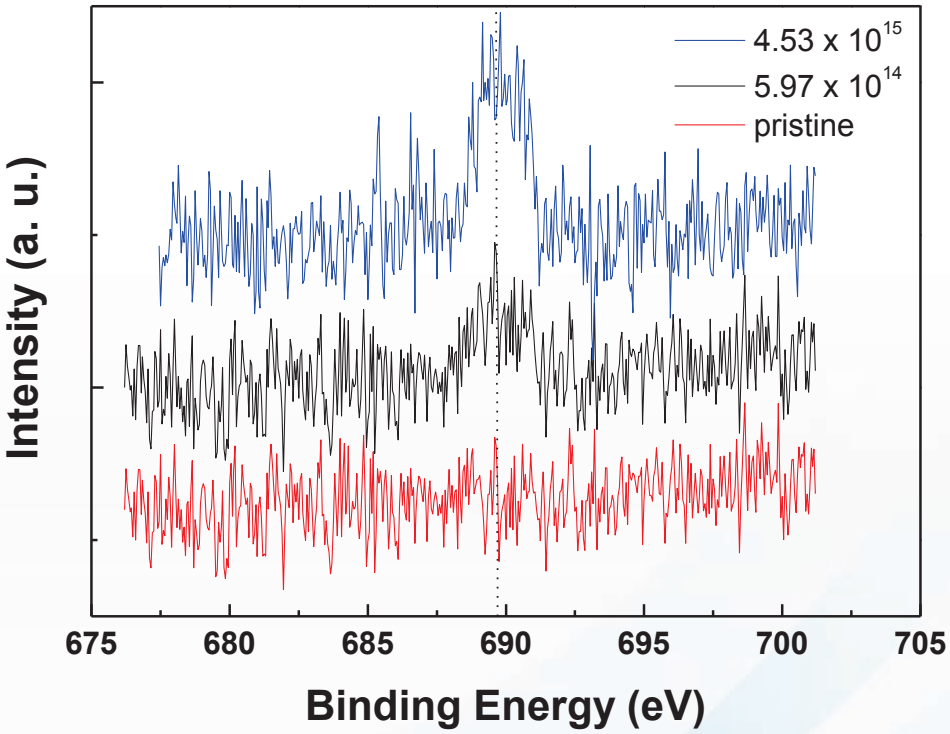
Results

3. XPS

	Be (At. %)	O (At. %)	C (At. %)	F (At. %)
Pristine	43.12	48.43	8.45	0
5.97 x 10^{14} cm^{-2}	39.62	47.94	12.33	0.11
4.53 x 10^{15} cm^{-2}	35.86	47.51	16.36	0.27

decreased

increased



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. CF_2 functional groups, providing hydrophobic property, were formed by the combination of produced C and F atoms.

Thank you for attention!