Ultrasensitive Non-Chemically Amplified Negative-Tone Electron Beam Lithography Resist

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Abstract

Electron-beam lithography[1] (EBL) is a well-known and powerful technique for top-down nanofabrication approaches[2]. However, EBL has some disadvantages for mass production like a low processing speed. Highly sensitive EBL resists are therefore desirable as they reduce the writing time considerably.

We have developed and characterized a new negative-tone EBL resist with an extremely high sensitivity. The resist is based on the dual copolymer mixture poly(2-hydroxyethyl methacrylate-*co*-2-methacrylamidoethyl methacrylate) (poly(HEMA-*co*-MAAEMA)) and has been synthesized using free radical polymerization of 2-hydroxyethyl methacrylate and 2-aminoethyl methacrylate (9:1 monomer feed ratio) with further methacryloylation of the amine side-chain groups.

The poly(HEMA-*co*-MAAEMA) resist exhibits a crosslinking threshold dose as low as 0.5 $\mu C/cm^2$ (Fig. 1), which is one order of magnitude smaller than those of commercially-available EBL negative resists. Unlike the latter, the high sensitivity of our copolymer mixture does not arise from a chemical amplification process induced by a photoacid generator, but caused by the presence of a large proportion of double bonds (~10%) into the resist composition, which increases the probability of electron-induced bond breakage significantly.

The copolymer mixture has been analyzed by ^1H NMR (Fig. 2). In addition, exposed and non-exposed resist films have been characterized by X-ray Photoelectron Spectroscopy (XPS) and Raman Spectroscopy to study the polymerized species.

Our resist possesses a contrast value as low as 1.2 (Fig. 1), making it particularly suitable for achieving grey (3D) lithography[3], and a half-pitch resolution of 100 nm. Dual-tone behaviour occurs at high electronic doses; in particular, the polymeric resist becomes positive for doses in the range of 5 – 10 mC/cm^2.

Exposed resist patterns show good adherence to silicon substrates without the assistance of adhesion promoters or thermal treatments, and have been shown to be adequate for use as a mask for both wet ($HF+HNO_3+AcOH$ solution) and dry (SiF_6-based Reactive Ion Etching) etching of Si.

The presented resist is highly transparent in the visible, which, along with its aforementioned 3D fabrication capability, makes it suitable as a structural material for the implementation of micro- and nano-optical components, such as microlenses (see Fig. 3).

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References

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Figures

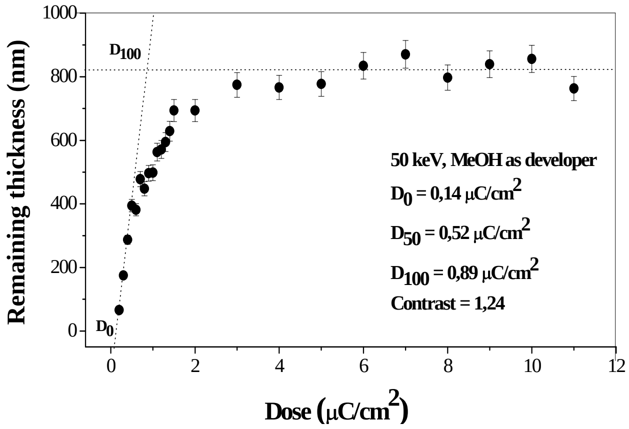

Fig. 1. Contrast curve for the poly(HEMA-*co*-MAAEMA) resist exposed at 50 keV and developed by methanol at room temperature.

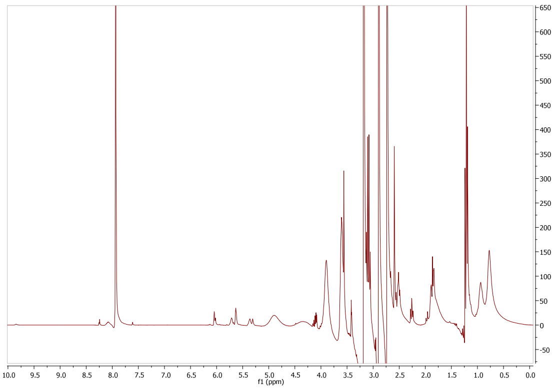

Fig. 2. . ^{1}H NMR spectra of the poly(HEMA-*co*-MAAEMA) copolymer.

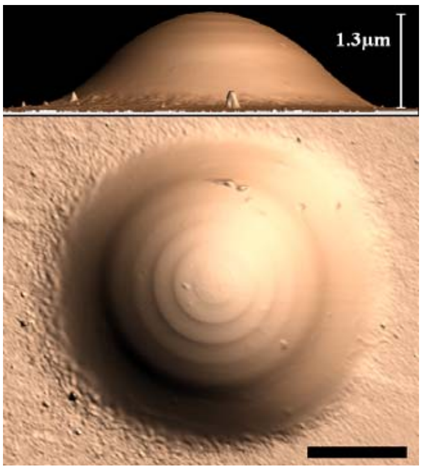

Fig. 3. poly(HEMA-*co*-MAAEMA) resist dome fabricated by exposing concentric circles with gradual doses from 0.5 to 50 μC/cm2. Dome height: 1.3 μm. Horizontal scale bar equals 10 μm.