Raman Scattering Study of *GaAs* grown on Porous Si by Molecular Beam Epitaxy

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GaAs was grown on Porous Silicon (PS) by Molecular Beam Epitaxy. Scanning Electron Microscopy (SEM) revealed *GaAs* wire formation on PS with averaged lengths of 5 μm and diameters of 80 nm. Raman Spectroscopy of these *GaAs* films showed the presence of two additional modes, located between the LO and TO modes. These modes are interpreted as *GaAs* surface phonons.

I. Introduction

Epitaxial growth of *GaAs* layers on silicon has been the subject of increasing interest since such a system provides the promising for utilizing the benefits of *GaAs* devices with the advantages of Si substrates. However, the large lattice mismatch, the differences between *GaAs* and Si thermal expansion coefficients make high-quality *GaAs* films difficult to grow. In order to try to reduce this difficulty we have grown *GaAs* films on Porous Si substrates by Molecular Beam Epitaxy (MBE). Porous Silicon (PS) consists of an array of randomly spaced pores and a coherent assembly of small crystallites with dimensions ranging from 25 to 80 Å. The PS can be considered a flexible material when the thermal expansion coefficients are relaxed due to the large misfit. The presence of defects in PS layer still exists at the *GaAs*/PS interfaces. The Scanning Electron Microscopy (SEM) pictures of these samples revealed that the growing had occurred in the shape of cylindrical and disordered "wires". We then realized their Raman spectra and no measurable stress between *GaAs* and PS was detected. The same measurements, however showed the existence of additional modes that can be associated to *GaAs* surface phonons.

II. Experimental procedure

II.1. Porous Si preparation and *GaAs* growing

The substrates used were (111) oriented, $10\,\Omega\,cm$ resistivity, boron-doped, p-type silicon. The anodization was carried out using 25 % HF solution in H_2O, at current density of $30\,mA/cm^2$ for $5\,min$. After etching, wafers were rinsed in ethanol and dried in ambient air. All samples exhibited visible photoluminescence at 300 K.

After the electrochemical preparation the PS was bonded by In in a molybdenum block and loaded in the lock-in lock system of MECA 2000 MBE installation. The *GaAs* epitaxial layers were prepared in two steps.

The preparation starts by heating PS under *Ga* flux for $2\,min.$ at $750°C$ in order to desorb the native oxide. Afterwards the *Ga* shutter was closed, and the heating process continued for $20\,min.$ in order to evaporate the *Ga* metal. The substrate temperature T_s was then lowered and the first step was initiated by depositing a $0.2\,\mu m$ buffer layer of *GaAs* at 200^0C with growth ratr of 0.1 μm/h, followed by a 5 min. annealing at 550^oC under As flux.

11.2. Raman scattering experiments

The Raman spectra were recorded at room temperature and at 80 K using the 5145 Å line of an argon ion laser as the excitation source. The scattered light was dispersed in a Jobin-Yvon U1000 double spectrometer and detected using standard photon counting technique. The measurements were performed either in a backscattering geometry or at grazing incidence, the spectral resolution being 1.5 cm^{-1}. Laser power of 200 mW was used. The laser polarization was kept parallel to the sample surface, but the scattered light was not analysed.

III. Experimental results

The surface structure of the epitaxial layer at low magnification in tlie SEM is shown in Fig. 1. The epitaxial layers have variable size island structures. The wires of GaAs appear at 400°C growth temperature with 5 μm length crystals. and diameter of 80 nm at tlie top.

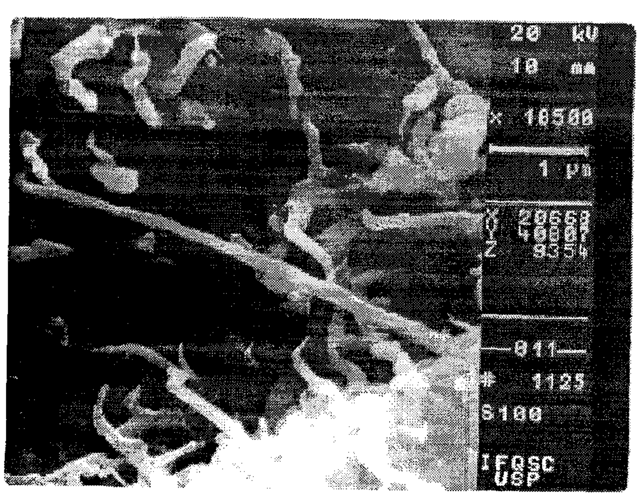

Figure 1: SEM view of a typical sample of $GaAs$ grown on porous Si, showing wires of averaged lenghts of 5.0 μm and diameters of 80 nm.

