Determination of Raman Efficiency in SiGe Alloys

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Raman spectroscopy is an effective tool for the determination of composition and strain properties of bulk and structured SiGe alloys[1,2] but, despite of the several fundamental studies and the applicative importance, a systematic measurement of the Raman efficiency as a function of excitation wavelength and concentration is still lacking. Only two accurate measurements of the Raman cross section in pure bulk Si[3] and Ge[4] are present in the literature, while other two works report few data for alloys with composition values x equal to 0.77 and 0.6.[5,6] Moreover, these data cannot be directly compared. The knowledge of the dependence of the Raman cross section on composition at given wavelength is nevertheless fundamental for the interpretation of spectra from inhomogeneous samples, such as multilayers or self-assembled nanostructures.[7-10]

In this work, for several excitation wavelengths (364, 402, 458, 488, 532 and 633 nm), the Raman cross section of bulk $Si_{1-x}Ge_x$ alloy has been obtained as a function of the composition in the whole range from pure silicon to pure germanium.

The sample was a graded SiGe buffer grown on a (001) silicon wafer by low-energy plasma-enhanced chemical vapor deposition. The local composition in the graded buffer varies linearly with the thickness from pure silicon to nearly pure germanium. The sample was cleaved along a (110) surface. The measurement of the Raman efficiency was performed by scanning the graded layer along the growth direction, with the use of a micro-Raman spectrometer in backscattering configuration, moving with steps of 0.3 microns, corresponding to intervals $\Delta x = 0.02$ in composition. The intensity of each spectrum was corrected by taking into account the optical absorption and reflection, as well as the instrumental efficiency. The result was a series of curves of the Raman efficiency as a function of composition for several excitation energies.

As in silicon[3] and germanium[4], several resonant peaks were observed in correspondence of the predicted energies of the direct electronic transitions E_1, $E_1+\Delta_1$ and E_0, $E_0+\Delta_0$. The occurrence of the resonance peaks is plotted in Figure 1.

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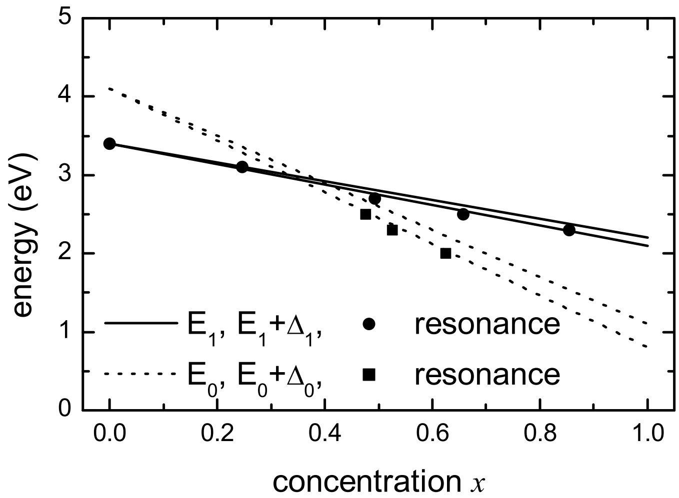

FIGURE 1. Plot of the the E_1, $E_1+\Delta_1$ and E_0, $E_0+\Delta_0$ direct electronic transitions[11] in SiGe as functions of composition. For each value of the excitation light energy, the dots show the composition values corresponding to the observed resonance peaks.

At fixed wavelength, the Raman cross section at the $E_1/E_1+\Delta_1$ resonating composition is enhanced for a factor between one and two orders of magnitude with respect to the composition values far from resonance; the half width at half maximum of the resonance bands is in the order of $\Delta x \approx 0.15$. Moreover, we found that the amplitude of the resonance in pure Si is more than four times the maximum value of the efficiency in $Si_{1-x}Ge_x$ with x=0.5. The resonances and their relative amplitudes are discussed in terms of variation of the electric susceptibility for the E_1 and the $E_1+\Delta_1$ transitions.

The results of this work can be used to design resonant experiments for the selective characterization of different regions in inhomogeneous samples. As a case study, we will present a structural characterization of self-assembled nanoislands.

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