Optimizing the Direct Fabrication of Nanoparticles for Cancer Diagnostics

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Abstract:

Nanoparticles with specific ordered structure and composition can produce unique optical or electromagnetic signatures. These nanoparticles are finding new uses such as biomarker scaffolds in cancer diagnostics. This work involved optimizing the process of direct fabrication using nanoimprint and other techniques common to device manufacturing in order to produce these nanoparticles. In particular, our work focused on creating nanoimprint templates and optimizing their use in thermal nanoimprinting. In order to optimize the direct fabrication process, solution phase synthesis and various characterizations, such as scanning electron microscopy (SEM) of metal nano-structures were used [1]. Nanosphere lithography (NSL) of wafer-scale arrays was achieved through Langmuir-Blodgettry (LB) and careful reactive ion etching as shown in Figure 1. We utilized LB in order to bypass many of the limitations of the current fabrication methods and still be able to create close-packed nanoparticle arrays over large scales.

This is unique in the field of NSL and originates primarily in the use of nanoparticles of silica as a direct mask for etching. The motivation behind this research was to develop an optimized method of fabricating magnetic nanoparticles for highly selective and sensitive cancer bioassays.

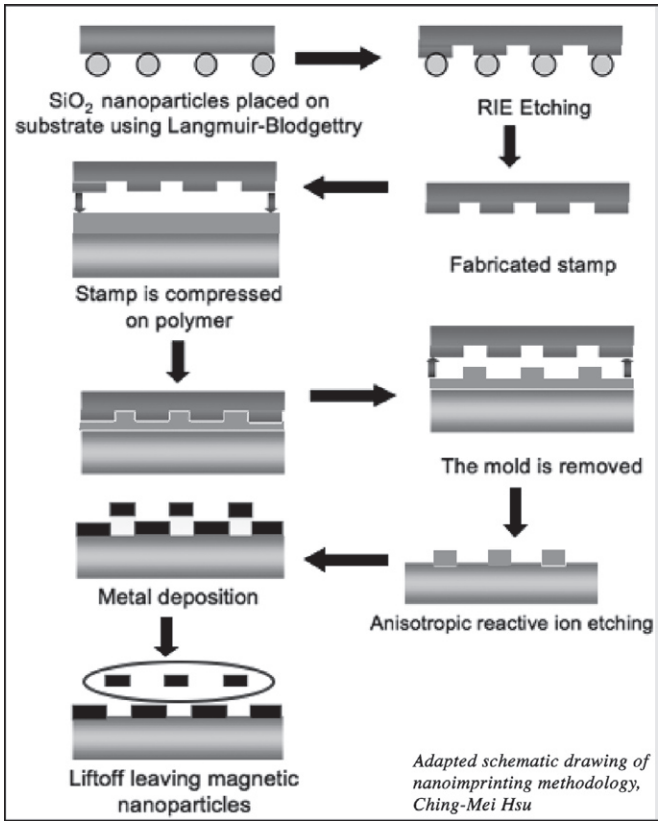

Figure 1: Fabrication of the magnetic nanoparticles.

Introduction:

Magnetic nanoparticles were first developed approximately 35 years ago [1]. These nanoparticles have shown remarkable potential for curing the cancer disease and have brought new dimensions to cancer research. Our group has previously demonstrated the use of the Langmuir-Blodgett (LB) method to produce stamps, and used those stamps for to produce templates for synthetic antiferromagnetic (SAF) nanoparticle fabrication. However, the complete process to use these stamps and templates to produce the SAF nanoparticles has not yet been done. We fabricated stamps which will be utilized in this process so that the SAF nanoparticles can be fabricated and investigated as bioassays for cancer.

In order to enhance the process of direct fabrication, we needed to make high-density arrays of the SAF nanoparticles, which are typically made using either electron beam lithography or photolithography methods. However we utilized the LB method, which is relatively fast, inexpensive and uses only small amounts of raw material, whereas lithography is expensive, time consuming and uses large amounts of raw material. The LB method utilizes the LB trough.

In brief the LB trough, as shown in Figure 2, is an instrument that is used to study the properties of a monolayer of amphiphilic molecules. Among other applications, the instrument can compress the monolayer to deposit LB films on a solid substrate, such as silicon.

