Electrically Induced Pillar Arrays Formed Using Photocurable Materials

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Overview of Research Interests

My research interests are in nanofabrication, both the formation of nanomaterials and the patterning and assembly processes required to make useful nanoelectronic devices. Ultimately my focus will be on creating, developing, and optimizing various nanofabrication techniques and using these techniques as collaborative tools for practical applications.

My graduate research has been primarily focused on materials development and novel patterning techniques such as imprint lithography and directed-assembly. In this preprint, I will briefly provide background on my imprint related work, but primarily focus on my recent work on pillar arrays formed via electrohydrodynamic instabilities.

Imprint Lithography

Interest in alternative patterning techniques has grown as the resolution of traditional photolithography begins to approach fundamental limits. In particular, there is a heightened interest in imprint technology due to its ability to rapidly pattern a massive number of nanometer scale features at low cost.[1-4] Step and Flash Imprint Lithography (SFIL) is a high-resolution imprinting technique that utilizes a transparent, quartz template with a relief structure to transfer a pattern to a UV curable monomer formulation on a substrate (**Figure 1**). A pattern of 60 nm lines imprinted using SFIL is shown in **Figure 2**.

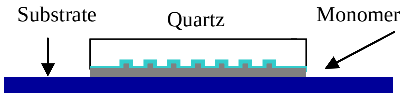

Figure 1. The imprinting step of SFIL: A UV curable acrylate monomer solution is photopolymerized under a patterned quartz template.

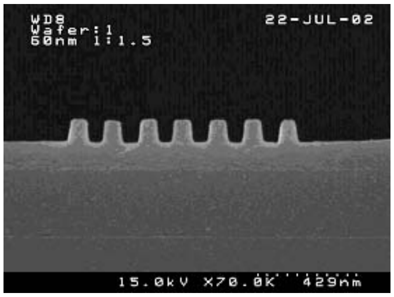

Figure 2. Cross section of an imprinted pattern formed using SFIL.

My research has primarily involved material development for SFIL and modeling of the photopolymerization kinetics.[1,5-11] There are a number of material requirements for the SFIL photocurable monomer solution, which is called the “etch barrier” because of its ability to provide etch resistance in the final steps of SFIL.[12] Resistance to an oxygen plasma etch is accomplished by the inclusion of silicon in the polymer. The material must photocure rapidly to obtain high process throughput. The monomer solution must also contain a cross-linker to provide the necessary mechanical properties of the photocured polymer. When the template is removed, the photocured polymer must adhere entirely to the substrate and maintain structural integrity. Finally, the etch barrier needs to have a low overall viscosity to facilitate the rapid displacement of fluid during imprinting. These processing requirements were met by investigating various material formulations. The photopolymerization kinetics of the formulation with the best properties was subsequently modeled.

Electrodhydrodynamic Directed Assembly

The infrastructure for the SFIL process is quite amenable to another patterning technique that produces pillar arrays by the amplification of electrohydrodynamic instabilities.[13, 14] A transparent template (patterned or unpatterned) is brought into proximity of a film, forming a simple capacitor device (**Figure 3**). Applying an electric field across the gap results in the formation of an array of uniformly sized pillars. Pillars form due to the force imbalance at the film interface where the electric field amplifies film undulations against the restoring forces of gravity and surface tension. Features as small as 140 nm have been created using this method through the use of templates with relief patterns.[14]

To date, this process has only been performed on polymer films, which require a heating step to induce flow prior to pillar formation and a cooling step to lock the columnar structures into place after formation. Our work has focused on developing photocurable monomer systems capable of forming pillars at room temperature. This reduces the processing time from hours to seconds due to the lowered film viscosity and the elimination of the heating / cooling cycle required for polymers. The pillar structures are locked into place by irradiating the photocurable solution through the transparent template.

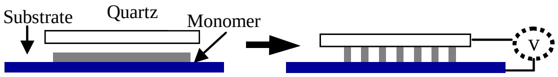

Figure 3. The pillar array formation process: An electric field is applied across a thin monomer film, with a bias (V). The electric field amplifies film undulations, resulting in pillars, which are then photocured through the transparent quartz template.

The advantages and disadvantages of various classes of materials were investigated. In addition, we have developed an active gap tool capable of stretching the pillars. This tool is capable of dramatically increasing the aspect ratio of the structures, which is critical for patterning. This tool has allowed us to study pillar stretching, as well as investigate the effects of geometry on low viscosity systems.

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