Multi-modal spectroscopic characterization and defect detection in SnO$_2$/Ga$_2$O$_3$ nanostructures.

Praveena Manimunda$^1$, João-Lucas RANGEL$^2$, Didier Hocrelle$^2$, Francis Ndi$^1$, Emilio Nogales$^4$, Bianchi Méndez$^4$

$^1$Horiba Instruments Inc, Piscataway, NJ, USA
$^2$HORIBA FRANCE SAS, 14 Boulevard Thomas Gobert - Passage Jobin Yvon, CS45002 - 91120 Palaiseau, France.
$^4$Departamento de Física de Materiales, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Spain.
Email: praveena.manimunda@horiba.com

Semiconducting oxide nanostructures with wide range of morphologies are emerging as a viable candidate for applications such as optical and mechanical resonators and solar cells. However, attaining effectively doped oxide nanowires with controllable conductivity is still a challenge. Designing semiconducting oxide nanostructures requires extensive understanding of their morphology and demands efficient multimodal characterization methods. Multimodal spectroscopy is the concept of combining several different spectroscopies onto one platform, thereby expanding the range of analytical capabilities available on that single platform. Besides the obvious benefit of cost reduction, having multiple analytical spectroscopies offers the added benefit of sample colocalization so that multiple complementary measurements can be made at the same location of the sample. The benefit of colocalization is particularly important as feature sizes get smaller, from a few microns to nanometers in size. In this study, Scanning Electron Microscope was integrated with cathodoluminescence (F-CLUE) and as a complementary information an external optical microscope coupled with photoluminescence (PL) and Raman spectroscopy were used to achieve co-localized high-resolution imaging and chemical mapping. Further shape engineered SnO$_2$ nanostructures grown on Ga$_2$O$_3$ nanowires were characterized in detail to understand the optical properties and defect characteristics. Panchromatic CL images identified region of illumination on connected nanowires. The CL emission from Ga$_2$O$_3$ composed of two components (3.3 and ~ 3.0 eV). However, the Ga$_2$O$_3$ nanowire tested had covered SnO$_2$ nanostructures and hence a weaker 3.3 eV emission, a stronger orange band (~ 1.94 eV) corresponding to the SnO$_2$ nanostructure was observed. The orange band was attributed to the oxygen vacancies in SnO$_2$. Photoluminescence and Raman mapping of the nanowires are carried out to understand the chemical nature of the local defects on SnO$_2$/Ga$_2$O$_3$ nanostructures.
Figure 1. (a) Combined scanning electron microscope-cathodoluminescence (SEM-CL) and Photo luminescence system image. (b) SEM micrograph of the Ga$_2$O$_3$ nanowire with SnO$_2$ nanoclusters. (c) Panchromatic CL (PCL) image showing illumination region on the sample.
Figure 2. Monochromatic CL (MCL) images and its corresponding spectrum. (a) Ga$_2$O$_3$ (b) SnO$_2$. (c) Photoluminescence map (640 nm) and spectra from Ga$_2$O$_3$ nanowire with SnO$_2$ clusters.