Control of silicon nano-crystals growth for nano-electronics devices

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To be successfully integrated in nano-electronics devices, silicon quantum dots (Si-QDs) density, size, and disposition must be controlled with a great precision. As shown on figure 1, Nanometric size crystalline silicon can be deposited on insulators by SiH_4 LP-CVD[1]. Their formation includes two steps : nucleation and growth. We study the experimental parameters which influence each step in order to improve the control of the Si-QDs morphology.
We show that the nucleation step is almost independent of the furnace process conditions : T, and carrier gas. In fact, they influence the nucleation kinetic but not its amplitude. Only the SiH_4 partial pressure influence significantly the Si-QDs nuclation. We prove that the nucleation is governed by the reactivity of the substrate with the Si precursors. On SiO_2 or Al_2O_3, OH groups are identified as nucleation sites [2]. As shown in figure 2, by controlling the OH density on the SiO_2 surface, we can monitor the Si-QDs density on more than one decade for the same process conditions. Moreover, Si-QDs density as high as 1.5 10^{12} /cm² can be obtained on chemically treated SiO_2.
On the contrary, the growth step depends mainly on the furnace process conditions. By modifying the gas phase composition, it is possible to improve the control of the Si-QDs size for a fixed density. Thus, Si-QDs with precise diameter ranging from 2 nm to 10 nm and more can be grown.
The limitation of this technique is that, because of the spontaneous character of the Si-QDs nucleation, the Si-QDs are randomly positioned at the substrate surface. We propose specific methods such as nano-manipulation by Scanning probe microscopy (SPM) and local modification of the substrate chemical properties to achieve the control of the Si-QDs positioning. Figure 3 shows a Si-QDs line realized by manipulation of the Si-QDs. We show that such line can be integrated in nano-metric devices to study the electronic transport through the Si-QDs.

[1] T. Baron, F. Mazen, C. Busseret, A. Souifi, P. Mur, M. N. Séméria, H. Moriceau, B. Aspard, P. Gentile, N. Magnea, Micr. Engin. , 61-62, 511 (2002).
[2] F. Mazen, T. Baron, N. Buffet, N. Rochat, P. Mur, G. Brémond, M. N. Séméria , J. Electr. Soc. , to be published.

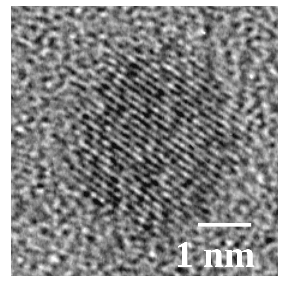
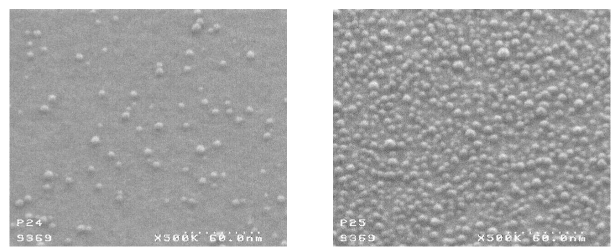


Figure 1 : High Resolution Transmission Electron Microscopy of a a single Si-QDs deposited on SiO_2.



a b

Figure 2 : Influence of chemical modification of the substrate on the Si-QDs nucleation. SEM images of Si-QDs deposited on as grown SiO_2(a) and chemically treated SiO_2 (b) in the same process conditions. The Si-QDs density are 1.7×10^{11} and 1.5×10^{12} on a and b respectively.

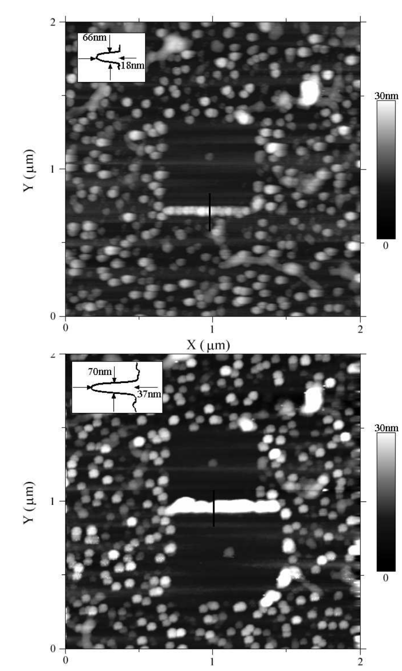


Figure 3 : Si-QDs line realized by nano-manipulation of the Si-QDs with a SPM tip.