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 SiH₄ 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 SiH₄ partial pressure influence significantly the Si-QDs nucleation. We prove that the nucleation is governed by the reactivity of the substrate with the Si precursors. On SiO₂ or Al₂O₃, OH groups are identified as nucleation sites [2]. As shown in figure 2, by controlling the OH density on the SiO₂ 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 × 10¹²/cm² can be obtained on chemically treated SiO₂.

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-meteric devices to study the electronic transport through the Si-QDs.