Novel Resist for Electron Beam Lithography on Insulating Substrates

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Electron beam lithography (EBL) has the capability for extremely high-resolution patterning, and is used for mask making, low-volume high-value manufacturing, prototyping and other nanotechnology research. In EBL electrons are used for patterning, and it is general necessary to use conductive substrates. However, if the substrate is an insulator (e.g. glass), or made with poorly conducting materials (e.g. GaN) patterns become distorted and misaligned due to the buildup of charge in the substrate. Traditionally this issue has been treated by using a conductive discharge layer under or over the resist or an organic conductor mixed into the resist[1].

Due to increased process complexity and poor resolution with such approaches, we are developing an electron beam resist which is inherently conductive. Previously we have demonstrated an epoxy derivative of triphenylene, which is highly sensitive and capable of patterning below 20 nm feature sizes[2]. Triphenylene derivatives are well known as excellent photoconductors[3], and due to their hexagonal columnar discotic liquid crystal structure [4]they show fast hole mobility (e.g. 10^{-3} $cm^2V^{-1}s^{-1}$) [5]along the columns. Therefore this project aims to develop a triphenylene derivative with good lithographic properties, that also out as an electron dissipation layer.

Initial experiments with 2,3,5,6,10,11-hexapentyloxy-triphenylene have been performed. The material forms good quality films by spin coating on glass and silicon substrates. The sensitivity of the non-chemically amplified material is ~4 $mC/cm^2$and a resolution of 12 nm isolated and 20 nm half-pitch on silicon is achieved as shown in figures 1(a) and (b) respectively.50 nm half-pitch was achieved on glass with an exposure dose of 4.7mC/cm^2in a variant of the material as shown in figure 2 (a). For comparison PMMA was exposed on glassat 345 $\mu C/cm^2$dose with 400 nm pitch as shown in figure 2(b). The exposed trench width was ~140 nm (target 100 nm). Smaller pitches and lower doses did not expose properly. The samples have been coated with gold after development to allow imaging in the SEM. Finally a chemically amplified variant was patterned on a glass substrate. Lines with a CD of 55 nm were achieved on a pitch of 150 nm using a dose of 50 $\mu C/cm^2$,as shown in figure 3. Some low frequency line wiggle is seen, most likely due to swelling of the resist during development. Further work will focus on optimizing process conditions to maximize resolution and minimize swelling.

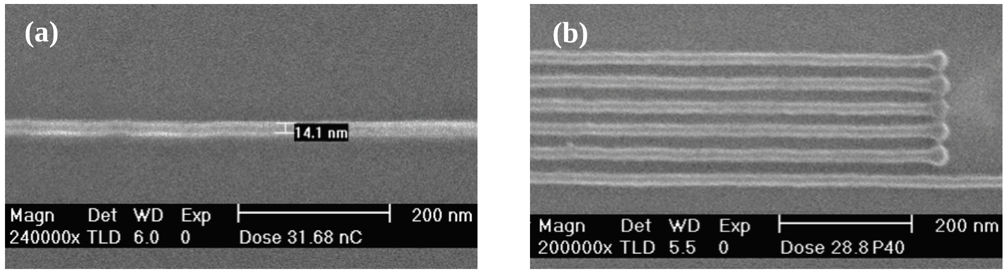

Figure 1: Pure triphenylene patternson Silicon: (a) 14 nm line on a 28 nm thick film at 31.6 nC/cm dose and (b) is 40 nm dense pitch with 28.8 nC/cm dose.

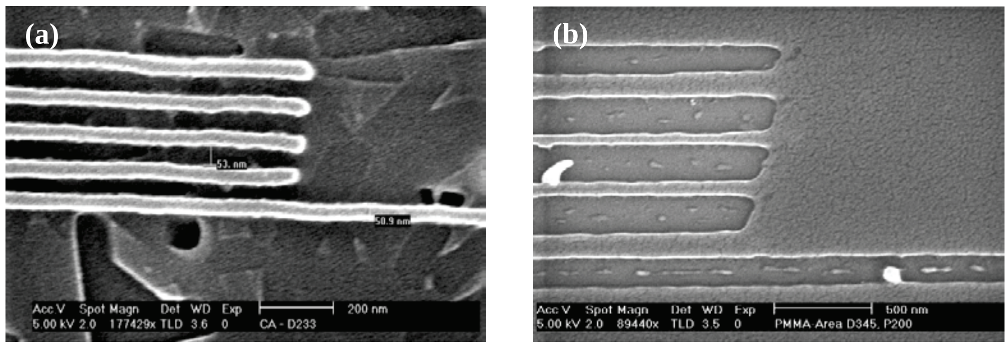

Figure2: (a)50 nm lines on 100 nm pitch in 82 nm thick triphenylene resist coated on glass and exposed at 4.7 mC/cm^2, and (b) ~140 nm lines (target 100 nm) on 200 nm pitch in 98 nm thick PMMA on glass, exposed at 345 µC/cm^2. Samples have been coated in gold for imaging.

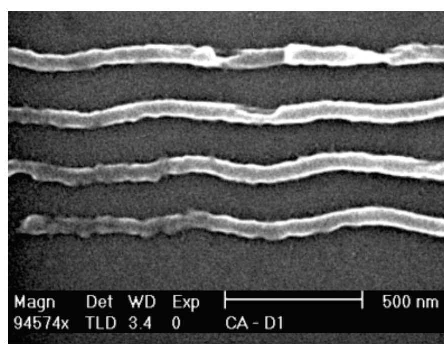

Figure 3:55 nm lines on a pitch of 150 nm exposed at 50 µC/cm^2 on glass.The sample has been coated in gold for imaging

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