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Transition metal swift heavy ion implantation on 4H-SiC

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ABSTRACT

This work reports on the realization of *Quantum Ring* (*QR*) and *Quantum Dot* (*QD*) like structures on 4H-SiC through SHI implantation and on their Raman studies. 4H-SiC is SHI implanted with Transition Metal (TM) Ni ion at different fluences. It is observed that a vibrational mode emerges as the result of Ni ion implantation. The E_2 (TO) and the A_1 (LO) are suppressed as the fluence increases. In this paper Raman and AFM studies have been performed at room temperature and the queer anomalies are addressed so new devices can be fabricated.

1. Introduction

The demands of today's technology revolve around high power and better performance. The environment in which the devices are deployed are quiet harsh. These radiative environments affect the performance and efficiency of the device or even permanently damage them. In the high power and high frequency domain Silicon Carbide (SiC) and Gallium Nitride (GaN) are very good contenders. They are over par excellence in comparison to current Silicon (Si) based devices [1,2]. Silicon Carbide is a well-known wide bandgap material with over 200 polytypes [3]. It has a high thermal conductivity and low leakage currents making it suitable for high frequency switching applications. Each of the polytypes exhibits different optical and electrical properties which are the result of the stacking sequence. 3C, 4H and 6H–SiC are also widely used as substrates for GaN, InGaN, AlN based LEDs [4].

There are specific possible methods to introduce defects into a material system in order to tailor the system for applications. During the irradiation the penetrating ion loses its energy via two independent mechanisms. One is an elastic collision with the nuclei known as nuclear energy loss and the other is inelastic collision with the atomic electrons known as the electronic energy loss. When the latter dominates the former they are termed as Swift Heavy Ions (SHI) [5]. SHI initially produce defects in a cylindrical zone which are termed as ion-tracks. The changes produced depend on the ion species, its energy and its fluence. Implantation is widely used in semiconductor devices to produce confinement such as quantum lasers [2].

2. Experimental

Samples used in the experiment are crystalline 4H-SiC. The irradiation was done using Nickel (Ni) ion at room temperature in order to prevent the sample from heating. The fluence was varied by varying the irradiation time and the same was calculated using the equation

$$T = \left(f \times \frac{A}{I} 6.25 \times 10^9 \right) \text{sec}$$

where,
T – time in seconds,
f – fluence (number of ions per cm^2),
A – area,
I – current in pnA.

4H-SiC was irradiated with the transition metal Nickel (Ni) ion with varying fluences of 5×10^{10}, 1×10^{11}, 5×10^{11}, 1×10^{12}, 5×10^{12}, 1×10^{13} ions per cm^2. The irradiation parameters were calculated using SRIM pro code (in full cascade mode) [6,7] with the specific gravity 3.21 g cm^{-3} and tabulated in Table 1. As implantation was the requirement for the studies the irradiation was done on the target at 125 MeV.

Micro-Raman measurements were made using HORIBA Jobin Yvon Lab RAM HR 800 equipped with a thermo-electrically cooled charge coupled device (CCD) detector and an automated XY motorized stage. The instrument was configured in a 180° backscattering geometry with a 632.8 nm He–Ne laser as the excitation source. The laser beam was focused onto the sample surface by means of a 50× magnification microscope objective, the

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Table 1
SRIM calculations for Ni ions on SiC target.

Ion	Ion energy	dE/dx electronic loss	dE/dx nuclear loss	Projected range	Longitudinal straggling	Lateral straggling
Ni	125 MeV	35.30	0.050	14.51 µm	4450 Å	4250 Å

