

## The Research on Swelling Phenomena of PMMA with X-ray Lithography

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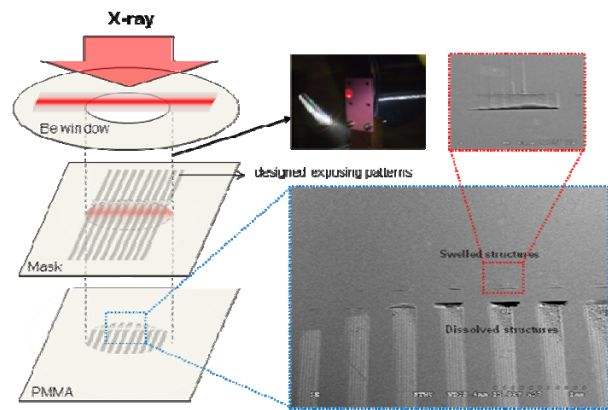
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The swelling phenomena of irradiated PMMA during development process have been discovered and investigated. PMMA has been widely used as a positive resist in deep x-ray lithography and it will be dissolved in GG developer with the irradiated dosage higher than the threshold dose. It is considered that GG developer becomes ineffectual to PMMA when the dosage is less than  $0.2 \text{ kJ/cm}^2$ . However, we find that PMMA swells in irradiated positions during long time development and some raising structures are generated. In this report, the behavior of PMMA swelling is observed including the swelling rate and the shapes of swelled structures. Moreover, by properly arranging the exposed dosages and the irradiated positions of PMMA, different kinds of interesting structures can be manufactured.

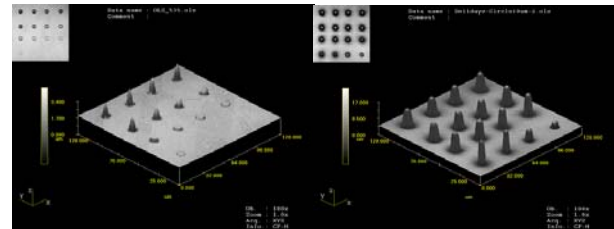
Figure 1 shows the setup of the experiment we discover the projecting structures accidentally in x-ray lithography with PMMA. The scanning device of beamline broke down so that we was forced to expose the PMMA sheet to a fixed Gaussian X-ray beam. Because of the Gaussian distribution of beam intensity, the dosages in the edge of exposure area would be deficient, and the GG developer could not take effect theoretically. However, the swelling structures were discovered from SEM photographs and were confirmed by confocal microscopic images and  $\alpha$ -step surface profiler.

For further understanding of the swelling rate, the PMMA sheets are arranged to the irradiation by  $10\mu\text{m}$  square mask patterns with exposure times from 0.62 to 18.6 seconds on indicated locations, and are developed for 1 day to 15 days. The result is shown in Fig. 2. It shows OLS3000 confocal microscopic photographs of swelling structures during different developing time and the relation between swelling height and exposure times under specific developing time.

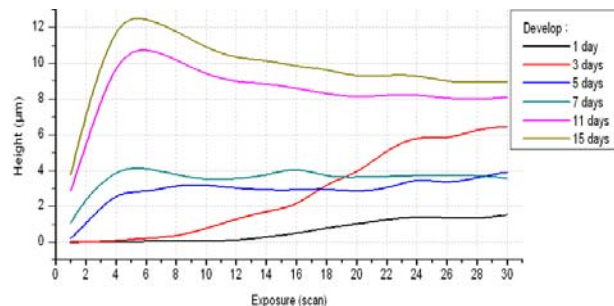
**Fig. 1:** The setup of the experiment we discover swelling phenomena of PMMA. The beam is Gaussian distribution and consequently irradiate lacking dosages to the edge of exposure area. The swelling structures are discovered from SEM photographs.



**Fig. 2:** (a) OLS3000 confocal microscopic photographs of swelling structures during 1 day & 11 days development. (b) The relation between swelling height and exposure times under specific developing time



(a)



(b)