Lateral porous silicon membranes fabricated within 2D microchannels through local ion implantation

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Keywords: Porous silicon; Membrane; Ion implantation; Microfluidics; Lab-on-a-chip

Abstract

In this work, we present a novel fabrication process of lateral porous silicon membranes with tunable pore size and porosity for microfluidic applications. Our proposed method relies on the fact that the formation of porous silicon by anodization is highly dependent on the dopant concentration (Fig. 1) [1]. Here, we use ion implantation to manipulate the local dopant concentration in order to control the pore propagation. Precise control of the membrane properties is simply achieved by monitoring the current during the silicon anodization process.

Recently, there has been a great interest in integrating porous membranes into lab-on-a-chip devices for microfluidics applications such as size or charge-based molecular separation and ion concentration polarization. Out of the various materials readily available to constitute porous membranes, porous silicon offers the advantage to enable interferometric biosensing. Moreover, the process of creating porous silicon membranes by electrochemical etching of silicon provides means to control the membrane physical properties by adjusting the anodization conditions. Porous silicon membranes are usually integrated into microfluidic chips by sandwiching fabricated membranes between two micromachined layers, resulting in three-dimensional fluidic networks. However, other integration approaches are highly desirable to provide solutions compatible with planar fluidics that are usually easier to package and use. To this aim, we have recently proposed a fabrication process leading to porous silicon membranes with lateral pores.

In our previous work [2], we successfully integrated lateral porous silicon membranes into planar microfluidics using silicon-on-insulator substrates. This fabrication technique relies on the patterning of local electrodes to guide pore formation horizontally within the membrane, and on the use of silicon-on-insulator substrates to spatially localize porous silicon within the channel depth. The disadvantage of this approach is that the buried oxide layer is exposed to high concentrated hydrofluoric acid during anodization, which limits the anodization time (and the membrane thickness). Besides, the current lines that control the pore direction of propagation are influenced by the presence of the electrode on the top silicon surface. In Figure 2, we present the new fabrication process based on boron and phosphorus implantation. The phosphorus-implanted layer and the n-type substrate are of low dopant concentration, thus preventing the formation of pores, while pores are created solely within the high-concentration boron implanted layer. This fabrication process solves the limitation of anodization time, which enables bigger range of pore size and porosity. Meanwhile, the P-N junction formed by implantation prevents charge injection through the top silicon surface, resulting in pure lateral current flow. Thus, as shown in Fig. 3, we see that our approach results in lateral porous silicon membranes. Beside, we demonstrate here that we are able to manipulate the pore size (5-35nm) and porosity (10-70%) by adjusting the current density (Fig. 4).