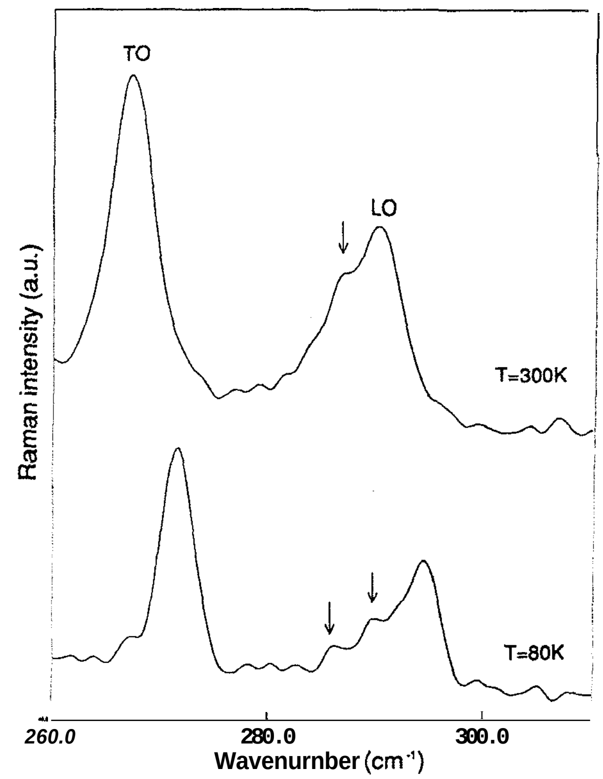

Figure 2: Raman spectra of $GaAs$ on PS, at room temperature and at 80 K.

Raman scattering of these samples were realized at room temperature (Fig. 2) and presented, as expected, both *GaAs* TO and LO phonon modes, as the GaAs wires showed no preferential orientation. No shifts were dctected in these lines that could be associated with strain between GaAs and PS. It is however noticeable the presence of a "shoulder" in the left part of the LO line, with its maximum around 287 cm^{-1}. This additional line pcrsisted for all the measurements made at this teinperature.

Lowering the temperature until 80 K (spectrum also showed in Fig. 2), we could notice that this feature was resolved in two lines, located at 290.0 and 286,2 cm^{-1}. The hypothesis of phonon coiifiiieinent. expected for nanostructures[1] was considered but neglected, since for this we should have wires with diameters around 10 nm, not observecl from the SEM pictures.

A possible explanation for our results is given by the model of Ruppin and Englman[2] for the phonon behavior of finite crystals. According to them, for these crystals a series of modes exist with tlie characteristics of surface modes. For cylindrical samples, their frequencies depend on the cylinder radius and on the dielectric constant of the adjacent surrounding medium, but they are always located between the TO and the LO phonons of the bulk. An observation quite similar to ours was made by Watt et al[3] in the Raman spectra obtained from an array of *GaAs* cylinders fabricated using electron beam lithography. For cylinders typically with diameters of 80 nm, and heights of 310 nm, they observed a broad mode around 288 cm^{-1}, at room temperature, in close agreement with our observation. They did the experiments only at room temperature. The authors in ref [3] used the model proposed in ref [2] in order to calculate the lowest order surface phonon frequencies as a function of the cylinder radius. The agreement between the phonon frequency observed and the theoretical curve is very good, as an evidence that it can be assigned to a surface phonon.

In our experiments as stated before, the low temperature spectrum revealed the splitting in two well resolved modes around the original value and we believe that his fact could mean the appearance of a higher order surface phonon, as previewed in ref. [3].

In conclusion, we have studied the *GaAs* grown on porous *Si* using Raman Spectroscopy. Due to the appearance of very fine *GaAs* wires in these samples, surface phonons could be observed.

Acknowledgements

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