Epitaxial Growth of $Ge_{1-x}Sn_x$ with high Sn content by Reduced Pressure CVD

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The most promising route towards photonic integrated circuits on Si relies on the development of appropriate group IV semiconductors, such as (Si)GeSn alloys. At high Sn contents these alloys present a direct energy band-gap [1] which is the requirement for efficient light emitters and detectors. Moreover, (Si)GeSn layers may act as buffer layers to introduce tensile strain in Ge [2] for high mobility channels of high performance MOSFETs. However, synthesizing these alloys is very challenging, because of the low solid solubility of Sn in Ge of about 1 at.%.

We are investigating epitaxial $Ge_{1-x}Sn_x$ layers grown by low temperature Reduced Pressure CVD using an AIXTRON Tricent® cold wall system with a showerhead technology [3]. Ge_2H_6 and $SnCl_4$ are employed as Ge and Sn precursors and N_2 as carrier gas. At a reactor pressure of 60 mbar the $Ge_{1-x}Sn_x$ layers were grown at susceptor temperatures between 375 - 475°C. The layers were studied by Rutherford Backscattering/Channeling (RBS/C) and Transmission Electron Microscopy (TEM) to analyze the layer stoichiometry, thicknesses and crystal quality. XRD measurements and Raman spectroscopy are employed to measure the strain status of the structures.

$Ge_{1-x}Sn_x$ layers were grown on Si(100) substrates and Ge buffer layers at different growth temperatures and Sn precursor fluxes in order to investigate GeSn growth properties on different substrates. In Fig. 1(a) the Sn concentration, measured by RBS, is shown as a function of the partial pressure ratio of Ge_2H_6 and $SnCl_4$ for layers grown at 475°C on Si(100). It is found, that decreasing the partial pressure ratio the Sn concentration increases from 1.8 % to about 18 %. However, SEM and RBS analysis reveal Sn segregation at these growth conditions for $x > 1.8$ %. Using this optimized partial pressure ratio and decreasing the growth temperature to 375°C single crystalline layers with Sn concentration up to 10 % were grown (Fig.1b). Minimum yield values χ_{min} of 20 % prove a substitutional fraction of Sn atoms of about 80 %. The GeSn growth is significantly improved in terms of crystal quality and surface roughness using Ge buffered Si(100) substrates. Figure 2(a) shows RBS random and aligned spectra of a partially relaxed 195 nm thick $Ge_{0.925}Sn_{0.075}$ layer grown on a Ge buffer layer. Both, high crystal quality and a high substitutionality of Sn > 90 % are proved by a χ_{min} of 6 %. Raman spectra for three $Ge_{0.925}Sn_{0.075}$ layers with thicknesses of 30 nm, 90 nm and 195 nm are presented in Fig. 2b. As a reference for the Ge-Ge modes a spectrum of Ge bulk sample is shown in black. The Raman shift towards lower wavenumbers for increasing layer thickness is due to the strain relaxation. This is confirmed by the TEM image in Fig. 3. For the partially relaxed $Ge_{0.925}Sn_{0.075}$ layer dislocations are visible at the GeSn/Ge interface. FWHM values of about 4 cm^{-1} indicate high crystal quality. Moreover, the TEM image of the 30 nm thick $Ge_{0.925}Sn_{0.075}$ layer (Fig. 3) shows no dislocations at the GeSn/Ge interface, indicating pseudomorphic GeSn growth on Ge(100).

References

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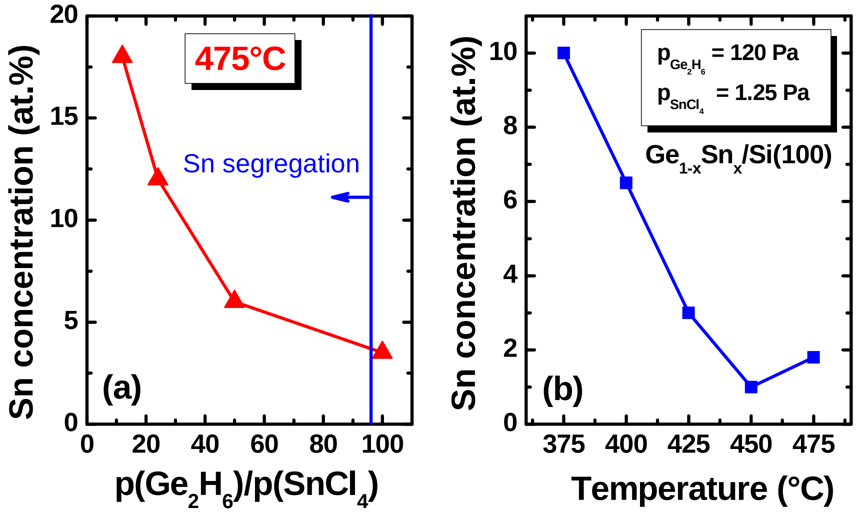

Fig. 1 (a) Sn concentration as a function of the partial pressure ratio of Ge_2H_6 and $SnCl_4$ grown at 475°C on Si(100). For smaller ratios, strong Sn segregation is observed. (b) Sn concentration as a function of growth temperature at a fixed partial pressure ratio.

