

Lithographic Effect of Synchrotron Irradiation on the DNQ/Novolak Type Photoresist

Hsiung-Min Lin (林勳銘)^{1,2}, Fu-Hsiang Ko (柯富祥)^{1,2}, and Bor-Yuan Shew (許博淵)³

¹Institute of Nanotechnology, National Chiao Tung University, Hsinchu, Taiwan

²Degree Program of Semiconductor Material and Processing Equipment, National Chiao Tung University, Hsinchu, Taiwan

³National Synchrotron Radiation Research Center, Hsinchu, Taiwan

A zwitter-resist is a resist with positive tone and negative tone depended on the applied doses. We have previously studied the pattern formation mechanism of ArF resist by the electron beam irradiation [1]. However, the I-line photoresist has not been reported to exhibit the performance of zwitter-resist property under synchrotron radiation source. In this study, we prepare the resist with combined high and low molecular weight, and use the synchrotron radiation source ($\sim 1\text{nm}$ wavelength) to study the characteristic of diazonaphthoquinone (DNQ)/Novolak photoresist.

The contrast curves of the Novolak polymer and DNQ/Novolak resist by synchrotron radiation are illustrated in Fig. 1a. The resist with only Novolak polymer behaves negative tone under synchrotron radiation. Interestingly, the DNQ/Novolak resist can exhibit both the positive and negative tones. This observation indicates the resist without DNQ losses its usual positive tone characteristic. Hence, the synchrotron radiation only induces the cross-linkage reaction. For the case of DNA/Novolak, the reaction of DNQ in the resist plays an important contribution on positive tone as the dosage less than $800\text{mA}\cdot\text{min}/\text{cm}^2$, while the cross-linkage reaction of Novolak polymer becomes dominance at the dosage ranging from $800\text{mA}\cdot\text{min}/\text{cm}^2$ to $3000\text{mA}\cdot\text{min}/\text{cm}^2$. It was the same trend as traditional positive-tone resist in the first state; the thickness was decreased with increasing beam exposure energy. Photoresist can be totally dissolved by 2.38% Tetramethyl-ammonium hydroxide (TMAH) as the exposure energy higher than the threshold dose ($500\text{--}1200\text{mA}\cdot\text{min}/\text{cm}^2$). When the irradiated energy was elevated than $1200\text{mA}\cdot\text{min}/\text{cm}^2$, the thickness increased with exposure energy increase. Photoresist was gradually harder to be dissolved, and eventually resist film can not be dissolved by TMAH. Similarly, the N-Methyl Pyrrolidone (NMP) developer also demonstrates the same trend. The UV-vis measurement was conducted for the resist coated onto quartz wafer. In Fig. 1b, the resist film without any synchrotron beam irradiation has the highest absorption property for the light wavelength in $330\text{--}450\text{nm}$. However, the resist film is bleach under synchrotron irradiation and lowers the absorption. The bleaching effect is gradually increased as elevating the dosage from 200 to $2500\text{mA}\cdot\text{min}/\text{cm}^2$. The thermal stability of two types of photoresist is determined by their SEM morphology. The SEM for the resist prepared by high/medium/low molecule weight of Novolak polymer exhibits the thermal stability up to 120°C , while the resist prepared by high/low molecule weight of Novolak polymer in Fig. 2 shows a higher thermal stability up to

125°C . This observation suggests the resist polymer after separating the medium molecule weight polymer having superior thermal stability on the formation pattern. The zwitter-resist exhibits both the positive and negative tones under different applied dosages. We use the specific character to fabricate the patterns for the same resist film. Figure 3 demonstrates the capability of the same resist on achieving the trench, hole and line patterns. The detailed characterization of the prepared zwitter-resist will be given in this conference.

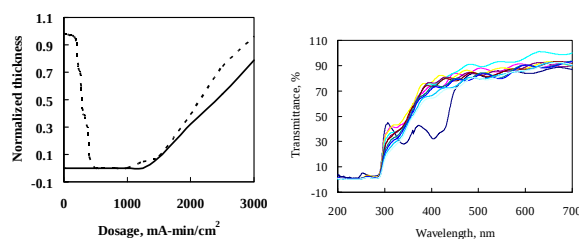


Figure 1. a. Contrast curve of Novolak polymer (solid line) and DNQ/Novolak resist (dash line) under various synchrotron irradiation doses. The developer is TMAH. Figure 1b. Transmittance of the DNQ/Novolak resist films under various synchrotron irradiation doses.

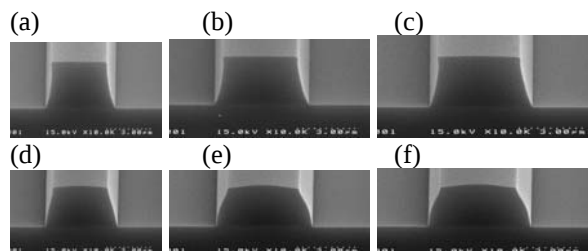


Figure 2. Thermal stability of the resist pattern with combined high/low molecular weight polymer, and 90 sec thermal treatment under (a) 110, (b) 115, (c) 120, (d) 125, (e) 130, and (f) 135°C .

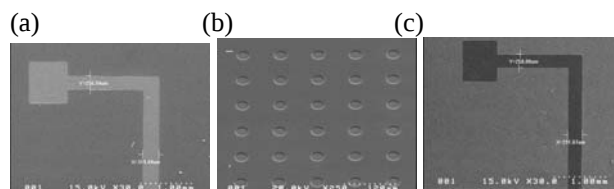


Figure 3. SEM images of the zwitter-resist with combined high/low molecular weight polymer under synchrotron beam fabrication at positive tone (TMAH development) of (a) trench pattern and (b) hole pattern, and negative tone of (c) line pattern (NMP development).