Property of In-vacuum Direct Photo-etching of PTFE Brought by High Energy Synchrotron Radiation Irradiation

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Poly-tetrafluoroethylene (PTFE) is very attractive material for various fields, because of its chemical resistance and hydrophobic property, etc. However, it is difficult to fabricate PTFE microstructures with conventional techniques such as semiconductor process or micro machining. We had succeed in the fabrication of high-aspect-ratio micro fluidics parts of PTFE by direct in-vacuum photo-etching using synchrotron radiation (SR) with energy from 2 to 12keV.[1)] As shown in Fig 1, fabrication accuracy of the high-aspect-ratio structure was confirmed to be submicron level or less. It is known that SR induces the scission of polymer chain of plastics due to inner shell and valence electron photo excitation[2)]. The decomposed photochemical products generated by high energy x-rays of SR continually desorb from surface of the substrate, which leads to the etching of PTFE, while there induced recombination of radials in the bulk. It has been known that CF_x ions are the dominant decomposed species of SR irradiated PTFE from mass spectrometry (MS) investigation[3)]. We found the stoichiometry of PTFE is maintained even after the exposure as shown by the result of x-ray photoelectron spectroscopy in Fig 2, even though photodesorption involve the absence of fluorine to produce CF_X. Next notable property is that the roughness of PTFE surface is greatly decreased by SR irradiation at the elevated temperature above 150℃ as shown in Fig 3 and Table 1. The origin of these phenomena were investigated in this work. We considered that the melting point of PTFE during SR irradiation becomes lower than normal (327^{o}C) due to continual photo-fragmentation in the deep PTFE bulk induced by high energy x-rays, and this leads to the liquescence of the solid PTFE. The liquefied PTFE flows into pore textures of the bulk and only irradiated part of material is continuously etched specifically. It is speculated highly decomposed photoproducts such as CF, CF_2 will be generated due to inner shell excitation, which leads to the stoichiometry sustainment and achievement of remarkable high aspect ratio of etching above 200, which confirmed for the first time by using the high energy x-rays of SR.

Reference

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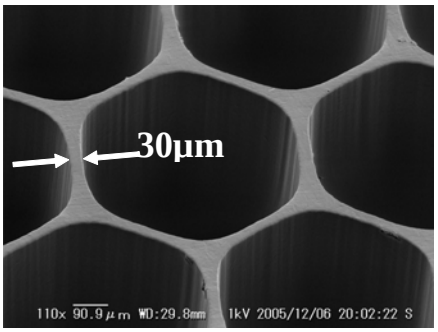

Fig 1 The high-aspect-ratio structure of PTFE

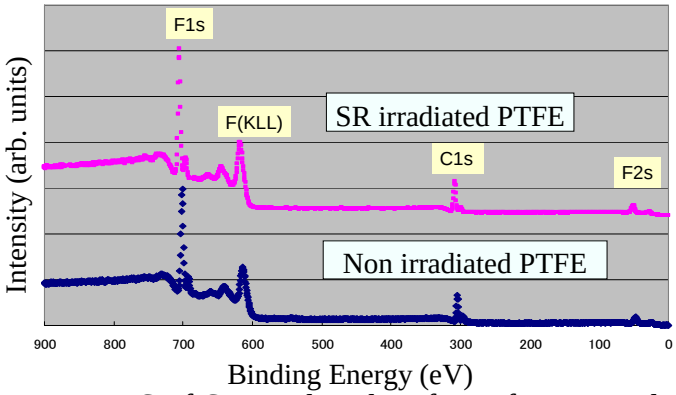

Fig 2 XPS of SR irradiated surface of PTFE and Non irradiated surface

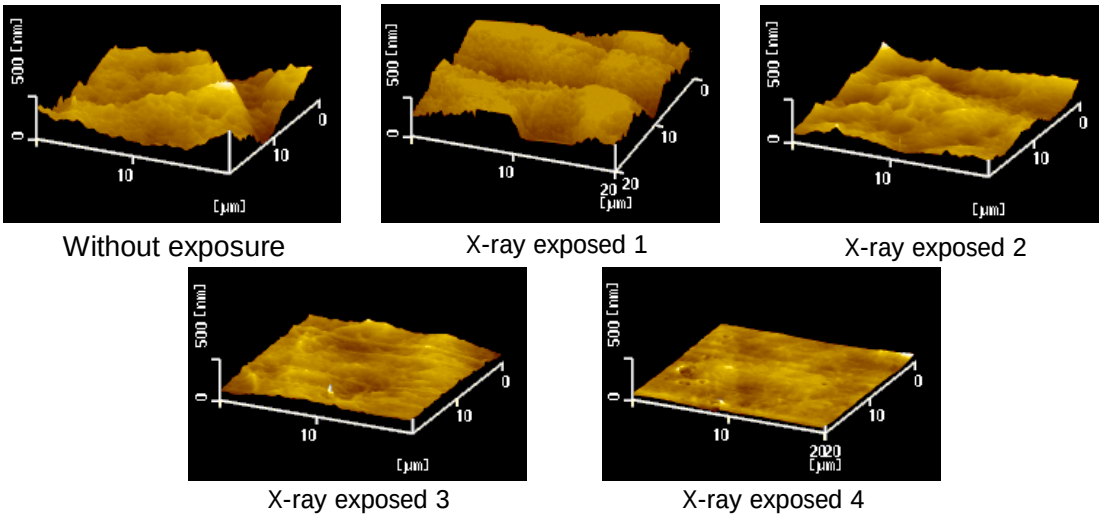

Fig 3 AFM measurement of irradiated PTFE surface

	Substrate temperature	Dose(mA・hr)	RA(nm)
Without exposure	Room temperature	0k	93.52
X-ray exposed 1	45℃	200k	64.67
X-ray exposed 2	104℃	200k	39.08
X-ray exposed 3	149℃	200k	21.75
X-ray exposed 4	200℃	200k	5.63

Table 1 The roughness of irradiated PTFE surface that changed with substrate temperature at x-ray irradiation of the same dose