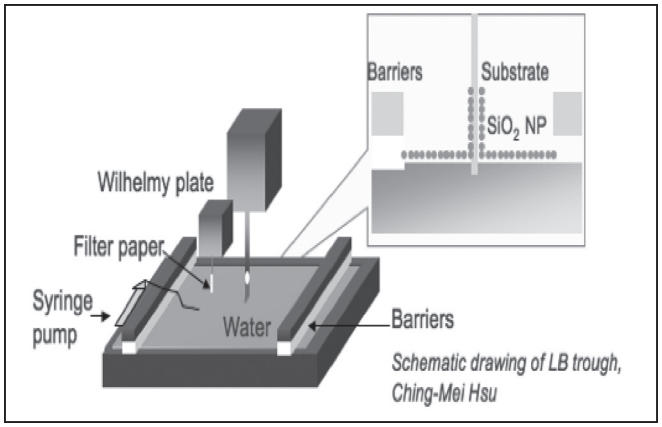

Figure 2: Langmuir-Blodgett trough and deposition.

Utilizing this method we hoped to accomplish our objectives of enhancing the process of direct fabrication using nanoimprint and other techniques, such as the LB trough for deposition, in order to produce uniform arrays of silicon nanopillars across the substrates surface, create many nanoimprint templates in a short amount of time and improve their use in thermal nanoimprinting. Finally we hoped to employ an optimized method of fabricating magnetic nanoparticles for use in highly selective and sensitive cancer bioassays. Our particular research area concentrated on placing the SiO_2 nanoparticles on the Si substrate to be used as etch masks to create silicon nanopillars for nanoimprint templates.

Experimental Procedure:

Functionalization of SiO_2. Two mL of the cleaned silica nanoparticles solution was diluted into 14 mL absolute ethanol 1 mL water, and 100 µL 3-aminopropyl (diethoxymethyl-silane). 97% (APDES) is added with vigorous stirring. The sample was stirred overnight and then heated at 100°C for one hour while being covered in aluminum foil. Cleaning was then performed on the functionalized sample by centrifugation into ethanol and methanol, in 15-minute intervals for a total of five intervals. The solution-based sample was then taken for deposition, with final dispersion into the spreading solvent desired for LB.

Langmuir-Blodgett Deposition. The functionalized samples of silica nanoparticles were injected onto the water subphase by means of a syringe pump. The film was then compressed until a sharp rise was observed in the surface pressure, indicating the formation of a monolayer. Dip-coating depositions were usually performed on oxygen plasma cleaned silicon substrates with the substrate perpendicular to the water surface. The substrate was dipped through the monolayer at 40 mm/min, followed by raising the substrate at 5 mm/min to collect an even film. The surface pressure for optimal deposition was strongly dependent on the size of the nanoparticles, with larger silica samples commonly reaching pressures of 5 mN/m^2.

Results and Conclusions:

It is clearly seen in the SEM image shown in Figure 3 that uniform arrays of masked nanoparticles are evenly formed across the silicon wafer. (See T. Sengupta's report, page 28, for etching the Si using this mask, and producing the stamp.) Thus, the Langmuir-Blodgett method bypassed many of the limitations of the current fabrication methods on the nanoscale. Additionally, we produced close packed arrays of SiO2 nanoparticles by LB deposition. Using this process and subsequent etching, a stamp for the fabrication of magnetic nanoparticles was produced.

Future Work:

In the further experimentation of the LB process, we hope to investigate the limitations of the current functionalization method, such as defects, incomplete coverage and imperfect hydrophilicity that occurs in certain regions of the substrate after deposition. Also, we hope to utilize these stamps to produce magnetic nanoparticles for cancer bioassays.

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References:

[1] Hsu, C. and S. Connor, Nanosphere Lithography. 2-8 (2007).

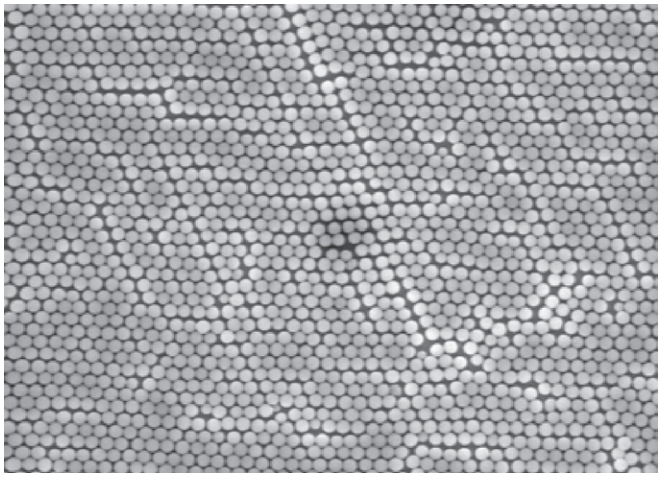

Figure 3: Uniform nanoparticles are formed across the silicon wafer. SEM taken at 25000x.