Soft Lithography – Materials and Applications to Plasmonic Sensing and Surface-Enhanced Raman Scattering

Tu T. Truong Final Seminar December 15, 2009

The interest in unconventional techniques for nanofabrication has grown exponentially in recent years due to demanding requirements in micro/nanoscale structures, especially in photonics, microfluidics, biotechnology, and flexible electronics. Soft lithographic methods use elastomeric stamps, molds, and conformable photomasks as patterning elements to provide capabilities that are unavailable with conventional techniques: patterning at molecular scale resolution (~1 nm); ability to form three dimensional (3D) structures directly in a single step; experimental simplicity and applicability to large areas. [1, 2]

The most commonly used material for molds and stamps in soft lithography is poly(dimethylsiloxane) (PDMS) prepared from Sylgard 184 (Dow Corning) which is normally referred to as soft PDMS (s-PDMS). Although PDMS has various attractive properties such as relatively low surface energy, low Young's modulus, and transparency; PDMS is not very good for high resolution and high fidelity patterning. For example, its low Young's modulus leads to unwanted deformation including roof collapse, buckling, and merging. [3] The key to improve the resolution for soft lithography is increasing the Young's modulus of the material for the molds in relation to other properties such as conformity or the ability to have conformal contact with other surfaces, surface energy, as well as chemical and solvent resistance.

This seminar will describe three topics of my dissertation research: (i) First, the use of a commercially available perfluoropolyethylene (a-PFPE) in a variety of soft lithographic techniques for high fidelity and high resolution patterning. Due to the rigidity of the a-PFPE, the stamps and molds are fabricated in a composite design which consists a thin layer of a-PFPE and a backing layer of s-PDMS or a thin sheet of poly(ethylene terephtalate) (PET). [4] a-PFPE with its high Young's modulus, low surface energy, transparency to UV/Vis light, chemical inertness, and solvent resistance appears to hold promise as an alternative to PDMS for certain soft lithographic methods. (ii) Second, a class of plasmonic crystal that consists of square array of nanoposts formed by soft nanoimprint lithography as shown in Figure 1. As sensors, the structure shows higher bulk refractive index sensitivity in the visible wavelength range as compared to plasmonic crystals consisting of square arrays of nanoholes with similar dimensions. [5] Finite-different time-domain (FDTD) calculations are used to model the optical properties of the crystals. (iii) Third, we demonstrate the use soft lithography as a simple and easy strategy for fabricating surface-enhanced Raman scattering (SERS) substrates with highly uniform and reproducible response, as shown in Figure 2. The highly uniformity nature of the crystals also enables direct, spatial imaging of SERS signals. [6]

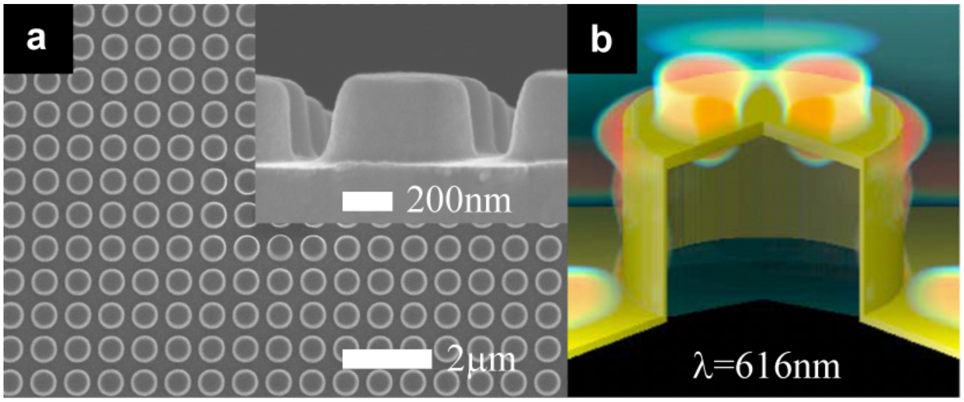

Figure 1: (a) Scanning electron micrograph (SEM) of the molded nanopost plasmonic crystal. The inset shows the cross section of the crystal. (b) Three-dimensional image of the computed electromagnetic field intensity for the nanopost crystal in aqueous solution associated with the resonance in transmission at the wavelength of 616 nm.

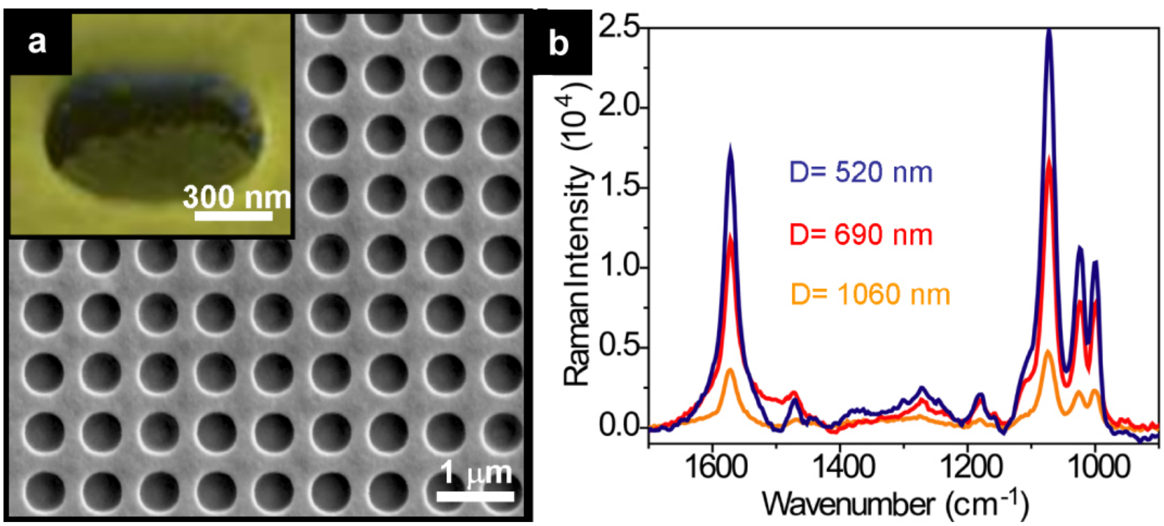

Figure 2: (a) Scanning electron micrograph (SEM) of a representative SERS substrate consisting of nanohole arrays. The inset shows a colorized tilted view of a single nanohole. (b) SERS spectra of benzenethiol adsorbed onto areas of a molded SERS substrate composed of nanoholes with different diameters (D). Blue D=520 nm; red D=690 nm; and orange D=1060 nm.

References

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