Silicon Nanoparticules embedded in silicon rich silicon oxinitride films for memory and photovoltaic devices

Abdelilah Slaoui, Fabien Ehrhardt, Florian Delachat, Gérald Ferblantier, Dominique Muller

ICube, CNRS-UdS, 23 rue du Loess, F-67037 Strasbourg, France

Abdelilah.slaoui@unistra.fr; phone +33 388 10 63 28; ww-iness.c-strasbourg.fr

Silicon nanoparticles (Si-nps) have been of great interest in recent decades since they can be very useful in many applications such as in data storage, lasers or photovoltaics. Most of the reported works on Si-nps embedded in a SiO_2 dielectric matrix which are often obtained upon high temperature annealing of silicon rich silicon oxide (SRSO)[1,2] while very few concerned silicon rich silicon nitride (SRSN)[3,4]. For some applications such as LEDs the choice of SRSN than SRSO is motivated by the lowest bandgap that facilitate the carrier injection through the tunneling mechanism. For photovoltaic applications, the silicon nanoparticules embedded in a dielectric matrix can be used either as a photon converters from UV to infrared or to form a meta-material with a tunable bandgap that can be used for pure tandem Si cells. In case of SRSN, it can be used as a surface passivation layer as well as an antireflection coating film in addition to be a photon converter. On the other hand, SRSO allows the formation of smaller nanoparticles thanks to the oxidation process during the high thermal annealing step needed for phase separation. An intermediate dielectric matrix such as Silicon oxynitride (SiO_xN_y) may be a good alternative since its properties can be tuned from SiO_2 to Si_3N_4.

In this work we investigate the structural properties of silicon nanoparticules as formed upon high temperature annealing of silicon rich silicon nitride (SRSN) or oxinitride (SRSON) deposited by plasma enhanced CVD method. The effect of the gas precursor type and flows on the atomic composition and the structural properties was assessed by RBS and ERDA analysis and by infrared spectroscopic measurements. The morphological and crystalline properties were investigated by TEM and Raman spectroscopy. We show that the formation of Si-nps , their size and crystalline fraction depends strongly on the silicon excess in the SiN or SiON layer. We have found that the use of an SiON matrix allows a better control of the Si-nps size for (2 – 7 nm) and that less Si_{excess} is required. The results are thoroughly discussed. The use of such structures for memory or photovoltaic devices will be presented.

[1] Wang Q., Kong G.L., Chen W.D., Dia H.W., Chen C.Y., Zhang S.B., and Liao X.B., "Getting high-efficiency photoluminescence from Si nanocrystals in SiO_2 matrix" Appl. Phys. Lett. 81, 4174-4176 (2002).

[2] Gourbilleau, F., Dufour, C., Rezgui, B. & Brémond, G. "Silicon nanostructures for solar cell applications" Materials Science and Engineering: B 159-160, 70-73 (2009).

[3] Delachat F., Carrada M., Ferblantier G., and Slaoui A., Bonafos C., Schamm S., Rinnert H., "Structural and optical properties of Si nanocrystals embedded in SiO2/SiNx multilayers" Physica E: Low-dimensional Systems and Nanostructures 41, 994-997 (2009).

[4] Wang Q., Wang Y.G., Cao L. and Cao Z.X., "High-efficiency visible photoluminescence from amorphous Si nanoparticles embedded in silicon nitride" Appl. Phys. Lett. 83, 3474-3476 (2003).