Efficient Nanoscale Pattern Transfer Process for Porous Silicon

E. Chow, I.S. Chun, and X. Li
Department of Electrical and Computer Engineering, Micro and Nanotechnology Laboratory
University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA

Research in porous silicon has generated lots of interests largely due to its light emitting property and the large surface to volume ratio. Patterned porous silicon structures are potentially useful for integrated optical and sensing applications.

A simple and effective porous semiconductor formation method, where etching was assisted by metal without external bias, was first reported by Li et al. [1] and reproduced by many other groups. The metal does not act as a mask, rather as a catalyst for hole (h^+) generation for semiconductor dissolution. In addition to the simplicity, the metal assisted chemical etching allows patterned porous silicon to be formed. Sub-millimeter scale patterning using this approach has recently been reported [2]. We demonstrate here true nanoscale 3D patterns in light emitting porous silicon, transferred from 2D metal nano-patterns in less than one minute etching time, with controlled topography and luminescence properties.

Various nanoscale metal patterns were written on PMMA with p-type Si substrates (~7 Ωcm), using electron beam lithography. Platinum (Pt) and Titanium (Ti) metals were evaporated and followed with standard lift-off. Metal patterned substrates were then etched in the $\underline{H_2O_2}$ $\underline{me}$tal-$\underline{H}$F (HOME-HF) etchant [1] for 15 ~ 60 seconds.

Fig. 1 shows scanning electron microscope (SEM) and Atomic Force Microscope (AFM) images of an as-patterned boomerang contour array. The height of the metal (Pt/Ti) is 10 nm as indicated by the AFM depth profile. Fig. 2 shows the SEM image and AFM images of the same sample after 30 second HOME-HF etching. The areas covered with metal now show a depression (70-100nm) in depth with the metal appears to be engraved in the body of silicon. Fig. 3 shows a close-up SEM image of the area (indicated by the rectangle in Fig.2) where the surface underneath the metal is revealed due to the peeling of the metal. It can be seen clearly that both the areas underneath and around the metal show porous features, but with different pore sizes. This is consistent with the macroscopic metal-assisted porous silicon formation behavior [1]. The faster etch rate underneath the metal not only leads to larger pore sizes but also the removal of materials at this scale, leading to the formation of 3D patterns in porous silicon. Preliminary data shows that this simple patterning technique can be used to create a variety of nanoscale patterns for porous Si. Initial optical characterization with photoluminescence and cathodeluminescence shows promising light emission enhancement. Detailed optical characterization and potential applications will be discussed.

1. X. Li and P. W. Bohn, "Metal-assisted chemical etching in HF/H_2O_2 produces porous silicon," *Appl. Phys. Lett.*, vol. 77, pp. 2572, 2000.
2. V. Kapaklis, A. Georgiopoulos, P. Poulopoulos, and C. Politis, "Patterning of porous silicon by metal-assisted chemical etching under open circuit potential conditions," *Physica E*, vol. 38, pp. 44, 2007.

