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Single and dual ion implantation of c:Si with Fe^+ and C^+: microstructural characterization

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Microelectromecanical systems (MEMS) are devices with characteristic lengthscales between 1 mm and 100 nm that combine both mechanical and electrical functionalities [1]. Due to their small dimensions (high surface/volume ratio) surface forces such as capillarity and Van der Walls forces become predominant over the regular operation forces, that may lead to high adhesive forces between contacting surfaces causing stiction (permanent adhesion), high wear, and permanent damage of the component. Si is still the most used material for the MEMs production but, in fact it presents a poor tribomechanical behaviour which is amplified by the characteristic operational conditions of MEMS previously described. Over the years some approaches to overcome these limitations have been analysed, mainly consisting of applying different types of coatings such as DLC`s [2] and SAM´s [3] in order to change Si surface properties. Since throughout ion implantation surface properties can also be tailored, in the present work, Si <100> wafers were singly implanted with Fe^+ and C^+, and with both elements simultaneously in the same surface, at room temperature and normal incidence. The chosen fluences were between $5x10^{16}$ and $2x10^{17}$ cm^{-2}. Afterwards the samples were annealed in vacuum at 800 and 1000 ºC for 30 minutes.

FEG-SEM (JEOL 7001F), XRD and RBS characterization of the samples show that all the as-implanted samples are formed by a featureless amorphous layer with a thickness smaller than 250 nm. After annealing some differences were observed between the samples implanted with different species and conditions. The implantations of Fe^+ results in different microstructures, depending on the fluence and temperature. For the lower fluence it is always observed the formation of $\beta - FeSi_2$ nanoprecipitates after annealing at 800 ºC (Fig. 1(a)). After annealing at 1000 ºC, larger $\alpha- FeSi_2$ are formed, Fig. 1(b). For the high fluence Fe^+ implantation the microstructures change considerably, Fig. 2(a). After annealing at 1000 ºC a biphasic microstructure is observed, composed of lighter ($\alpha- FeSi_2$) and dark regions (Si with a low content of Fe^+) (Fig 2(b)). Regarding the dual implantation of both Fe^+ and C^+, for the lower fluence, an evolution quite similar to the low fluence Fe^+ was observed. For higher contents of both C^+ and Fe^+, small precipitates ($\beta - FeSi_2$) are observed after annealing at 800 ºC, Fig. 3(a), while after annealing at 1000 ºC again a biphasic microstructure can be observed with an addition of large irregular precipitates ≈ 1 μm (Fig. 3(b)).

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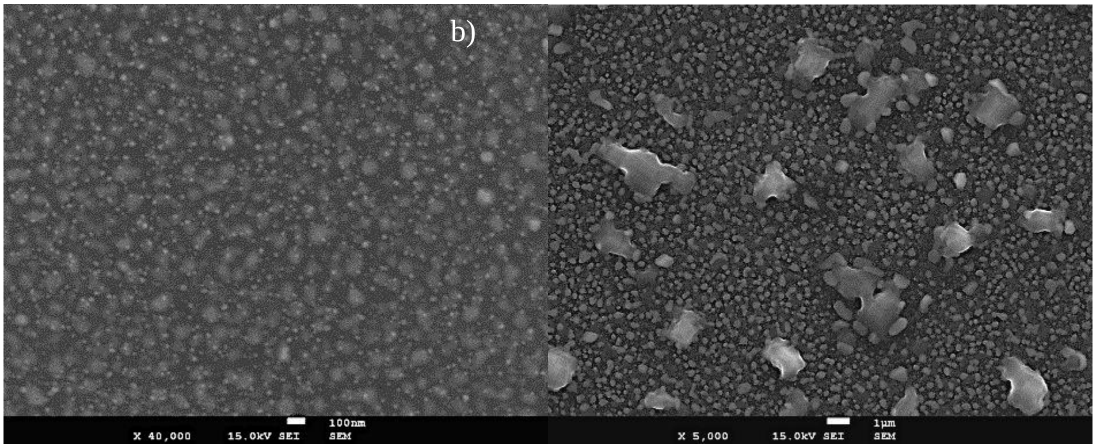

Figure 1. Micrograph of Si <100> implanted with Fe^+, $\Phi = 5x10^{16}$ cm^{-2} with energy of 150 keV´s (a) annealed at 800 ºC (b) annealed at 1000 ºC.