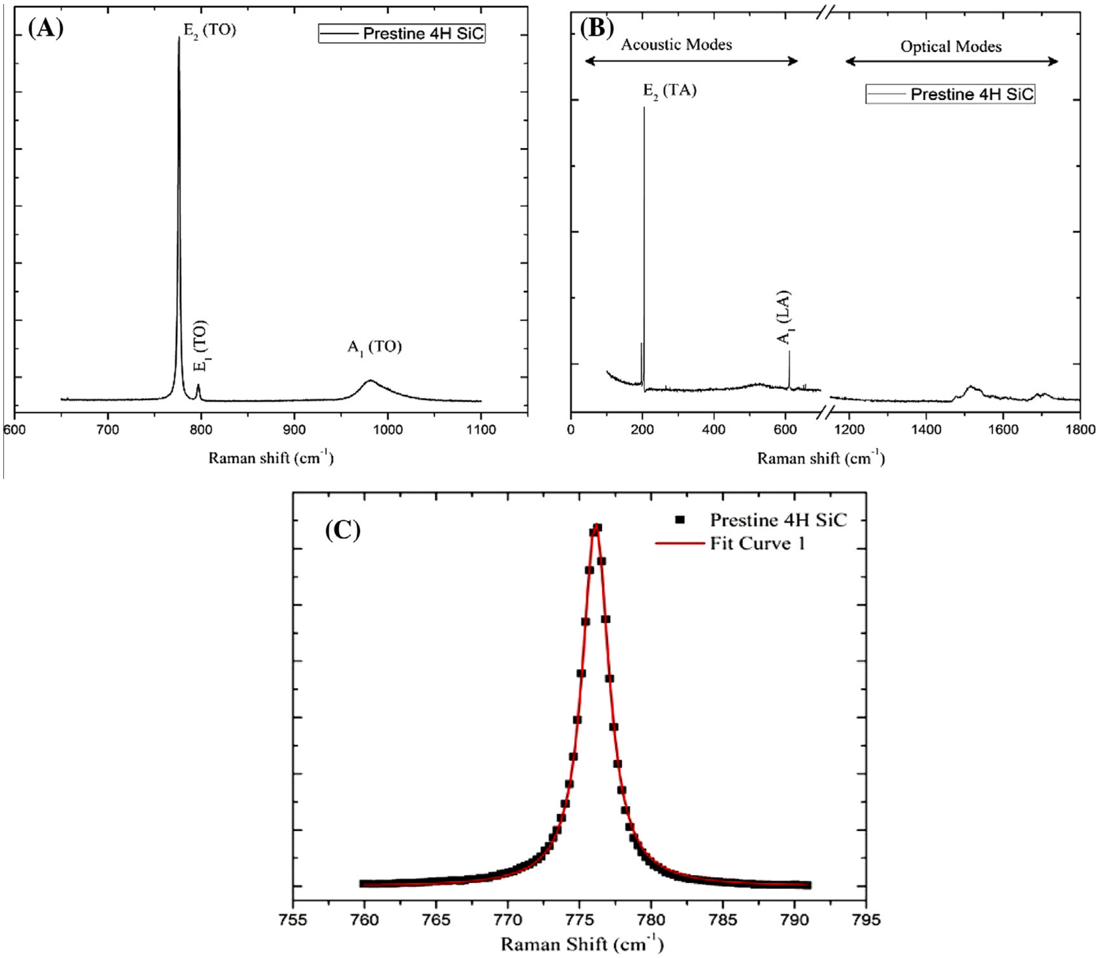

Fig. 1. (A) First order Raman peaks. (B) Second order Raman peaks. (C) Raman spectra of pristine SiC (dotted line) and the Lorentzian fit to the data (solid line).

spot diameter was about ~1 µm width. The spectral resolution of the instrument is approx. 0.3 cm^{-1} and the typical output of the system is 17 mW; however taking into account the numerical aperture of the objective and the exposure time the actual power reaching the sample is optimum.

Before the measurements were performed, the micro-Raman spectrometer was well calibrated using 521 cm^{-1} Raman line of single crystalline Silicon (Si) wafer. The spectrograph consists of a holographic grating of 1800 grooves/mm and the confocal hole of the spectrograph was set to 100 µm. The Raman mapping measurements were made using the same spectrometer and the source of excitation. The mapping was performed over a square of dimension 1 µm. The XY stage was moved 10 × 10 steps totaling to a collection of 100 Raman spectra per sample. The intensity was mapped over the 1 µm^2 area in a contour plot. The mapping of the spectrum was done within a few minutes so that the exposure of the sample to the laser beam was very minimal.

AFM images were obtained using Park XE-100. The AFM uses a micro machined cantilever with a sharp tip to measure the force

Fig. 2. Raman map of pristine 4H-SiC.