Porosity and Dimension Constraints of Macropore Arrays in n-doped Silicon

G. Barillaro, A. Nannini, G. Pennelli, F. Pieri
Dipartimento di Ingegneria della Informazione
Università di Pisa
Via Diotisalvi 2, 56126 Pisa-Italy

Electrochemical etching of silicon in HF-based electrolytes is a well known technique for regular macropore formation [1]. Recently, a macropore fabrication process in *n*-type silicon substrate has been demonstrated as a tool for silicon micromachining. A multitude of silicon microstructures (microwalls, microspirals, micropillars, microchannels, microtips, etc.) were presented [2]. Applications to silicon field emitter arrays fabrication [3], X-ray filters [4], photonic crystals [5] have been proposed as well. Despite the large number of publications on this topic, the limits of macropore formation process (hole dimension and spatial period, porosity variation, etc) are still debated [1, 6, 7]. Some authors state a strong dependence of hole dimension and period on the substrate resistivity [1], while others report a more relaxed dependence [6, 7]. In any case, the porosity (etched silicon to initial silicon ratio) was thought to be a constant throughout any given sample, and to depend on the etching current density only.

In this work we demonstrate that the constraints on the dimension, pitch and porosity of regular macropore arrays can be relaxed. We show that it is possible to fabricate regular macropore arrays with large variations of hole dimension (up to 500%), period (up to 400%) and porosity (several ten percent), simultaneously on the same sample.

The fabrication process is sketched in fig. 1. The starting material was an *n*-doped silicon wafer, ⟨100⟩ oriented, 2.4-4 Ω·cm resistivity. Regular patterns were lithographically defined in a thermally grown silicon dioxide layer (fig. 1a). Patterns were constituted by several square hole arrays with different characteristics (hole dimension, period, porosity) arranged side by side to form a larger array (multi-array). Three types of multi-arrays were placed on the same sample: 1) constant porosity, variable period, variable hole dimension; 2) constant hole dimension, variable period, variable porosity; 3) variable hole dimension, period and porosity. Initial seeds for electrochemical etching were created by KOH etching through the patterned silicon dioxide (fig. 1b). Electrochemical etching in HF was then used to fabricate regular macropore multi-arrays in the patterned substrate (fig. 1c).

Figure 2 shows two adjacent arrays belonging to a type 1 multi-array. Pores with about a 100% variation of hole dimension and period, and with the same porosity (about 60%) were fabricated side by side. Fig. 3 refers to the same sample (and thus the same etching current density), but for a multi-array of type 3. It is evident that the two arrays have different hole dimension, pitch and porosity (about 60% for the right array, about 70% for the left array).

The presented results allow us to state that, once the current density is given, macropore arrays with different hole dimension, period and porosity can be simultaneously fabricated on the same silicon sample, only by using a properly chosen initial pattern.

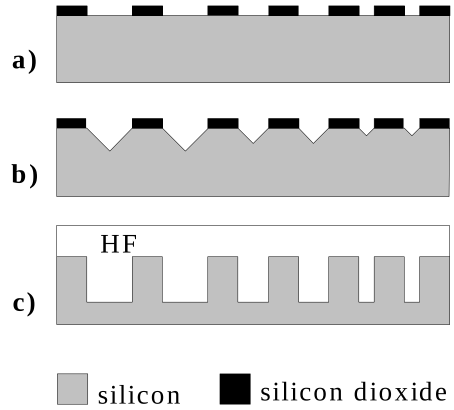

Figure 1. Macropore multi-arrays fabrication process.

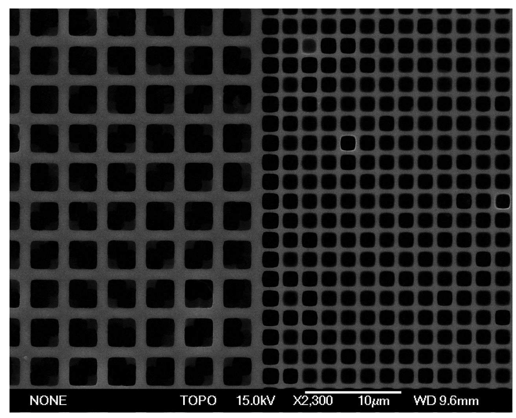

Figure 2. Two adjacent arrays with the same porosity, different period, different hole dimension.

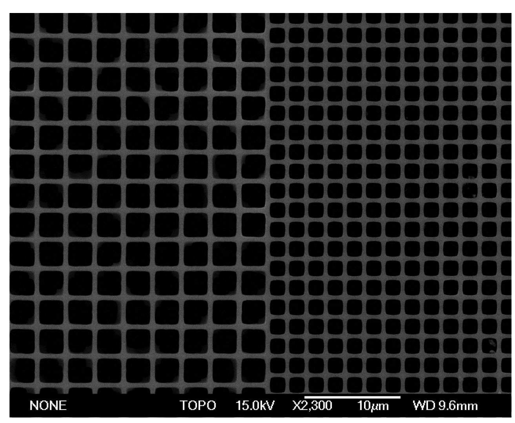

Figure 3. Two adjacent arrays with different porosity, period and hole dimension.

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