DUAL EXPOSURE GLASS LAYER SUSPENDED STRUCTURES (DEGLASS): A NOVEL FABRICATION PROCESS FOR GLASS MICRO-FLUIDIC NANOSTRUCTURES ON PLANAR SUBSTRATES

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1. Introduction

Microfluidic systems that can be easily integrated with microelectronics have the potential to generate a variety of new sensor and separation technologies. Typical fabrication techniques require a combination of lithography, dry etching, multi-layer thin film deposition, thermal or anodic bonding, and specialized materials with high etching selectivities. We propose a new approach to fabrication of microfluidic systems.

2. Theory

The DEGLaSS process uses a single layer of spin on glass (SOG) material with two negative tone exposures at two different exposure energies to define the channel ceilings and channel walls respectively. A low energy exposure has a very short penetration depth, similar to a top surface imaging process, and defines the channel ceiling. A second exposure is performed with a higher energy that penetrates through the entire glass layer thickness, resulting in channel walls that support the ceiling. There is no processing between the exposures, and the order of the exposures does not matter. Both patterns are developed simultaneously in TMAH which removes all the unexposed material, including the material inside open ended channels. Samples can be transferred through an ethanol bath to a critical point CO_2 dryer to prevent ceiling collapse due to surface tension in the drying of large open cavities. After development the three-dimensional cross-linked SOG structures can be densified converting them to an amorphous glass structure. Any two dimensional pattern can be used for both the support structure and the ceiling structure, as long as the ceiling structure does not contain isolated unsupported regions which will either wash away or fall flat to the substrate. Thus ceiling structures can be patterned with irrigation holes to enhance development, or supported underneath by pillar arrays to enhance structural rigidity or to create artificial sieves.

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3. Experimental Results

We have demonstrated the DEGLaSS process using low energy electron beam exposures of Hydrogen Silsesquioxane (HSQ). HSQ was chosen for its high resolution and sensitivity in negative-tone electron beam lithography.[1] Variable energy electron beam lithography allows control of the electron penetration depth over three orders of magnitude, from 10 nm to 10 µm with a single exposure tool. We have demonstrated the process in HSQ films with a thickness between 200 nm and 1.2 µm. We have used 1-2 keV electrons to define our channel ceilings, and 3-10 keV electrons to define our channel walls. The 1 (2) keV exposures produce suspended ceilings 40 (110) nm-thick. Channels have been demonstrated with lengths up to 150 µm without irrigation holes with reasonable development times. The channel ceiling and walls can be fabricated with a resolution near 100 nm depending upon electron energies channel heights. The HSQ structures can be converted to SiO_2 using thermal annealing in an oxygen ambient or an exposure to an oxygen plasma. The channels are optically transparent, and demonstrations of dye molecules flowing in the channels will be presented.

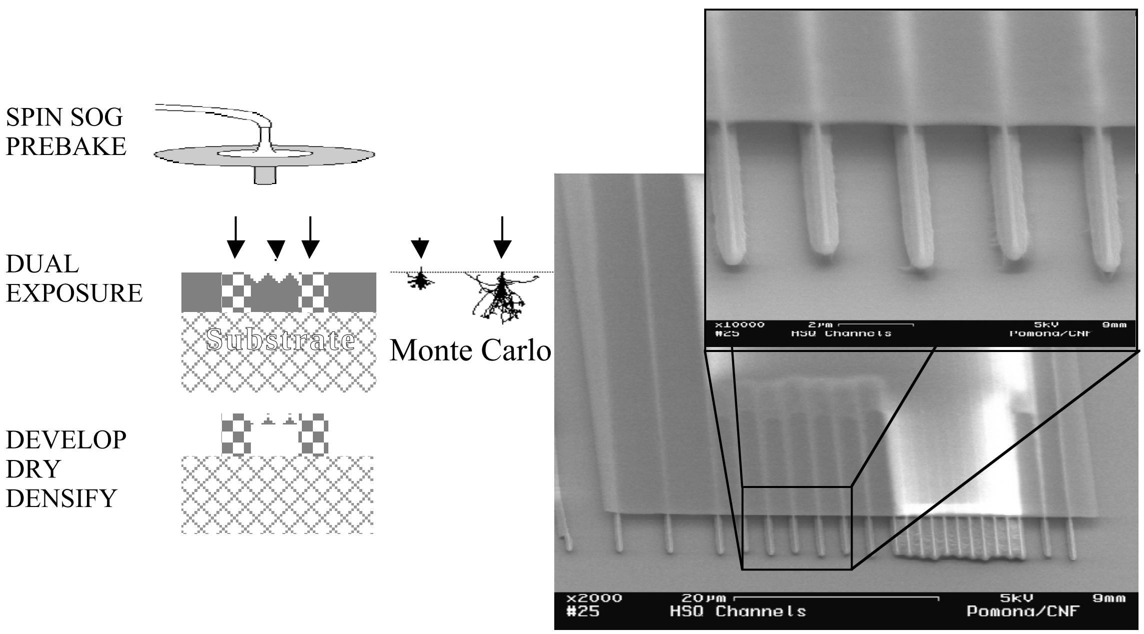

Figure 1. DEGLaSS Process Flow and Fabricated Channels.

4. Conclusions

The DEGLaSS process can be easily expanded to include more exposure energies allowing more intricate internal structures to be fabricated inside channels, such as those needed for separation technologies, flow sensors, valves, etc. The DEGLaSS process eliminates the need to do reactive ion etching or anodic bonding and can be performed on any planar substrate, even above existing integrated circuits, since the ceiling and walls are fabricated from the same SOG in an additive process.