Electrochemical microstructuring of silicon surfaces for field emission enhancement.

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Enhanced field emission of electrons from silicon devices was obtained by electrochemical surface microstructuring. Columnar emitting tips are fabricated, with diameter in the 100 nanometer range and length in the 1-50 μm range, depending on the process parameters. Morphological characterizations were carried out on the basis of SEM analyses: as shown in figure 1, the columns are originated at the top of silicon pyramids. When their length exceeds a few tens of microns, they give rise to “spaghetti-like” filaments, tending to collapse in groups of a few tens, as shown in figure 2. Columns are randomly distributed on the surface, with a relative spacing of a few microns.
The preparation process is based on the electrochemical oxidation of boron-doped silicon wafers in organic solutions containing HF at concentration in the 1-5 mol/l range. The samples were back-contacted by sputtering of Al followed by annealing at 625 K in inert atmosphere. Oxidations are performed in galvanostatic regime with current density in the 1-10 $mA/cm^2$ range. Silicon resistivity is the 0.1-10 ohm cm range. A suitable series of rinsing steps is carried out in order to prevent stresses on the microstructures; after drying the samples are normally stored in air.
Electron field emission properties were characterized in vacuum ($P < 10^{-6}$ Torr). Current-voltage measurements were carried out on several samples, prepared in different conditions, in order to investigate the effects of modifications in the parameters of technological process.
Emission threshold was found to be strongly correlated with the overall charge exchanged during electrochemical oxidation (see fig. 3). In the best conditions, the threshold field for emission is shown to be lower than 11 V/μm: as shown in fig. 4, this value is favorably compared with field emission thresholds of other materials currently studied for the same application (diamond like carbon DLC and polycrystalline diamond).
This property makes silicon-based electron field emitters very interesting for application in several kind of devices, especially in the aerospace electronics.

References

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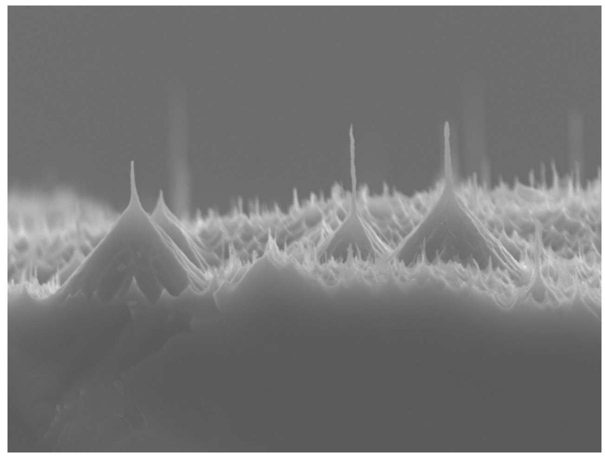

Fig 1: emitting tips at the top of silicon pyramids..

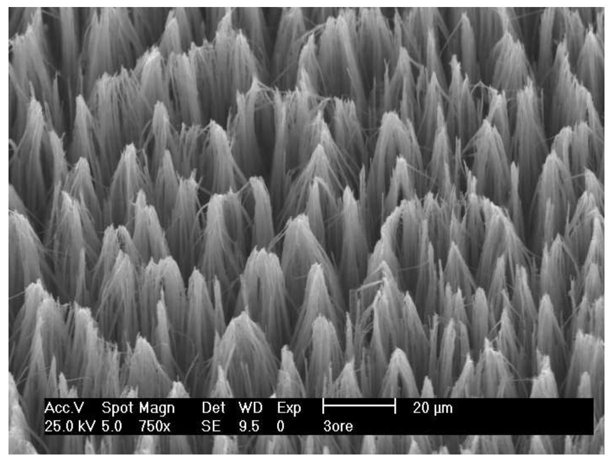


Fig 2: “spaghetti-like” silicon filaments.

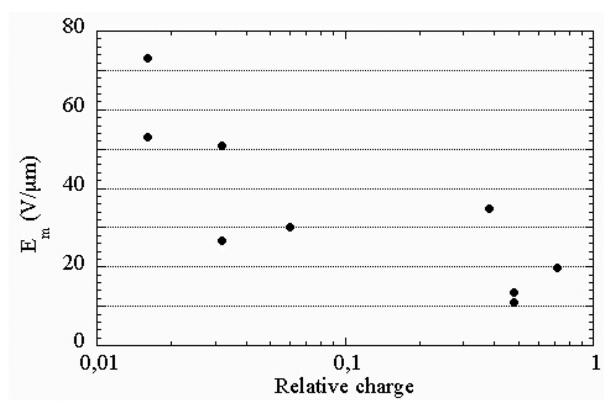


Fig 3: Emission threshold vs oxidation charge.

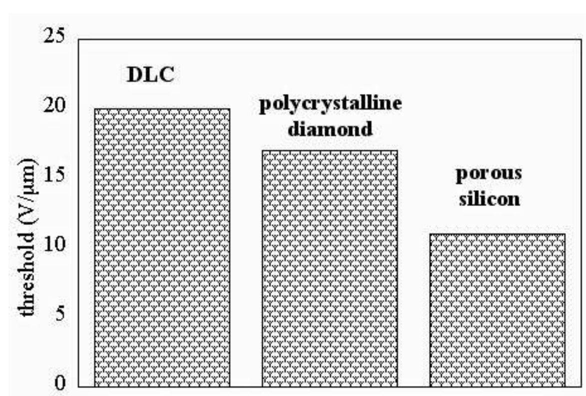


Fig 4: emission threshold for several materials.