LPCVD of Silicon Germanium poly-crystalline films

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We have developed a Low Pressure Chemical Vapor Deposition (LPCVD) process for the growth of poly-crystalline $Si_{1-x}Ge_x$ films, with $0.15 < x < 0.45$. The films were grown in ASM's Advance® 400 Series of vertical batch furnaces on 200 mm and 300 mm silicon wafers. A novel method for mixing and distributing the SiH_4 and GeH_4 process gases inside the LPCVD reactor has been used. This method solves the issues on film uniformity that are inherent to conventional gas distribution systems. Results of the process development, including film composition and surface morphology, as well as the reactor design and its principles are described in detail.

Accurate film thickness and film composition are determined by using Rutherford Backscattering Analysis (RBS). In Figure 1 RBS results from a 155 nm thick Poly-Si film are given, obtained by scattering 2 MeV He ions of the sample. The film was deposited on a 300 mm Silicon wafer. The figure shows both the film thickness as well as Ge concentration within a 300 mm wafer located in the center of the vertical batch furnace.

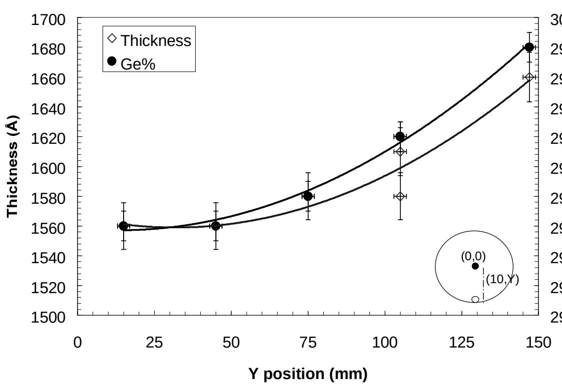

Figure 1. Within Wafer Ge concentration (right axis) and Film Thickness (left axis) as a function of position on the wafer. Film thickness and composition were determined by Rutherford Backscattering Analysis.

With our novel method of gas injection we are able to control the furnace at the same temperature over it's 5 internal zones allowing for the film to grow on each wafer inside the furnace with the same deposition rate. This results in very uniform films on all wafers distributed across the furnace as illustrated in Figure 2. The 5 wafers were distributed equidistant over the 100 product waferload. The figure also shows excellent so-called Run-to-Run uniformity since the data of three consecutive runs are plotted in the graph. The Ge% as measured by RBS amounts to an average value of 28.8 ± 0.4%, the film thickness is not plotted.

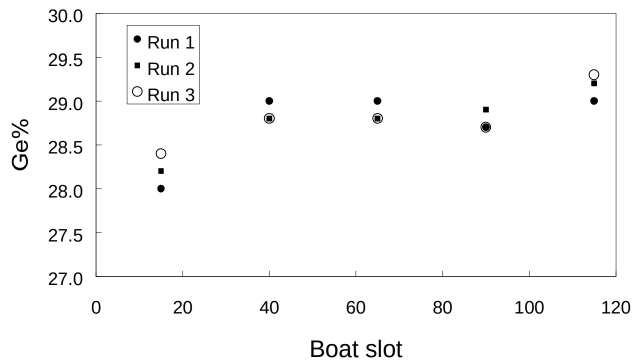

Figure 2. Ge concentration measured for three different runs. The films were deposited on 5 wafers distributed along the wafer carrier ('boat') inside the vertical furnace.

The crystal structure of the films was investigated by means of X-ray Diffraction. In Figure 3 an example of a typical Theta-2Theta scan is given. These films were also deposited on 300 mm wafers.

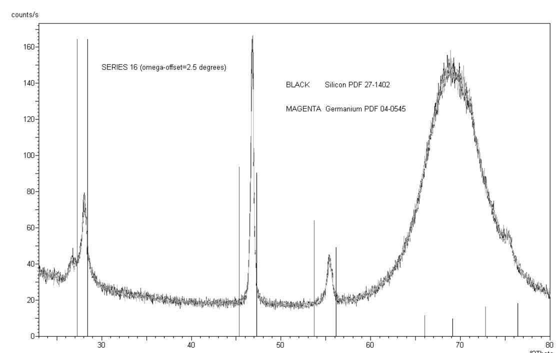

Figure 3. XRD analysis of samples taken from 3 different 300 mm test wafers distributed over the 100 Product waferload inside the vertical furnace. The three 'small' diffraction peaks arise from the polycrystalline $Si_{70}Ge_{30}$ films with no detectable difference between the wafers.

Grain size formation and surface roughness are essential parameters to control within the limits required by the gate application of these films in deep sub-micron CMOS. We have investigated these parameters by using high resolution scanning electron microscopy (SEM).

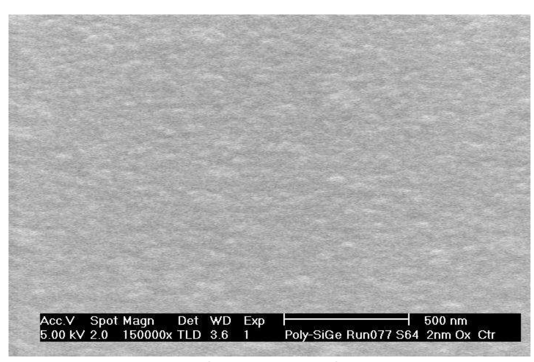

Figure 4. SEM analysis of a $Si_{70}Ge_{30}$ film grown on a 200 mm wafer showing a void free and smooth film. The SiGe layer was deposited on a 2 nm thin furnace Gate Oxide by depositing an extremely thin (less than 1 nm) amorphous silicon seeding layer.