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INELASTIC LIGHT (RAMAN) SCATTERING FROM CONFINED PHONOS IN STRAINED SHORT–PERIOD (001) Si/Ge SUPERLATTICES

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Abstract: We have observed confined optical LO and TO–like modes and a series of sharp excitations below the optical modes of the Si by inelastic light (Raman) scattering in strained short–period Si/Ge superlattices, lattice matched to relaxed Ge buffer layers on Si (001).

Introduction: The periodic structure of superlattices (SL's) affects strongly the bulk phonons of the constituents of the SL, resulting in folded LA phonons and strain shifted confined and quasi–confined LO phonons in Si/Ge SL's (1). Phonons of short–period Si/Ge SL's have been recently observed by Raman scattering (1,2). The effect of strain and confinement on the LO phonons of the SL has been separated in a number of Si/Ge SL's with different strain distributions and periods (1). We restrict our discussion in the following to confined phonons in SL's with thin Si layers, taking as an example a Si_2Ge_7 SL grown on a relaxed Ge buffer on Si (001).

Experimental: The crystalline quality of the MBE grown Si_2Ge_7 SL with 80 periods has been examined by Rutherford Backscattering (RBS) and channeling (χ = 6.5%) and by X–ray diffraction indicating pseudomorphic growth. Raman measurements were performed at 10 and 300 K in backscattering geometry ($z(x+y,all)\bar{z}$) in a helium atmosphere using an Argon laser with 50 or 100 mW power.

Discussion: The confinement of the LO phonons in the Si sublattice results from the fact that the phonon spectrum of Ge lies completely in the acoustic phonon spectrum of Si. Figure 1.a) shows a Raman spectrum of a Si_2Ge_7 SL in the energy range beyond the phonon spectrum of Ge. The excitation at 470 cm^{-1} is assigned to the confined LO phonon in the Si layers by subtracting the calculated strain–shift of the Si LO–like phonon (for strain of 4% : 31 cm^{-1}) (4) and the confinement shift of a two monolayer (ML) thick Si–layer (20 cm^{-1}) from the energy of the bulk Si LO phonon (520 cm^{-1}). The strong excitation at 400 cm^{-1} is related to interfacial bonds of the layers. Raman spectra of SiGe alloys (3) or relaxed alloy buffer layers on Si (001) show in the same spectral region similar excitations. But density of state effects reflected in the broader line shape of the two excitations observed in the alloy are absent in the SL. The strong intensity of the interface excitation can be related to resonance enhancement. This is confirmed by changing the incident photon energy. We conclude that alloying effects are not dominant in our Si_2Ge_7 SL.

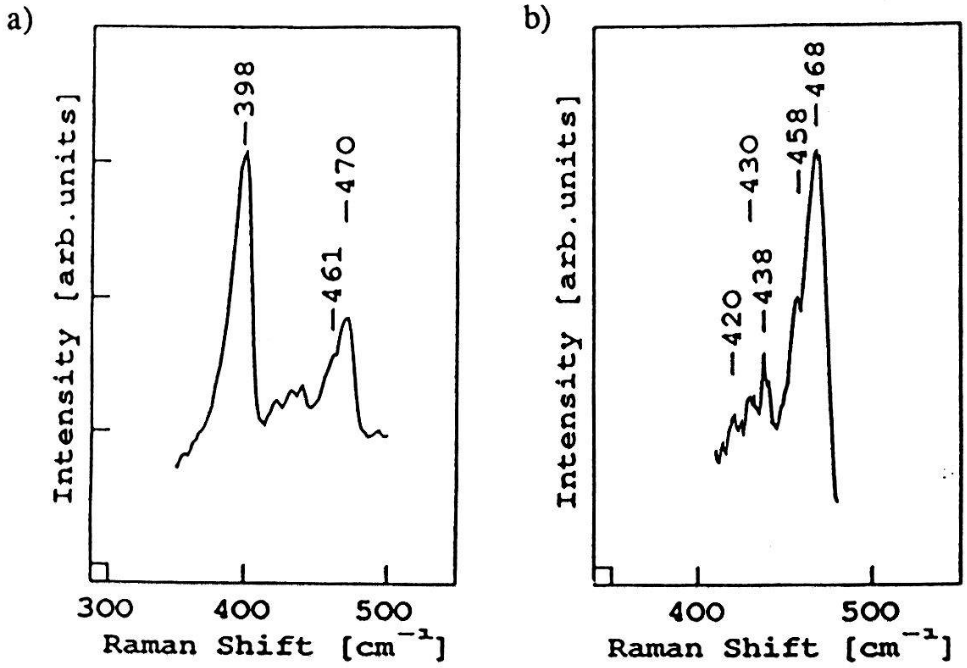

Fig 1.
Raman spectra of Si_2Ge_7 (Nr. 257) at 10 K and 514 nm from the Si optic phonon region.

Figure 1.b) shows the structure between the two main excitations seen in figure 1.a) in more detail. One clearly observes three sharp excitations and a splitting of the Si LO–like excitation. We assume that transversal excitations become possible in backscattering geometry through thickness fluctuations and interface roughness breaking momentum conservation. The excitation at 457cm^{-1} can then be explained by taking strain (20 cm^{-1}) and confinement (40 cm^{-1}) of the Si TO–like phonon into account (4). The remaining three peaks fall below the X edge of the TO phonons and in the gap of the TO and TA phonons of Si. It is interesting to note that the tensile strained Si layers of very thin thickness show distinct excitations. A more detailed discussion will follow in the future.

References:

1. W. Bacsa, M. Ospelt, J. Henz, H. von Känel, P. Wachter, Helv. Phys. Acta, Vol. 62, 211 (1989) and Refs. therein
2. E. Friess, H. Brugger, K. Eberl, G. Krötz, G. Abstreiter, Sol. St. Comm. Vol. 69, No. 9, 899 (1989) and Refs. therein
3. M.A. Renucci, J.B. Renucci, M. Cardona, Proc. of the 2nd Int. Conf. on Light Scattering in Solids, ed. M. Balkanski, Flammarion, Paris 1971, p. 326
4. F. Cerdeira, C.J. Buchenauer, F.H. Pollak, M. Cardona, Phys. Rev. 5, 580 (1972)