# TEMPERATURE-DEPENDENT LAYER THICKNESS OF GE/SI SUPERLATTICE DETERMINED BY FOLDED ACOUSTIC PHONON

C.-H. Lin[1], C.-T. Chia[1*], H. H. Cheng[2]

[1]Dept. of Physics, National Taiwan Normal University, Taipei 116, Taiwan ROC
[2]Center for Condensed Matter Science, National Taiwan University, Taipei 106 Taiwan ROC

We have performed the temperature-dependent Raman spectra of MBE grown Ge/Si superlattice[1] with different excitation energy, $Ar^+$ ion, second harmonic YAG (532 nm) and He-Ne lasers. Folded acoustic phonons due to the Ge/Si superlattice were observed, and the correspondent Raman shifts are well explained by the Rytov's theory, as shown in Fig. 1. At room temperature, the thickness of Si and Ge layers deduced from Rytov's theory [2] are about 175 Å and 24.5 Å respectively, which is consistent with the estimated thickness form the TEM image. The dispersion relation of folded acoustic phonon obtained from Rytov's theory can be expressed as

$$\cos(qd) = \cos\left(\frac{\omega d_1}{V_1}\right)\cos\left(\frac{\omega d_2}{V_2}\right) - \frac{1}{2}\left(K + \frac{1}{K}\right)\sin\left(\frac{\omega d_1}{V_1}\right)\sin\left(\frac{\omega d_2}{V_2}\right) \quad (1)$$

where $q$ is the wave vector of acoustic phonon, $d$ (=$d_1$+$d_2$)is the period of superattices, $\omega$ is the frequency of acoustic phonon, and $V_1$ and $V_2$ and $d_1$ and $d_2$ are the sound velocities and thickness for the Si and Ge layers, respectively. The parameter $K$ is $\rho_1 V_1 / \rho_2 V_2$, where $\rho_1$ and $\rho_2$ are densities for the Si and Ge layers, respectively.

The Raman intensities of folded longitudinal acoustic phonons ratio for the folded acoustic phonon con be described by [3,4,5]:

$$I_m \propto \omega_m (n_m + 1) \frac{\sin^2\left(m\pi \frac{d_1}{d}\right)}{m^2 \pi^2} \quad (2)$$

where $I_m$ is the intensity of the folded acoustic phonon which has $m$ quantum parameter, and nm is the Bose-Einstein factor. The fitting result is shown in Fig. 2.

The temperature-dependent Raman profile are analyzed by using equation (1) and (2), and the fitting result is shown in Fig(2). We can determine the thickness variation of both Si and Ge layers due to thermal effect can be determined accurately.

1. H. H. Cheng, C. T. Chia, V. A. Markov, X. J. Guo, C. C. Chen, Y. H. Peng, C. H. Kuan, Thin Solid Films **369,** 182~184(2000).
2. S. M. Rytov, Akust. Zh. **2**, 71(1956) [Sov. Phys. Acoust. **2**, 67(1956)].
3. C. Colvard, T. A. Gant, and M. V. Klein, Phys. Rev. B, Vol. **31**,2080 (1984).
4. G. Höhler, Karlsruhe, *Phnon Raman Scattering in Semiconductors, Quantum Wells and Supperlattices,* P. 69-74.

5. V. F. Sapega, V. I. Belitsky, T. Ruf, H. D. Fuchs, M. Cardona, and K. Ploog, Phys. Rev. B, Vol. **46**,16005 (1992).

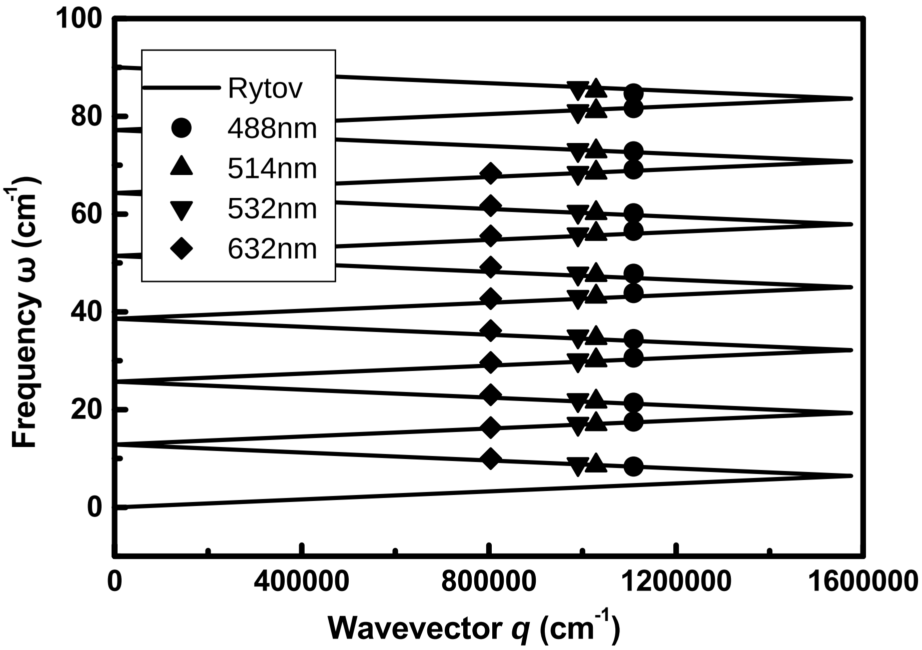


Fig. 1. Rytov theory compare with the experimental measurement of Raman shift of folded longitudinal acoustic phonons.

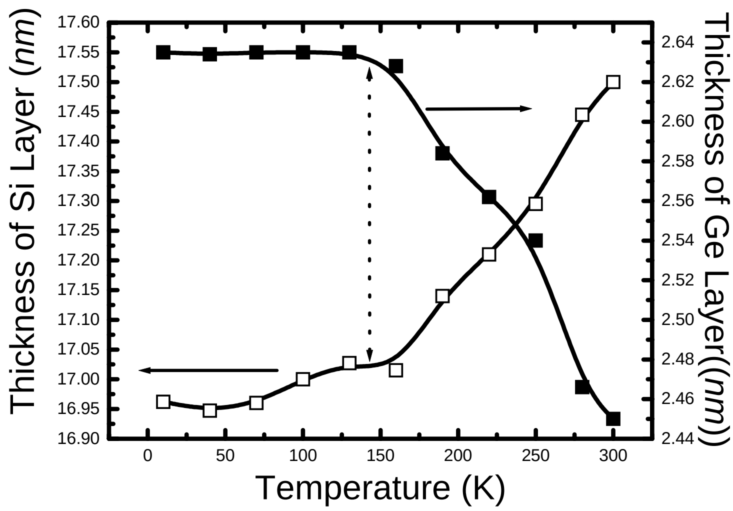


Fig. 2.The thickness of Si and Ge layers ploted vs. temperature.