NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Title: Sputtering growth of ZnO nanostructures and thin films for piezoelectric energy harvester

General Scope:

In the last decades, one-dimensional (1-D) piezoelectric nano-objects (nanowires, nanocolumns, nanorods) have emerged as the potential building blocks for piezo-generators and smart self-powered sensors. ZnO, a wurtzite piezoelectric semiconductor, is of highly interest as its nanostructures are formed relatively easily on various substrates, including Silicon which is low-price and compatible with microelectronic technology. Hydrothermal growth is a simple and cost-effective technique which can provide a uniform deposition of 1-D ZnO, but the grown materials usually have poor optical and electrical properties, consequently deteriorating the device performance. Magnetron sputtering, the widely used deposition technique with a reasonable running-cost and feasibility of mass-production, should offer the material with a better quality as they are obtained under high vacuum conditions. Despite numerous studies on ZnO sputtering, it remains crucial to explore a complete picture of ZnO sputtering of nanostructure formation and alloying to achieve desired elements for piezo-devices.

Research topic and facilities available:

In this internship, the student will use a DC/RF magnetron sputtering to deposit ZnO on Si substrate via radio frequency (rf) sputtering technique. The key issue is to optimize the growth conditions to achieve high crystal quality in a controlled morphology and desired crystal orientations that determines the piezoelectric properties. The student will investigate structural, morphological, electromechanical properties of the grown ZnO as a function of the deposition parameters such as deposition pressure, substrate temperature, sputtering power, target–substrate distance, deposition angle, layer thickness, O_2/Ar gas ratio, etc. The growth conditions will be optimized to achieve ZnO nanowires/nanocolumns without using any external catalyst to avoid the incorporation of an undesirable external impurity that likely affect the material quality.

Although ZnO has the highest piezoelectric coefficient (d_{33}) among wurtzite semiconductors, its value is relatively low compared to common piezoelectric ceramics such as PZT, limiting ZnO piezo-device efficiency. The impurity doping or alloying process potentially extends this value beyond the bulk one. For example, the d_{33} of ZnO can be enhanced from its bulk value of 12.5 pC/N to 127 pC/N which approaches that of piezoelectric ceramics, by modulating the chemical state and ionic size of Fe impurity in ZnO. According to the literature, the enhanced d_{33} of Fe-ZnO films is attributed to the substitution of Fe^{3+} for the Zn^{2+}, when the concentration of Fe atoms is less than 2.6 at. % in ZnO film. However, the chemical state of Fe in Fe-ZnO films changes from Fe^{3+} to Fe^{2+} with an increase in the amount of Fe. This challenge task to extend the d_{33} of Fe-ZnO nanostructures might be tested at the end of the internship when the growth conditions of ZnO nanostructures are optimized since it needs a fine tuning of the Fe concentration during the sputtering.

The comprehensive film characterization such as surface roughness, crystallography, piezoelectricity, and electrical resistivity will be performed with various techniques (SEM, AFM, PFM, electrical, etc) available at Néel Institute. The piezoelectric properties of ZnO will be studied and correlated with the electrical and electromechanical properties of large-scale piezo harvesters.

Possible collaboration and networking: Néel (NPSC, Optima, EpiCM) and CEA/Grenoble
Possible extension as a PhD: No funding is currently available, but we support the PhD grant applications.
Required skills: Material science, Semiconductors, Nanomaterials, Solid State Physics
Starting date: February/March 2024 (4 to 6 months), please apply for the position 2 months before the starting date.

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