L.7: Silver nanoparticle assisted etching process for nanostructuring of silicon wafers

Silicon and its nanostructures are important for different devices applications related to nanoelectronics, photovoltaics, sensors, opto-electronics, etc. Development of cost effective techniques for the fabrication of nanostructured semiconductors of different morphologies is continuously progressing to meet the demanding requirements and also to explore new applications. Metal nanoparticle assisted electroless chemical etching process is a promising route for nanostructuring of silicon substrate in hydrogen fluoride (HF) and hydrogen peroxide (H_2O_2) medium. Silicon substrate with silver nanoparticles on its surface produce two half-cell reactions when immersed in HF-H_2O_2 solution. Ag nanoparticles facing the etching solution act as cathode while silicon acts as anode. The Ag nanoparticles act as redox center in terms of short circuited galvanic cell and play as catalytic role. The overall spontaneous power generated from the galvanic cell reactions is utilized for highly localized etching of the silicon wafer. By utilizing this method, two different morphological nanostructuring of silicon wafers i.e., (i) nanoporous, and (ii) nanowire surfaces have been produced in our lab.

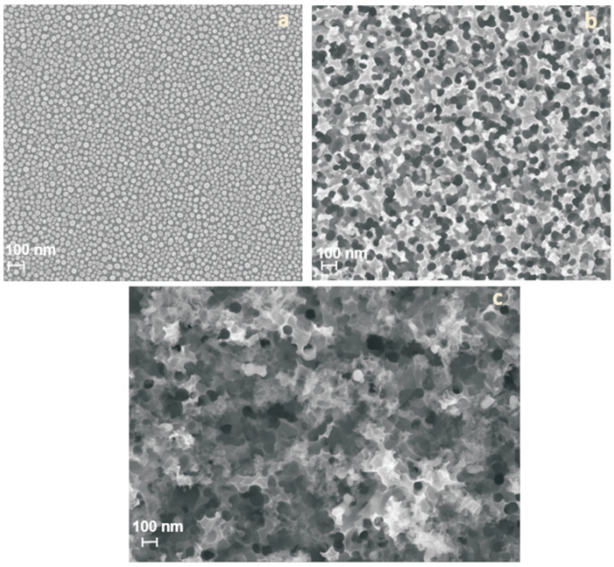

Fig. L.7.1: SEM images of (a) silver nanoparticles on silicon substrate and (b & c) etched silicon substrates, (etch time: 15 min (b) and 30 min (c)).

In order to produce these nanostructures, two different approaches have been adopted for deposition of silver nanoparticles. For generation of nanoporous silicon surface, the silver nanoparticles were deposited by pulsed laser deposition (PLD) while chemical route was used for generation of nanowire surface. Figure L.7.1 presents magnified images of PLD-grown densely packed silver nanoparticle films and the nanoporous silicon surface after etching. The size of resultant nanopores was found to be less than 100 nm. With increasing etch time, the pores get interconnected producing highly porous surface. In this method, pore size control can be achieved through optimization of PLD process parameters and chemical etching conditions.

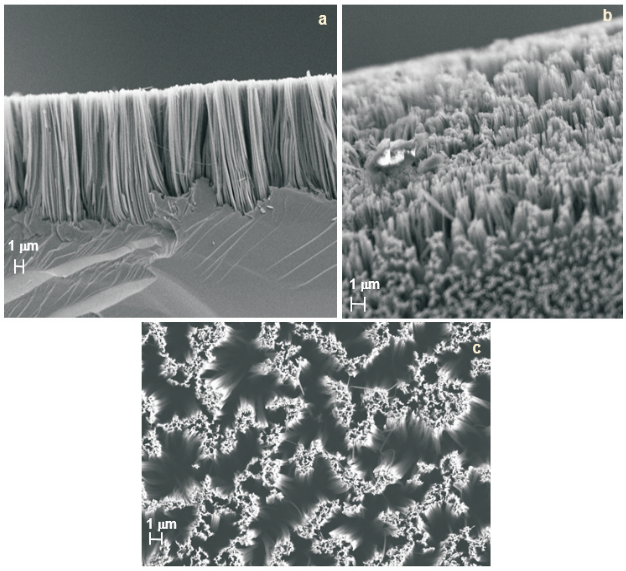

Fig. L.7.2: SEM images of silicon nanowires (a) side view, (b) inclined view, and (c) top view.

In the second approach, deposition of silver nanoparticles on silicon substrate was achieved in solution phase by reducing silver salt. In this case, etching has resulted in the formation of silicon nanowires (with diameter of few hundred nm and length of few µm), as shown in Figure L.7.2. The dimensions of silicon nanowires can be controlled through control of etching parameters. The nanostructured silicon surfaces displayed significantly reduced degree of reflection, thereby indicating efficient light coupling.

The grown nanostructured silicon substrates may find potential application towards development of cost effective high sensitive Raman substrates for trace molecular detection, efficient catalytic surfaces, photovoltaics, and chemical sensors. The proposed method for synthesis of these nanostructures is easily scalable for large-scale production.

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