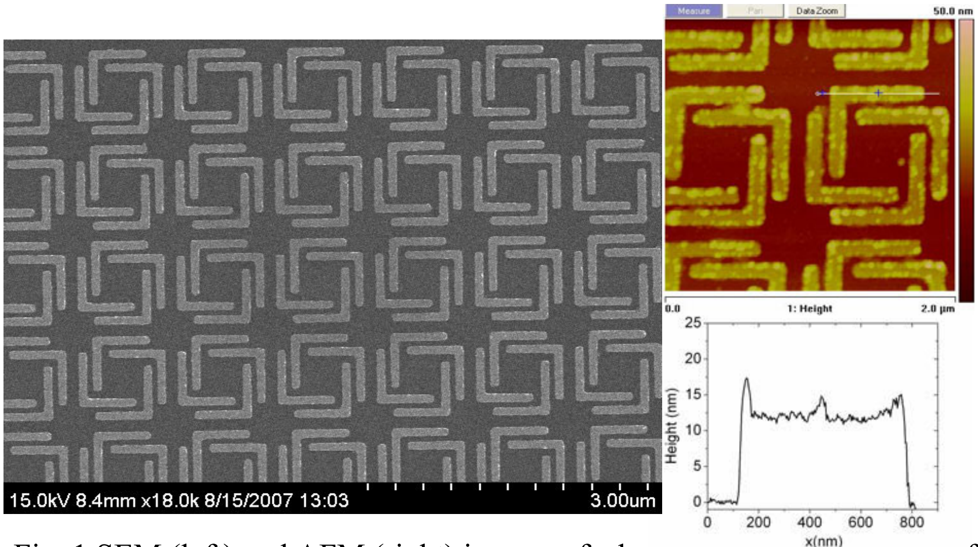

Fig. 1 SEM (left) and AFM (right) images of a boomerang contour array of Ti/Pt on a p-type Si substrate.

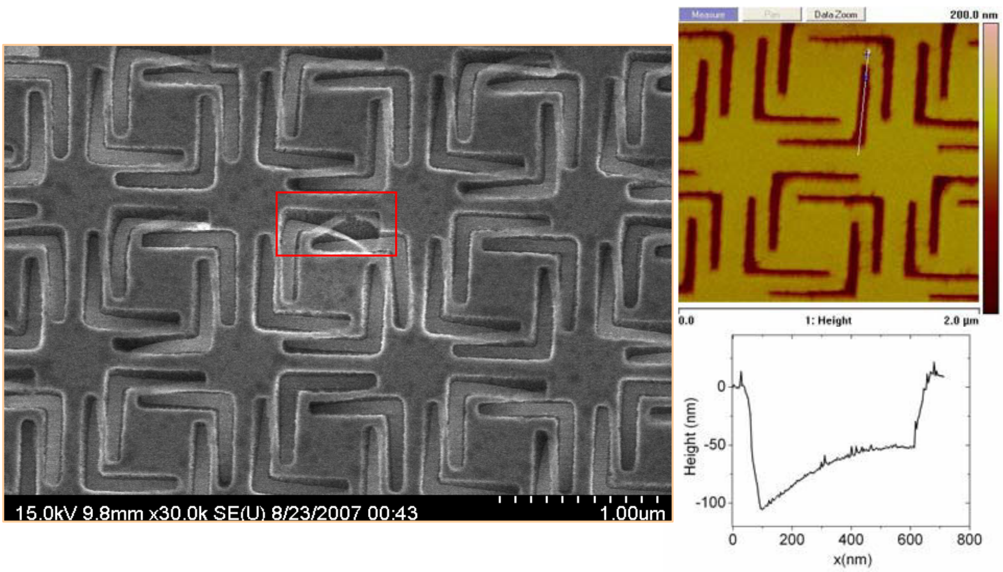

Fig. 2 SEM (left) and AFM (right) images of the same sample shown in Fig. 1 after 30 sec etching

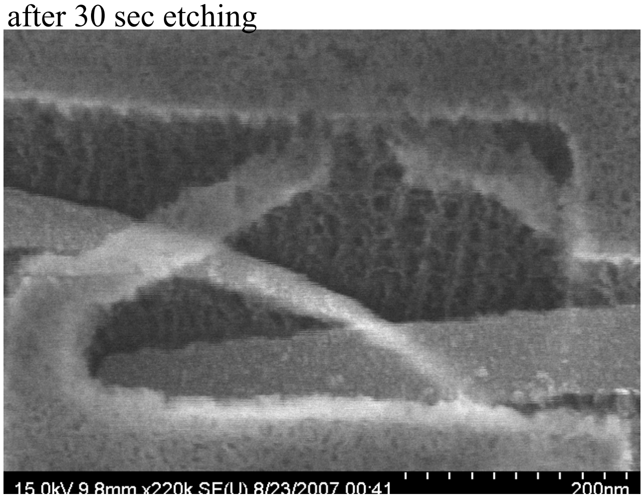

Fig. 3 A close-up SEM image of the etched sample in an area where the metal was peeled off (indicated by the red rectangle in Fig. 2).