Comparison of Fabrication Methods for Tunnel Regions in a Biosensor

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Abstract:

Recently, biosensor devices have become a major area of interest in nanotechnology. Many of these devices require microfluidic systems that include tunnel regions. The focus of this project is to fabricate tunnel regions using various methods in order to compare the clarity and characteristics of the tunnel regions. The first two methods use a sacrificial aluminum layer to form the tunnel. With this process, tunnels as small as 200 nm in height were achieved. Other methods studied include patterning channels in SU-8, polyimide, and PDMS.

Introduction:

Currently, there is high interest in using biosensors for the detection of water and air contamination. The basic components of a biosensor include biological recognition interfaced with a signal transducer. Some biosensor designs also require microfluidic channels in order to transport ion currents that are transduced into measurable currents and voltages [1].

The goal of the research reported here was to fabricate tunnel regions for the microfluidic system of a biosensor. As seen in Figure 1, the biosensor design in consideration requires tunnels to separate an artificial cell membrane from reservoir areas. The reservoirs are used to easily fill the microfluidic channels which sit below the artificial cell membrane.

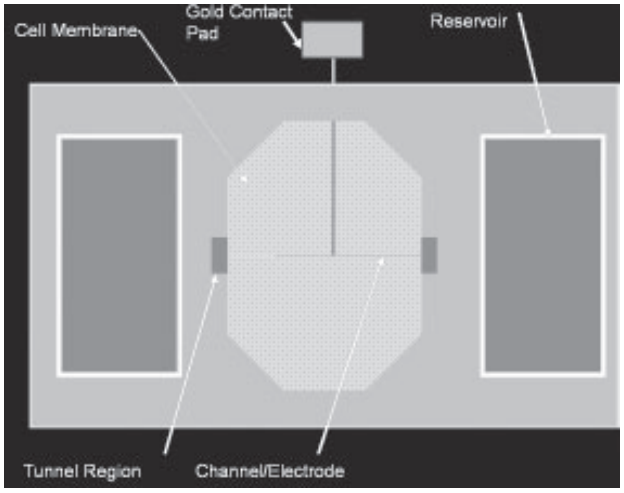

Figure 1: Biosensor layout.

When fabricating the tunnel regions, there are two main concerns. First, there must be complete isolation between the reservoirs and cell membrane area. Second, the tunnels must be clear and allow for careful filling of the channels from the reservoir. The methods explored include: (1) using a sacrificial aluminum layer; (2) patterning channels into SU-8; and (3) making a SU-8 mold to pattern the tunnels in PDMS.

Procedure:

Sacrificial Aluminum Layer: The first method, shown in Figure 2, used a sacrificial aluminum layer to create the tunnel regions. In order to create these regions, first a mask including the biosensor's channels, tunnel regions, and reservoirs (Figure 1) was created using the Mann 3600 pattern generator. The mask pattern was transferred to glass wafers using the EV 620 contact aligner. After exposure and development the pattern was etched down into the wafer approximately 1 μm using the Plasma Therm 72 Reactive Ion Etcher.

Following etching, lift off resist and Shipley 1827 were spun on the wafers and the contact aligner was used to expose only the tunnel regions. After development, 10 nm of Chrome and then 200 nm of Aluminum were deposited by electron beam evaporation. Lift off using 1165 remover was then performed, so that the aluminum remained only at the tunnel regions.

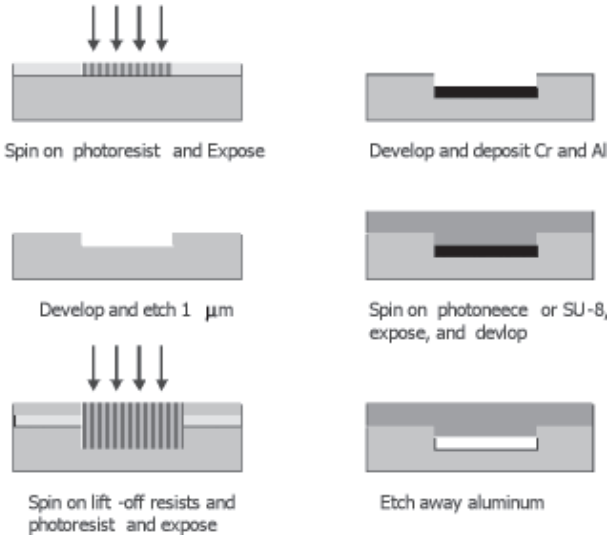

Figure 2: Sacrificial aluminum layer process.

