Self Aligned Concentric Nanostructures Formed by E-beam Overexposure of PMMA and Single Post Processing Steps

S. Gautsch, N. F. de Rooij

Ecole Polytechnique Fédérale de Lausanne (EPFL), The Sensors Actuators and Microsystems Laboratory (SAMLAB), Neuchâtel 2000, Switzerland
and
Centre Suisse d'Electronique et de Microtechnique SA (CSEM SA), Neuchâtel 2000, Switzerland
sebastian.gautsch@epfl.ch

In order to accomplish advanced tasks, nanostructures can have complex shapes that are usually created by top down techniques with subsequent processing steps. Adding such additional steps with nanometer placement accuracy challenges even the most powerful machines and increases the process time. To overcome such limitations, smart nanostructuring methods are required for fast patterning complex shapes in single steps.

We demonstrate the ability to control the creation of self aligned nanostructures by e-beam lithography, where a central nanopillar with circular rim is created in a single e-beam exposure [1]. This characteristic shape is formed by the energy density distribution of incident and backscattered electrons [2] and reflects the dual behavior of PMMA as positive and negative e-beam resist. In addition, the high energy incident electrons have a confined heating effect on the PMMA and carbonize the polymer from top to bottom. At the same time, electrons backscattered from the underlying material will break the polymeric bonds around this carbonized region and render the PMMA soluble in developer solution.
This structure formed in PMMA serves as initial pattern for creating more advanced devices. In the first example, a metallization in planetary mode is employed to create two concentric electrodes with nanometer sized gaps. Figure 1 shows an SEM image of a cleaved nanostructure.
In a second example, RIE etching has been used to transfer the PMMA structure into bulk silicon. Figure 2 shows an SEM image of an array. The inset shows the smallest achieved structure by this technique.

We will present the different phenomenon involved in the creation of the self aligned structures and a detailed analysis of the achieved geometries. Finally, we will suggest a variety of applications covering many fields of research.

[1] S. Gautsch, M. Studer, N. F. de Rooij, Microelectronic Engineering, Volume 87, 5-8, 2010, p.1139-1142
[2] S.A. Rishton, D.P. Kern, Journal of Vacuum Science and Technology, B 5 (1),1987, 135–141.

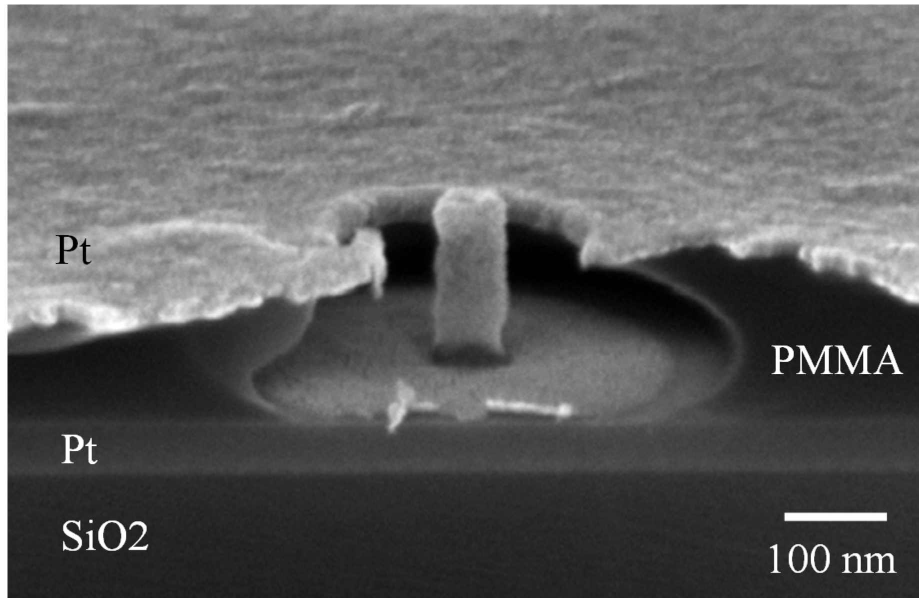

Figure 1: SEM image of a cleaved self aligned nanostructure in PMMA created by e-beam overexposure of a single dot and covered with a 20nm platinum film evaporated in planetary mode. This one-step process allows the creation of 2 concentric electrodes with 50 nm gap.

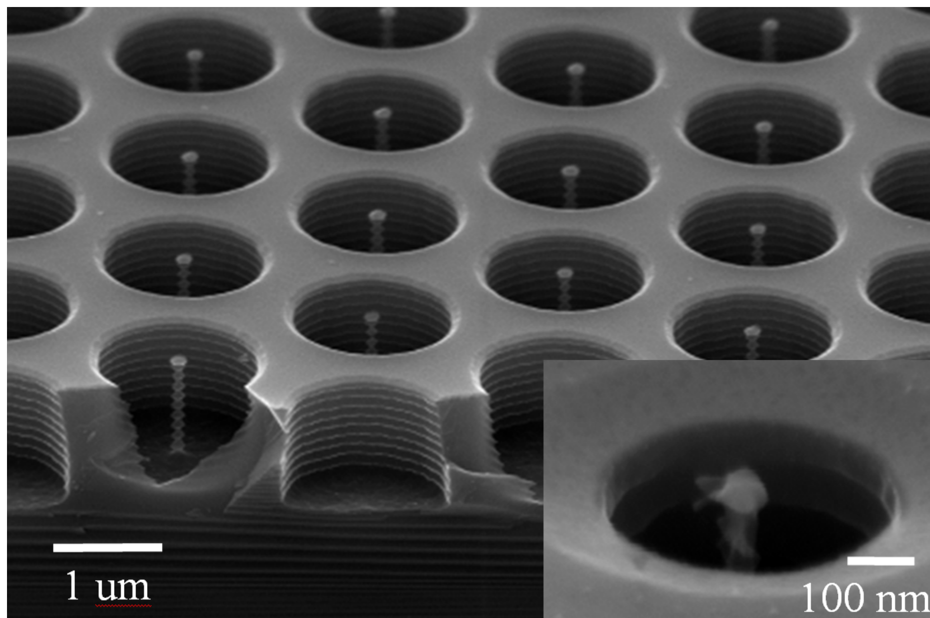

Figure 2: SEM image of a cleaved array of self aligned silicon nanostructures. The initial PMMA structure was first transferred into a silicon dioxide hard mask before using DRIE to transfer the pattern into bulk silicon. Inset shows the smallest concentric structure realized by this technique.