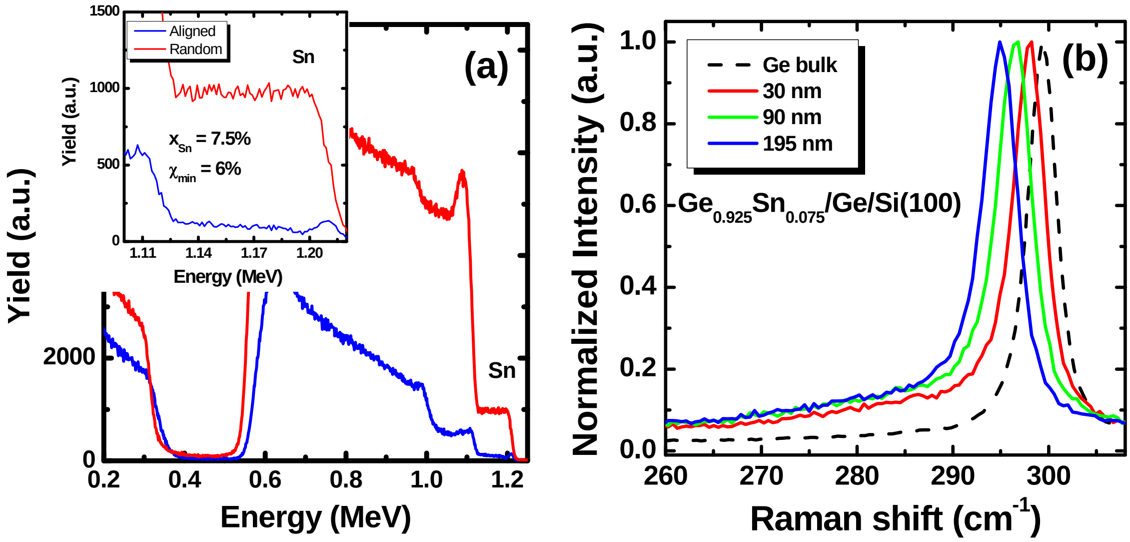

Fig. 2 (a) Rutherford Backscattering (RBS) random (red) and aligned spectra and (b) Raman modes for three $Ge_{0.925}Sn_{0.075}$ layers grown on a 600 nm thick Ge buffer layer.

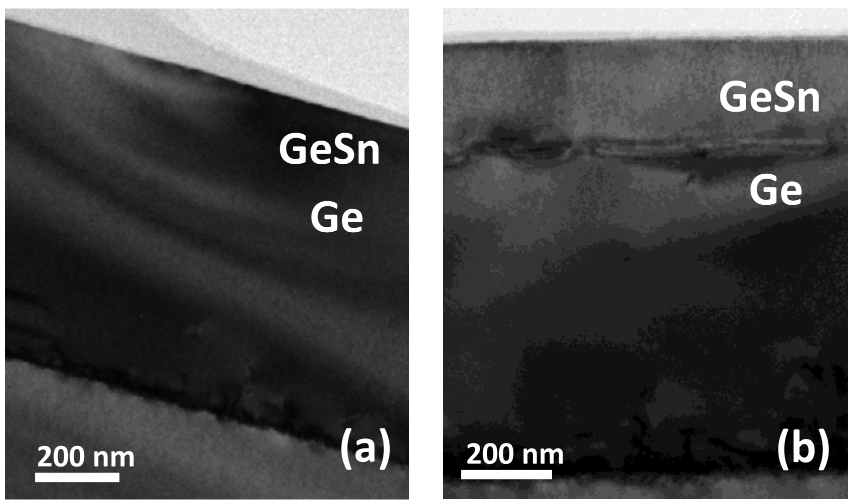

Fig. 3 TEM images of a (a) fully strained 30 nm thick $Ge_{0.925}Sn_{0.075}$ layer and a (b) relaxed 195 nm thick $Ge_{0.925}Sn_{0.075}$ layer grown on a Ge buffer layer.