Functional Materials 9, No.2 (2002) © 2002 — Institute for Single Crystals

Study of mechanical strain in $Si_{1-x}Ge_x$ layers using Raman spectroscopy

V.V.Artamonov, M.Ya.Valakh, V.N.Dzhagan, R.L.Politansky, V.O.Yukhimchuk*

Institute of Semiconductor Physics, National Academy of Sciences of Ukraine, 45 Nauki Ave., 03028 Kyiv, Ukraine
*Tchernivtsi National University, 2 Kotsyubinsky St., Tchernivtsi, Ukraine

Received June 15, 2001

Raman spectroscopy has been used to study mechanical straines in $Si_{1-x}Ge_x$ layers obtained by epitaxy and implantation of Ge^+ ions into Si substrate. The doping of $Si_{1-x}Ge_x$ layer during its growth has been shown to result in partial strain relaxation. The buried $Si_{1-x}Ge_x$ layers obtained by Ge^+ ion implantation into Si substrate followed by high-temperature annealing have been found to be fully strained.

С помощью спектроскопии КРС исследованы механические напряжения в $Si_{1-x}Ge_x$ слоях, полученных методами эпитаксии и имплантации ионов Ge^+ в кремниевую подложку. Показано, что легирование $Si_{1-x}Ge_x$ слоя во время его роста приводит к частичной релаксации механических напряжений. Установлено, что скрытые $Si_{1-x}Ge_x$ слои, полученные имплантацией ионов Ge^+ в кремневую подложку с последующим высокотемпературным отжигом, являются полностью напряженными.

Silicon-germanium solid solutions are used in various diodes, transistors, high-sensitivity IR radiation detectors, etc. Recently, the $Si_{1-x}Ge_x/Si$ system draws even more attention in connection with studies of self-organized $Si_{1-x}Ge_x$ nanoisland growth on silicon substrates [1]. A considerable mismatch between Ge and Si lattice parameters (4.12 %) results in that mechanical strain arise in Si–Ge thin layers obtained by pseudomorphic epitaxial growth on Si substrates. Those strain become relaxed in the course of subsequent growth or annealing. The strain relaxation takes place due to mismatch dislocation generation at the phase interface when the critical epitaxial layer thickness is exceeded. The presence of dislocations in the epitaxial layer deteriorates considerably its characteristics or makes it fully unsuitable for use in electronic and optoelectronic devices. To overcome this problem, various methods are used, such as $Si_{1-x}Ge_x$ film growing on buffer layers referred to as gradient ones [2], doping of $Si_{1-x}Ge_x$ films by carbon atoms [3], implanting hydrogen ions into the film [4], treatment in low-temperature RF plasma, etc.

The use of strained dislocation-free $Si_{1-x}Ge_x$ layers is of its own promises. In particular, the strain of a specific value and sign may cause increased charge carrier mobility [5]. The study of the strain value and spatial distribution as well as of their relaxation mechanisms will make it possible to develop novel technologies for growing such structures and to improve their characteristics. The purpose of this work was to study the internal mechanical strain in $Si_{1-x}Ge_x$ layers obtained by epitaxy as well as in such layers buried in silicon obtained by Ge^+ ion implantation into Si substrate followed by high-temperature annealing.