Sub 100 nm Pattern Fabrication Using Plasma Grafted Styrene Resist and E-Beam or Synchrotron Radiation Excited Etching

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There are several efforts to fabricate a fine pattern smaller than 100 nm. In this work, conventional lithography processes with using a resist and etching are applied for the fine pattern fabrication and studied about the possibilities. As proposed processes, plasma grafted styrene was used as a plasma etching resistive resist and plasma excited by electron-beam (e-beam) or synchrotron radiation was used for the plasma etching as a plasma with low ion energy. These processes of resist synthesis and plasma etching were developed by ourselves\(^1\)-\(^3\) and improved to realize the sub 100 nm pattern fabrication.

Plasma grafted polymerization was performed by a plug flow reactor with a parallel plate electrode and a pulsed 13.56 MHz power source.

The e-beam excited plasma etching was realized by solving problems of polyimide interface abrasion during the e-beam transmission. For 1 µm polyimide interface film, the abrasion by the electron transmission was significant at a few kV. To minimize the abrasion in this experiment, the acceleration voltage was set at 10 kV and the substrate was located at 4.5 cm from the interface film. The stable etching of Si wafer was realized at a negative bias condition in CF\(_4\).

The synchrotron radiation excited plasma etching was also realized at a negative bias condition using UVSOR-BL8A beam line at Institute of Molecular Science, Okazaki, Japan, where the electron energy and current were 750 MeV and 200-100 mA.

Plasma grafted styrene was formed at a gas pressure of 0.5 Torr and a discharge power of 10 W for the pulsed 13.56 MHz plasma of ON:OFF ratio of 0.1 sec:0.9 sec. After 1000 pulses, about 60 nm resist thickness on Si wafer was obtained. 50 nm L&S and 25 nm Line and 75 nm Space were delineated at 50 kV and 1 nA by an electron-beam patterning machine (JEOL, JBX-6000SG). The patterns were developed for 1 sec by hexane. The delineated patterns were developed successfully as shown in Fig. 1.

The e-beam excited plasma etching was stable at 50-100 mTorr of CF\(_4\). The etching of Si wafer through the developed resist patterns were performed at a bias voltage of -400 V as shown in Fig. 2. The delineated pattern structure was not developed clearly but the patterns were resolved without losing resist patterns.

The synchrotron radiation excited plasma etching was performed at 0.13 Torr. Effect of bias voltage on the etched patterns was studied. With decreasing the bias voltage, pattern resolution was improved.

Sub 100 nm pattern with using plasma grafted styrene and plasma etching excited by e-beam and synchrotron radiation was successfully performed. These processes suggested more fine pattern will be fabricated with decreasing the resist thickness.
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References