SILICON STRUCTURES OBTAINED BY DISOLUTION OF POROUS SILICON FROM METAL ASSISTED CHEMICAL ETCHING

O. PÉREZ-DÍAZ, E. QUIROGA-GONZÁLEZ*, N. R. SILVA-GONZÁLEZ
Institute of Physics, Benemérita Universidad Autónoma de Puebla, P.O. Box J-48, 72570 Puebla, Mexico. –
*E-mail: equiroga@ifuap.buap.mx

SUMMARY
In this work, an array of silicon structures was obtained by over-etching porous silicon previously obtained by metal assisted chemical etching. Photolithography was used to define the pattern of the array, before the etching processes.

INTRODUCTION
Silicon has been structured in different forms such as wires, pillars, and tubes, to cite some; this flexibility has allowed its use in optoelectronics, thermoelectrics, energy conversion and storage, and biomedicine [1]. There are numerous methods to obtain the silicon structures mentioned above, like electrochemical etching and metal assisted chemical etching (MACE), Vapour-Liquid-Solid deposition and reactive ion etching. Among these methods, the simplest and most economical is MACE, being thus a real alternative for mass production [2]. It consists of deposition of nobel metal particles such Au, Ag and Pt on a Si substrate and introduction of this in an HF.based etchant; the etching rate of Si is faster in the sections with metal particles.
Unfortunately, this method commonly produces a random distribution of structures (e.g. wires). The reason is that by the most of the metal deposition methods, the metal particles are deposited with random distributions. On the other hand, if the metal is not deposited as particles, but as plates with defined micron-size patterns (defined by lithography), there is a risk that during the MACE process the plates move into Si in a way given by their center of symmetry, and one cannot always get the desired structures (twisted or bent structures could occur).
Therefore we have developed a method to obtain structures, with MACE as an intermediate step. It takes advantage of photolithography to define patterns; additionally, metal particles are used for MACE, to allow a vertical transfer of micron-sized patterns. Patterns of porous regions are obtained after MACE, which works as sacrificial material, that is, it is removed to form the final structures. Is worthy to mention that the whole process takes place at room temperature without expensive equipment.

EXPERIMENTAL RESULTS AND DISCUSSION
For the present work, p-type <100> crystalline silicon (15-25 Ohm.cm) wafers have been used as precursor material. The microstructuring process takes place in four steps, as depicted in Figure 1. First, a pattern of photoresist is defined on a Si wafer by photolithography. Afterwards, Ag (or Au or Pt) particles are chemically deposited in an $HF\text{-}H_2O_2\text{-}AgNO_3$ solution. The sample with the metal is then immersed in an $HF\text{-}H_2O_2$ solution (MACE). At this point, a pattern of porous silicon is obtained, so to obtain the final structures the porous part is chemically consumed in KOH-based solutions.

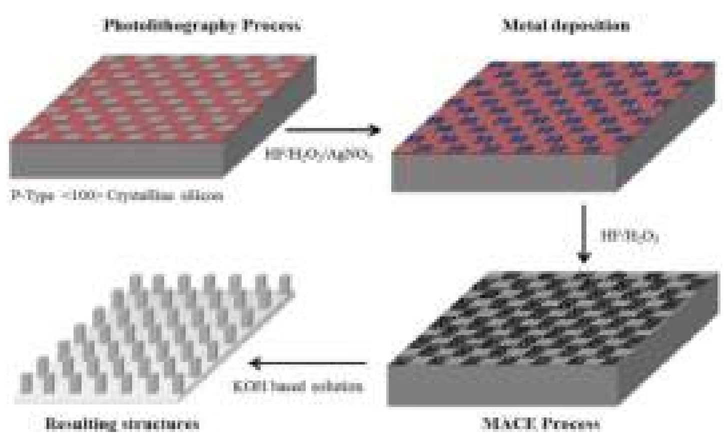

Figure 1. Proposed method to obtain silicon structures.