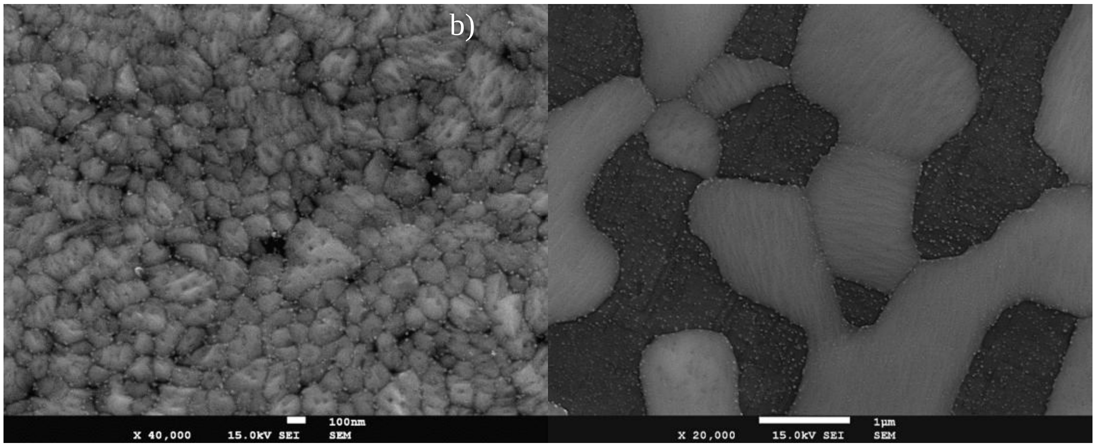

Figure 2. Micrograph of Si <100> implanted with Fe^+, $\Phi = 2x10^{17}$ cm^{-2} with energy of 150 keV´s (a) annealed at 800 ºC, (b) annealed at 1000 ºC.

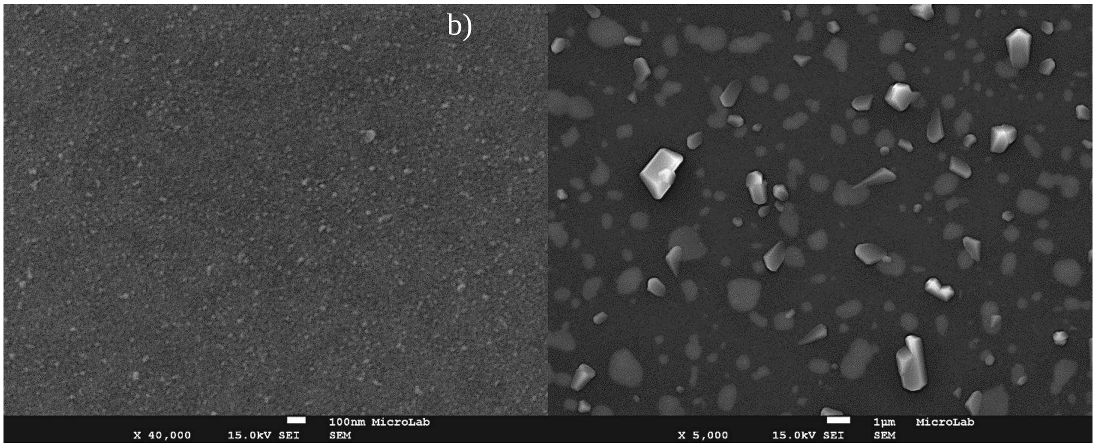

Figure 3 –Micrograph of Si <100> implanted with both Fe^+ and C^+, $\Phi = 2x10^{17}$ cm^{-2} with energy of 170 and 25 keV´s (a) annealed at 800 ºC, (b) annealed at 1000 ºC.