GROWTH OF Si AND Ge QUANTUM DOTS ON INSULATORS BY CVD

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Si and Ge quantum dot (QDs) memories are widely invoked as potential solutions to overcome the scaling limitations of conventional Flash and non volatile memories[1]. Chemical Vapor Deposition (CVD) is a promizing way to obtain QDs for industrial applications because of its MOSFET technology compatibility.

Si and Ge QDs are grown by CVD using SiH_4 and GeH_4 on thermal SiO_2, deposited Si_3N_4 and Al_2O_3.

The evolution of the nucleation growth rate of Si QDs with the inverse of temperature is plotted in Figure 1. The apparent activation energy is the highest for SiO_2, 3.8 eV, decreases for Si_3N_4, 2.8 eV, and is the lowest for Al_2O_3 surface, 1.8 eV. In Table 1, we have reported the maximum density obtained in function of the SiH_4 partial pressure. For SiO_2 and Si_3N_4 these values vary between $4.4x10^{11}$ and $6.5x10^{11}$ cm^{-2} and between $6.4x10^{11}$ and $1.3x10^{12}$ cm^{-2} respectively, whereas for Al_2O_3 it remains almost stable at 10^{12} cm^{-2}. Our Al_2O_3 presents an Al-OH surface, which could explain its particular behaviour for Si-QDs nucleation. To check the OH groups influence, we have studied the evolution of Si-QDs density with Si-OH density on a SiO_2 surface (Figure 2). We evidenced a strong increase from 4×10^{11} to 1.2×10^{12} cm^{-2} when the silanol density increases from 0.4 to 1.4 nm^{-2}. This experiment shows that the nucleation of Si-QDs is very sensible to surface silanol concentration.

The AFM picture of Ge QDs deposited on SiO_2 are reported in Figure 3. The growth time varied between 30 and 180 seconds and the diameter between 30 nm and 75 nm. The density was approximately the same among the four samples around $6x10^9$ cm^{-2}. X-Ray Photoelectrons Spectroscopy (XPS) measurements are shown Figure 4. For each level, the spectrum is splitted in two contributions related to Ge-Ge and Ge-O bonds. As the Ge-O contribution is much lower for the 3d level (high kinetic energy photoelectrons) than for the 2p level (low kinetic energy photoelectrons), we can conclude that the Ge-O contribution comes essentially from the surface of the QDs (a few nanometers). Metallic Ge concentration should be growing when going deeper to the dots center. Compared to SiO_2 substrate, the Ge QDs density on Si_3N_4 is ten times higher and can be varied between $2x10^9$ and $6x10^{11}$ cm^{-2}. The mean diameter can be adjust between 5 and more than 30 nm.

[1] De Salvo et al., IEEE Trans.Elec.Dev., 48, 1789 (2001).

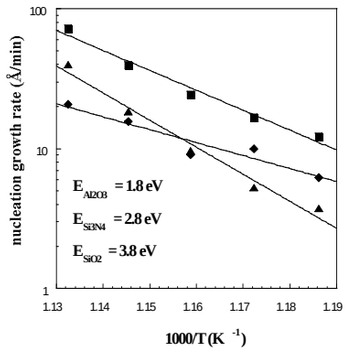

Figure 1 : Nucleation-growth rate versus the inverse of the temperature of Si dots, deposited on SiO_2 (triangles), Si_3N_4 (squares), and Al_2O_3. Activation energies are, respectively, equal to 3.8, 2.8 eV, and 1.8 eV.

Pressure (Torr)	0.035	0.12	0.2
on SiO_2 (cm^{-2})	$4.4x10^{11}$	$4.7\ x10^{11}$	$6.5\ x10^{11}$
on Si_3N_4(cm^{-2})	$6.4\ x10^{11}$	$1.3\ x10^{12}$	$9.1\ x10^{11}$
on Al_2O_3 (cm^{-2})	$9.6\ x10^{11}$	$1.2\ x10^{12}$	$9.4\ x10^{11}$

Table 1 : Evolution of the Si dots density deposited on SiO_2, Si_3N_4, and Al_2O_3 substrates with P_{SiH4}.

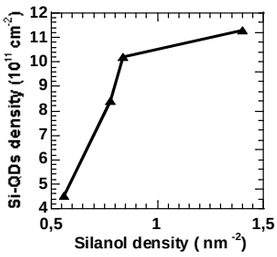

Figure 2 :Evolution of Si-QDs density versus OH density.

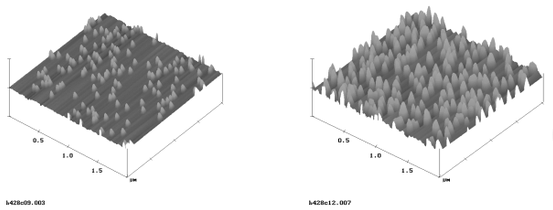

Figure 3 : AFM pictures of Ge QDs after a) 30 seconds and b) 180 seconds deposition time. The density, mean diameter and mean height are $7x10^9$ cm^{-2}, 30 nm, 25 nm and $6x10^9$ cm^{-2}, 75 nm, 50 nm.

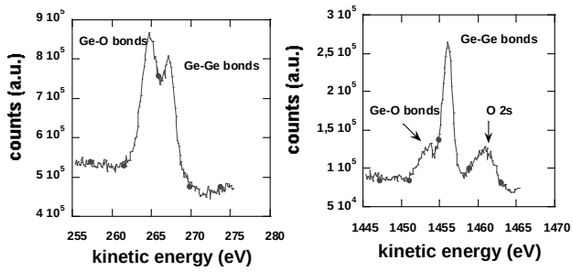

Figure 4 : XPS measurement performed on Ge QDs of 50 nm mean diameter. A) Ge2p level spectrum with great Ge-O contribution. B) Ge3d level spectrum with poor Ge-O contribution.