Figure 2 shows SEM micrographs of Si at two stages of the process: a) shows the silicon sample after metal deposition; b) shows the Si surface after MACE. The pore walls are 30 nm thick in in average. Such a porous material can be easily removed in KOH-based solutions.

a) b)

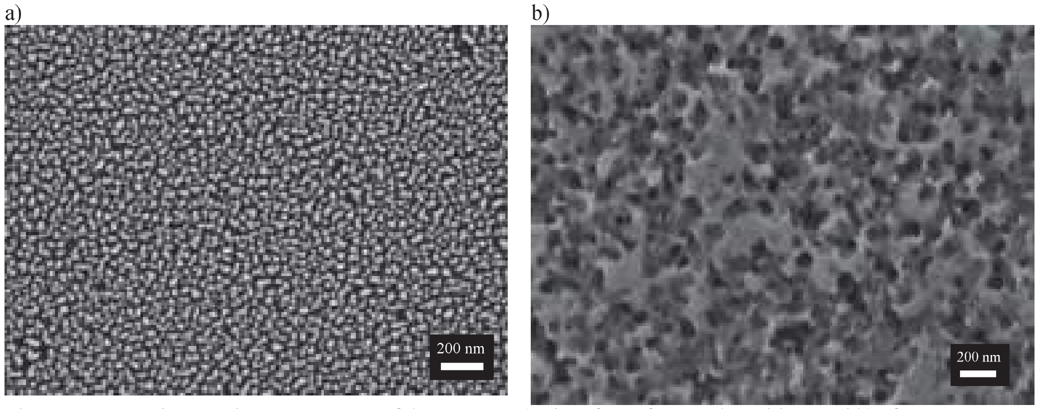

Figure 2. SEM micrographs at two stages of the process: a) Si surface after Ag deposition, and b) after MACE.

As bulk Si sections, defined by lithography, exist between the porous sections, it takes longer to dissolve them. It is can be seen that porous Si acts as sacrificial material to obtain the structures. Figure 3 shows a sample after removing the porous part; mesa structures (defined by photolithography for this work) are evident. Some mesas still have some porous parts, indicating that the over-etching time in KOH solutions was not enough; i.e. if the sample were left more time in this solution, the porous part will be totally consumed, and the structures would be totally solid. Nevertheless, with the present results it is clear that the proposed process works.

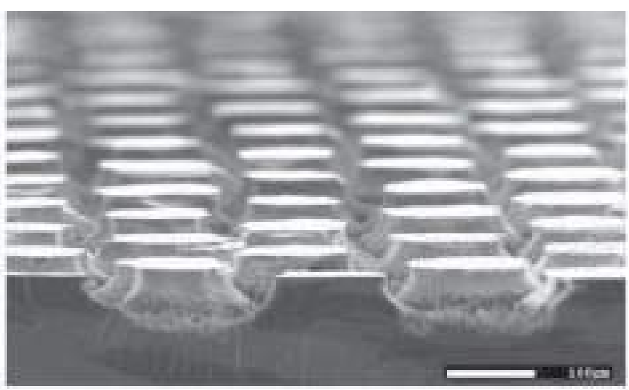

Figure 3. Mesa structures obtained at the end of the fabrication process.

CONCLUSIONS

A method to obtain silicon structures using MACE as intermediate step was presented. For the process, the porous material obtained by MACE is used as sacrificial material. Any kind of morphology can be obtained by this method; this is dictated by the pattern defined by photolithography.

REFERENCES

[1] S. Li, W., Y. Zhou, X. Chen, Y. Xiao, M. Ma, W. Zhu and F. Wei, Fabrication of porous silicon nanowires by MACE method in $HF/H_2O_2/AgNO_3$ system at room temperature, *Nanoscale Res. Lett.,* 2014, 9, 196.

[2] Z. Huang, N. Geyer, P. Werner, J. de Boor, and U. Gösele, Metal-Assisted Chemical Etching of Silicon: A Review, *Adv. Mater*. 2011, 23, 285.