Chemically Amplified Photoresists with Precise Molecular Structure

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Primary CNF Tools Used: ASML 300C DUV Stepper, AFM Bruker Icon, JEOL 6300 E-Beam, Woollam RC2, Zeiss Ultra SEM, YES HMDS Prime Oven

Abstract:

In most synthetic copolymers, monomer units are distributed randomly along the polymer chain. In sequence-controlled polymers such as peptides and peptoids, however, monomers are arranged in a specific, application-optimized order. Polypeptoids are thus attractive as a new category of photoresists for EUV lithography, as full control over the placement of individual functional groups yields in tunable properties with extremely low chemical, structural, and molar mass variability [1-3]. This report demonstrates the potential use of peptoids CAR resist using an electron-beam and deep-UV (DUV) lithography obtaining 36 nm line pattern.

Introduction:

Polymeric resists are typically based on random copolymers. These polymers are polydisperse and relatively large in size, with molar masses ranging from 5,000-15,000 g/mol [1]. Characteristics such as these can have a negative impact on resist performance, and therefore it is necessary to explore other architectures for new resist platforms. As a result, there has been research on using molecular glasses as photoresists due to their defined, repeatable structure, and low molecular weight compared to conventional polymeric photoresists. Like molecular glass, peptoids can be synthesized with a controlled sequence and chain length. Due to these properties, it is hypothesized that using peptoids as photoresist material may be the next promising path towards smaller feature sizes.

The goal of this project is to investigate and optimize the composition and sequence of the synthesized short peptoids to obtain resist with high resolution and good processibility, as the precise sequence of moieties is key to tuning the nano- and macro-scale characteristics of the resulting resists.

Results:

Peptoids with 10 repeat units were synthesized using a solid phase peptoid synthesis approach [3]. After activating the resin with bromoacetic acid for 30 min the first amine solution was added and the reaction was completed after 60 min. These steps were repeated until a peptoid with a total length of ten amines with a defined sequence was obtained, see Figure 1. Subsequently, the peptoid was cleaved from the resin under mild acetic conditions, purified and dried. Di-tert butyl decarbonate was used to protect the hydroxy groups to introduce solubility switching groups.

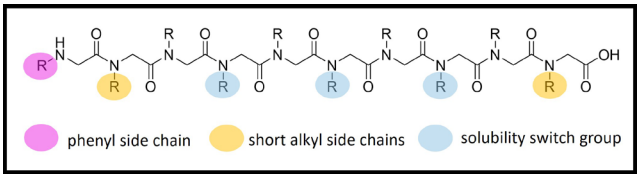

Figure 1: Peptoid 10mers used as positive tone chemically amplified resist (CAR).

The synthesized peptoids were characterized using matrix assisted laser desorption ionization (MALDI) time of flight (TOF) mass spectrometry, and differential-scanning calorimetry (DSC).

Resists with different sequences, composition, and hydrophobic side groups, were dissolved and spin coated on 4-inch silicon wafers. The resist film thickness was measured using a Woollam RC2 ellipsometer. The resist films were exposed using deep-UV (DUV) (ASML 300C stepper) and electron-beam (JEOL 6300). Sequence, composition, and the choice of hydrophobic side groups led to significantly changes in the solubility and performance.

The obtained patterns were characterized using scanning-electron microscopy (SEM) and atomic force microscopy (AFM Bruker Icon), see Figure 2. The micrographs of 24 nm-line pattern are demonstrating the potential of peptoids as new class of resists while the sequence, composition and total length are adjustable and are changing and affecting the lithographical performance. However, further research must be carried out to further improve the lithographical performance and demonstrate the potential of peptoids as a new generation of EUV resists.

Conclusions and Future Steps:

Sequence controlled peptoids were synthesized and successfully used as positive tone photoresist using the DUV and electron beam lithography. The obtained line patterns were characterized via SEM and atomic force microscopy, and proved the potential of peptoids as resists for electron and EUV lithography. However, further research on these new class of resists materials is required to optimize the properties of the resist as well as their performance.

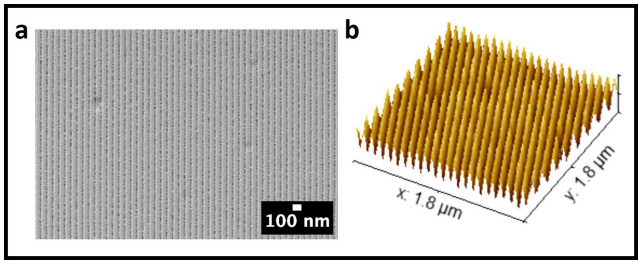

Figure 2: Line pattern by e-beam (a) SEM of line pattern 36 nm, (b) AFM 3D height profile.

References:

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[3] Culf, A. S.; Ouellette, R. J., Solid-phase synthesis of N-substituted glycine oligomers (alpha-peptoids) and derivatives. Molecules (Basel, Switzerland) 2010, 15 (8), 5282-5335.