Next, the cover layer was spun on and developed. This layer formed the border between the cell membrane and the reservoirs. Two cover layer materials experimented with were photoneece and SU8-50. Photoneece is an electrically insulating photosensitive polymide which uses the same development procedures as normal Shipley resists; the only difference in processing is that photoneece requires a 6 hour cure after development [2]. SU-8 is a negative epoxy-based photoresist capable of producing high aspect ratio features. It requires a lengthy soft bake (15 to 90 minutes) and development in SU-8 developer [3]. Once the cover layer was finished, the aluminum in the tunnel regions was etched out using a wet aluminum etch.

SU-8 and Photoneece Tunnels: The second method explored to make tunnels involved creating channels in SU-8 or photoneece and then making a cover layer out of PDMS. To test this method a pattern using a range of channels from 5 μm to 100 μm was used as a mask. The same development steps used to create the SU-8 and photoneece cover layers in the sacrificial aluminum layer method were used to create the channels. The cover layer material used, PDMS (polydimethyl-siloxane), is a durable silicon elastomer.

SU-8 Mold: The final tunnel fabrication method studied involved creating a mold out of SU-8, which was then used to form the channels of the tunnel regions in PDMS. In order to create a mold, similar SU-8 development procedures as used in the SU-8 tunnel method were implemented. However, in the mold the regions which before were trenches were the raised regions, and vice-versa. Once the mold was finished, it was cast with PDMS. The PDMS was then degassed to remove air bubbles and cured for 3 hours. After curing, the PDMS layer was manually peeled off the SU-8 mold. PDMS was also used as the cover layer in this method.

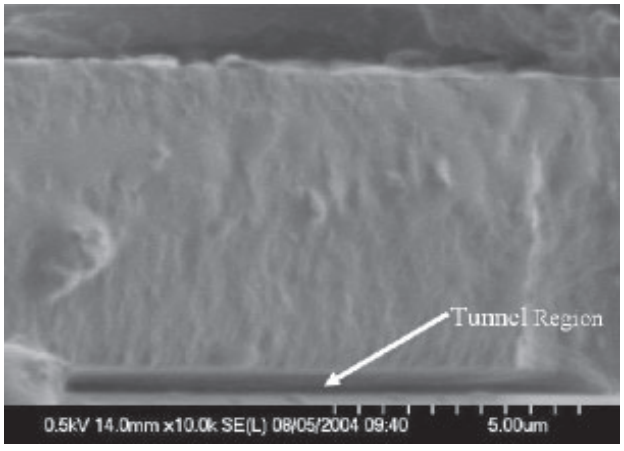

Figure 3: SEM image of tunnel formed by sacrificial aluminum layer method.

Results and Conclusions:

The sacrificial aluminum layer process produced clear etch through regions as small as 200 nm in height. A cross section of a tunnel region with a photoneece cover layer is shown in the SEM image of Figure 3. These channels would be ideal for controlled fluid flow in the biosensor and for channels using capillary action to transport fluid.

The photoneece channels were 5 μm high, and they resulted in clear pathways for channel widths as small as 5 μm. The recipe used for the SU-8 tunnels produced 100 μm high walls, but they did not produce clear channels for widths smaller than 50 μm. However, the SU-8 mold was clearly defined, which resulted in clear PDMS channels for widths down to 5 μm. Figure 4 shows images of the mold and the resulting channels.

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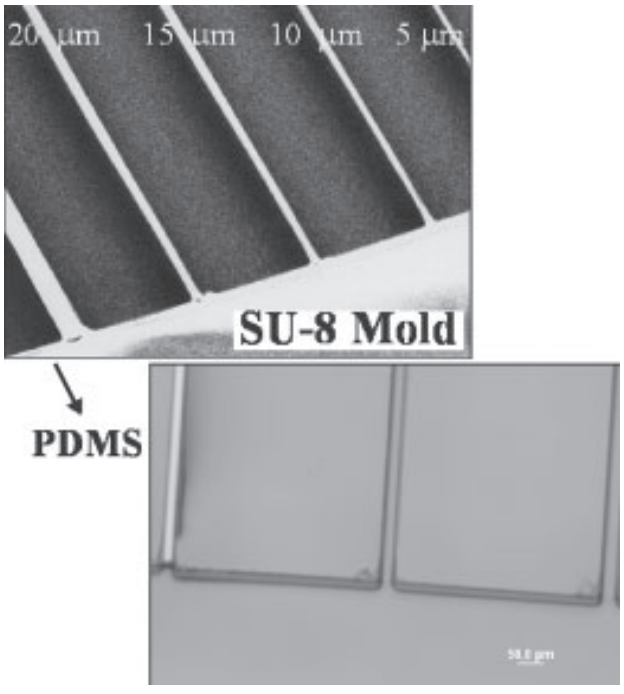

Figure 4: SU-8 mold and subsequent PDMS channels.