DEFECT ENGINEERING AND CONTROL IN NANOCRYSTALLINE SILICON

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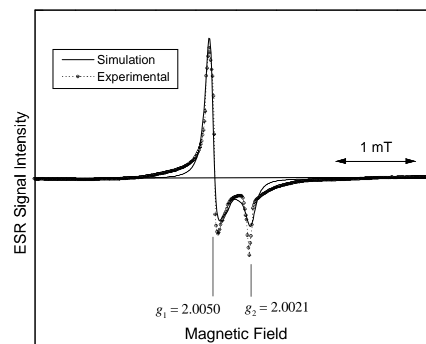
In recent years the memory cells based on the nanostructured materials have been investigated. The nanocrystalline silicon (nc-Si) is the most convenient for the integrated circuit production.
Mainly, due to the smallest sizes of nodes and cheap technology.

However, by the using nc-Si in memory cells design there are several problems. One of them is the nanocrystal spatial distribution. But the other problem is leakage current through the thin silicon oxide layer (1-2 nm).
In present work we studied the structural properties of nc-Si and defects' distribution impact on device performance. We tried to solve the problem of defect managing in silicon grain boundary by using additional annealing, hydrogen dilution by deposition and etching by means of silicon tetrafluoride gas.
We studied the nc-Si films by using Fourier-transformed infrared (FT-IR) spectroscopy, Raman spectroscopy, electron-spin resonance ESR), atomic-force microscopy (AFM), time-resolved laser picosecond spectroscopy.
ESR measurements show the appearance of floating bonds resulted in ESR signal at g=2.0055 [1]. Figure 1 shows the peaks in ESR intensity. The E'_δ paramagnetic center results in the value of Lande factor g=2.0021.The D (or P_b) centers (dangling bonds in silicon) is related to the Lande factor of ESR measurements equal tog=2.0054.
The dangling bond creation depends on the temperature as

$$N_{DB} = N_{0DB} \exp(-E_{DB} / kT)$$

where the value E_{DB} is the activation energy for dangling bond creation (or for migration). During chemical vapor deposition (CVD) process by high hydrogen dilution of silane the silicon dangling bonds are saturated by hydrogen. From previous ESR data for silicon films deposited by plasma-enhanced CVD (or PECVD) we can estimate the spin density for undoped and doped silicon films [2]. It is seen that by phosphorous doping the value of spin density increase up to the value 10^{20} cm^{-3} compare to the 10^{17} cm^{-3} for undoped silicon film.
According to the ESR data for the films deposited by PECVD at low temperature less than 300°C the Pb defects content is low, but for films deposited at 300°C the defect density is increasing. These structural properties causes the variation in several orders of magnitude the dark conductivity of samples.
By annealing the nc-Si films with significant hydrogen content (1-10 %) the hydrogen diffusion from grain boundaries increases. Because, the density of dangling bonds is, also, increases. It is necessary to note that the temperature dependence of conductivity is complicated due to the various kind of processes: diffusion process of hydrogen and bonding transformation (Si-OH→ Si-O-Si). The bonding transformation can be recognized by using spectroscopic (FT-IR) data. The Si-OH defects levels are in the range from E_c-0.26 eV to E_c-0.28 eV. But the Si-O-Si defect level reflected in electronic structure as E_c-0.14 eV, according to FT-IR data.
In conclusion, we studied the defects densities as function of hydrogen contents, conductivity properties, oxygen concentration, structural properties of films. There are many theoretical approaches in the solving of defect engineering problem [3,4]. The fundamental result of this



study is that the changing in defect spatial distribution results in conductivity due to the quantum size effect for silicon interface media.

References

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