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Atomic scale study of emerging UV-light LEDs by advanced transmission electron microscopy

Now-a-days it is very apparent that the advancements in solid-state lighting technologies based on LEDs is rapidly transforming the landscape of traditional models of lighting sources. This is evident over a broad spectrum of different realms of the society, from the light bulbs in our homes, outdoor lighting, automotive lighting, to the medical surgery theatres. Besides, LED lighting technologies have further expanded into emitting wavelengths shorter than visible light enabling the feasibility of UV-light LEDs. The emission in shorter wavelength range of 100-280 nm is known as UV-C range. The UV-light radiation with wavelengths of 254 nm or less have disinfecting properties as they are effective in killing bacteria, viruses and other microbes. It is owing to this fact that UV-LEDs hold the promise to replace the currently used mercury lamp UV-light sources as potential candidates for water purification applications. The succession of these conventional mercury lamp UV- light sources with UV-LEDs is highly desired. This is because LEDs sources are more environmentally friendly (non-toxic and low energy dependency), cost-effective, compact, and robust. Realization of such UV-LED sources with efficiencies at par with the mercury lamps would provide an opportunity to develop alternative portable water disinfecting systems that will be useful for decentralized and even household water purification purposes.

Recently a new class of AlxGa1-xN based UV-LEDs has attracted wide scientific interest. They show the promise to be potential next generation UV-LED source. In such Al composition graded AlxGa1-xN UV-LEDs the semiconducting p-n-junction is based on polarization-induced doping. Thereby it is possible to minimize the dependency on dopant atoms alone for doping. However, there are critical bottleneck challenges limiting their efficiency to 1-2 %. This is currently limiting their realization into viable UV-LEDs device based on AlxGa1-xN. Therefore, it is critical to understand the nature of efficiency limiting defects and interface related structural inhomogenities. Fundamental understanding of such defects may contribute towards developing more strategic solutions towards improving the currently limited low efficiencies of these budding AlxGa1-xN UV-LEDs.

The main objective of this project is to employ advanced transmission electron microscopy tools to investigate the structural and electronic properties across different interfaces in full scale UV-LED devices. The state-of-the-art advanced aberration corrected analytical transmission electron microscopy (S/TEM) provides an optimum suite of powerful characterization tools to explore the structure-property correlation at different length scales (micro, nano and atomic scales). This knowledge may provide the pathways to understand and scientifically optimize the device fabrication protocols to enable development of controlled, efficient and low cost commercially viable novel UV-LED devices for water purification. The strategic objective of this project is to achieve the above mentioned basic research, by conducting comprehensive TEM investigations on three different complete AlxGa1-xN UV-LED device structures. For this, three different growth substrates that will be explored in this work are sapphire, AlN and GaN/sapphire. Study of full-scale devices is an effective approach to understand and develop commercially viable LED devices. The proposed work will enable to do a comparative study between three potential device structures including the understanding of substrate specific efficiency limiting factors. The atomic scale advanced TEM study, employing complete suite of techniques, will be carried out in state-of-the-art FEI Titan3 double Cs-aberration corrected TEM. Such advanced TEMs are few in the world and EIT+ Wroclaw Research Centre houses one of them. This is the primary motivation for choosing it as the host institute for this project. The new knowledge generated in this project will be published in peer reviewed scientific journals. This will enable transferring of the knowledge generated in this project for optimizing the fabrication protocols to enhance the currently limited efficiencies of the AlxGa1-xN based UV-LEDs.