Interface Control of III-Nitride Semiconductors: From High Efficiency Artificial Photosynthesis to Ferroelectric Switching

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In this talk, I will discuss the recent advances of nanoscale III-nitride semiconductors and their applications in artificial photosynthesis and ferroelectric devices. Artificial photosynthesis, the chemical transformation of sunlight, CO_2, and H_2O into clean chemicals and fuels, has been extensively studied but faces fundamental challenges of efficiency, stability, and selectivity. Recent studies of III-nitride semiconductors, e.g., GaN, InN, and their alloys, have shown that their surfaces can be transformed to be oxynitride during harsh photocatalysis conditions, leading to significantly improved efficiency and stability. With the integration of various co-catalysts, we have demonstrated high efficiency, long-term stable solar water splitting and hydrogen production. The recent advances of converting CO_2 to liquid fuels, reduction of N_2 to ammonia, and methane oxidation to methanol will also be discussed.

Another recent exciting development is the discovery of ferroelectricity in III-nitride semiconductors. The incorporation of rare-earth elements such as scandium (Sc) can transform conventional III-nitride semiconductors to be ferroelectric. I will present recent advances of ferroelectric Sc-III-nitride heterostructures and nanostructures, including epitaxy, properties, and emerging device applications. Molecular beam epitaxy and properties of ScAlN and ScGaN with a wide range of Sc compositions will be discussed. The realization of ultrathin ferroelectric nitride heterostructures and the underlying physics and interface properties will be discussed, together with their applications in quantum photonics and electronics.