L.12: Study of laser induced oxidation in InAs nanowire using Raman spectroscopy

Laser assisted chemical modification was studied in InAs nanowire (NW) by using time dependent Raman spectroscopy. This work was done in Laser Physics Application Section (LPAS) of RRCAT. The time evolution of Raman spectra was taken for a time span of 8-16 min. and the laser power density was varied in the range of 30-800 kW/cm^2. Several paths i.e. conditions for thermal oxidation of InAs are explored by slow and controlled change of excitation laser power. It is found that the oxidation condition crucially depends on various parameters like NW diameter, heat sink, ambient condition, and control over laser power density.

Raman measurement was performed on a NW of 750 nm diameter and 40 μm length. A peak at about 214 cm^{-1} was observed, which corresponded to transverse optical (TO) phonon frequency of InAs NW. At low power density (30-90kW/cm^2), no significant change was observed. As the power density was increased above 100 kW/cm^2, several additional Raman modes appeared in the spectra, which were not reported in the literature. Upon detail investigation, it was understood that these additional peaks appeared due to thermal oxidation of InAs NW due to laser heating. At the medium power density (100-500kW/cm^2), the oxide layer that was formed on the NW surface consisting a mixture of $InAs_xO_y$, As_xO_y and As gave the additional Raman modes. Above 200 kW/cm^2, $InAsO_4$ is found to be a major component in the formed oxide, Fig. L.12.1(a).

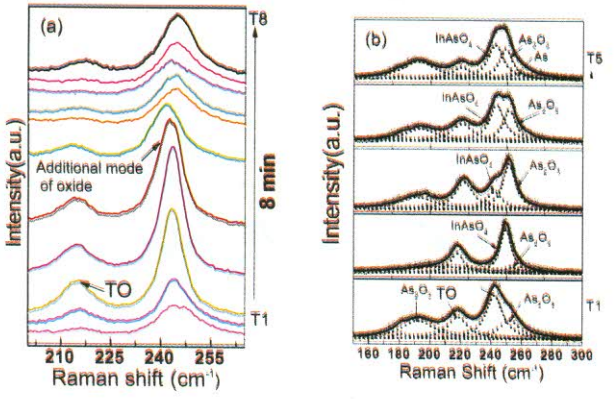

Fig.L.12.1: Time evolution of Raman spectra with laser power density 200-400 kW/cm^2 showing (a) emergence of oxide peaks (b)competition among the oxide peaks.

In the time scale, $InAsO_4$ forms its hydrate form ($InAsO_4.2H_2O$) absorbing the atmospheric moisture and with time it is transformed into anhydrous $InAsO_4$ again due to continuous laser heating. At further higher power density, i.e. 300-500 kW/cm^2, formation and decomposition of $InAsO_4$ was observed to be competitive phenomena, Fig. L.12.1(b)]. At power density of 600-800 kW/cm^2, $InAsO_4$ related peak was not observed but the removal of arsenic (As) occurred layer by layer from the top surface. The integrated intensity ratio (I_{As} / I_{TO}) of As with respect to TO phonon shows a periodic pattern, Fig. L.12.2. The periodic increase and decrease in the ratio with time indicated the removal of As layer by layer. Arsenic being volatile gets removed from the surface leading to reduction in the As related peaks. The next periodic increase was from the next layer modification. In the present experiment the oxides like $InAsO_4$, As_2O_3 are believed to be formed in their metastable phase.

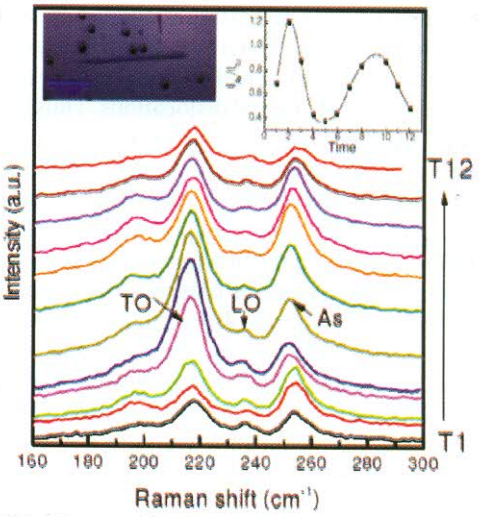

Fig. L.12.2: Time evolution Raman spectra of InAs NW at the incident laser power density of 650 kW/cm^2. Inset: Left: Video image of the NW before and after laser irradiation. Right: Variation of intensity ratio of As to TO phonon showing layer by layer removal of As.

The information obtained from this study can be used for position controlled laser induced chemical modification and processing of a NW based device without changing its core. The finding of this work established the time dependent Raman spectroscopy as a very sensitive probe for studying the metastable states, formed during ongoing laser assisted oxidation/chemical reaction process, which is otherwise extremely difficult to detect by any other techniques. For more details, please refer to Appl. Phys. Lett. 105, 012110 (2014) by Suparna Pal, R. Aggarwal, Vandna Kumari Gupta and Alka Ingale.

Reported by :
Suparna Pal (suparna@rrcat.gov.in) and Alka Ingale