L.8: Probing nanocomposites and nano/hetero structures using Raman and atomic force microscopy

Raman spectroscopy is a versatile and sensitive probe for composition, stress and structure analysis of the material. It can give a unique insight into formation of nano/heterostructures and nanocomposites, when it is combined with atomic force microscopy. Some interesting cases are discussed in the following.

In nanocomposites, functional nanocrystals are embedded in a matrix of materials and it is difficult to obtain information about these buried functional nanocrystals, as they are covered with thick matrix and secondly their sizes are very small. However, tapping selectivity and enhancement provided by resonance Raman scattering, CdS and Si nanocrystals embedded in a polyvinyl pyrrolidone (PVP) and SiO_2 matrix, respectively, were investigated using Raman and AFM mapping performed on the same site.The study shows that high density of CdS nanocrystals acts as stimulus for collapse of PVP from planer matrix to the sphere morphology. It further gives an important information regarding a co-operative growth mechanism of the CdS-PVP nanocomposite leading to monodispersive (size) CdS nanocrystals [*Ekta et al, J. of Alloys and Comp. 729C (2017) 597*]. Interestingly, in Si-SiO_2 nanocomposite, Raman intensity patterns and AFM images from the same selected areas (Figure L.8.1) reveals that clusters of Si NCs in SiO_2, small in size ~100 nm (organized in two dimension:II) and large in size ~2 µm (three dimensional:I) are formed, although the growth was performed to be multilayer (Si/SiO_2) [*Ekta et al, J of Alloys and Comp. 672 (2016) 403*].

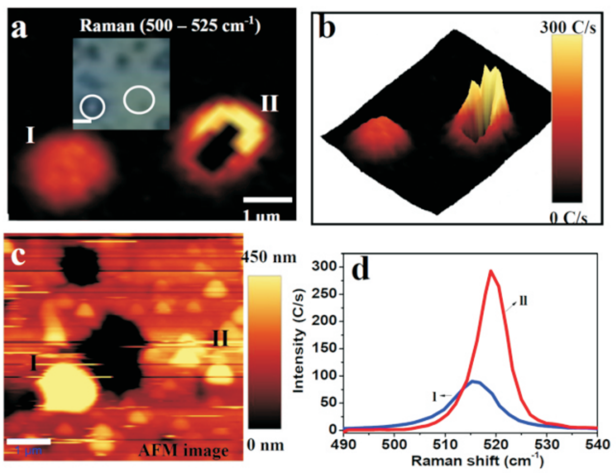

Fig. L.8.1: a) Raman mapping image of Si-SiO_2 nanocomposite with optical image as inset, b) Intensity profile of the Raman image c) AFM image on the same site and d) highest intensity Raman spectra for two clusters (I & II).

In the case of one dimensional nanostructures, like nanowires, it is important to study them along the length to gain better understanding about the one dimensional growth. The spatially resolved Raman spectroscopy along the length of tapered InAs micro-nanowires (MNW), incited the investigation of polytypism along the length of a MNW, wherein, AFM was used to study the topography. The correspondence of stress as a function of diameter along the length of a MNW and variation of the relative content of wurtzite to zincblende phase was established [*Vandana et al, J. Raman spectroscopy 48 (2017) 855*].

In the case of a semiconductor heterostructure, like GaP/Ge (111), there are epitaxial growth related issues such as polar material on a nonpolar substrate. The Raman and AFM measurements on the same site (Figure L.8.2) of nucleating and thick epilayers are examined to understand the role of buffer layer surface on the crystalline quality of the thick GaP epilayer. Raman spectra obtained from the cross sectional surface of cleaved interface of GaP/Ge(111) facilitated the stimulants for existence of wurtzite phase of GaP near the interface [*Rahul et al, Appl. Surf. Sci. 427(2017)754*].

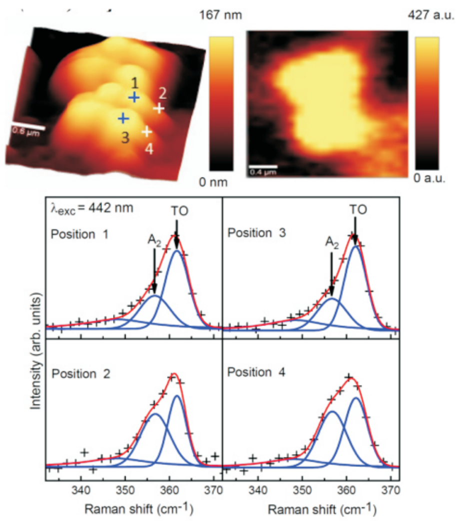

Fig. L.8.2: AFM and Raman mapping images on the same site along with Raman spectra for positions marked on the AFM image, showing correlation of Raman spectra with the morphology.

The unique insight into growth mechanisms of nanocomposites, nanostructures using Raman and AFM mapping together is very useful for growing a desired nanocomposite/nanostruture. Further, innovative use of Raman and atomic force microscopy gives better understanding of surface and interface of semiconductor heterostructures.

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