AlGaN/AlN Quantum Dots and Dots-in-a-Wire for UVC Emission

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Abstract

The demand for germicidal UVC lamps has significantly risen during the COVID-19 pandemic, as they are widely used for disinfection purposes. Initially, low-pressure mercury lamps were the primary choice, but they are now being replaced by AlGaN LEDs due to their enhanced safety and sustainability benefits. However, AlGaN LEDs emitting at 270 nm still face challenges in terms of efficiency and cost per Watt compared to mercury lamps, primarily due to issues related to efficient electrical injection. Additionally, the 270 nm wavelength poses health risks such as carcinogenic and cataractogenic effects, which has spurred research into radiation sources with shorter penetration depth, particularly around 230 nm. To tackle this challenge, electron-pumped UVC lamps using AlGaN nanostructures as active material have emerged as a promising solution to provide high radiant power [1]. These lamps consist of a vacuum tube with a semiconductor dice onto which electrons are pumped using a cold cathode, typically made of carbon nanotubes or microfibers.

Our research focuses on investigating the growth and performance of dots-in-a-wire structures and AlGaN/AlN Stranski-Krastanov (SK) quantum dot (QD) superlattices using molecular beam epitaxy. The aim is to develop efficient anodes for electron-pumped UVC emitters [2]. In the case of nanowires, we adjust precisely the growth parameters to achieve uniform active superlattices spanning over 400 nm in length, matching the penetration depth of the electron beam. Regarding SK-QDs, we optimize the incorporation of Al, metal/N ratio, and deposition time to attain efficient emission in the 270 nm to 230 nm range [3]. Both types of nanostructures exhibit high internal quantum efficiencies, averaging around 50% at room temperature, attributed to the effective three-dimensional carrier confinement within the quantum dots. Moreover, these efficiencies remain stable as a function of the pumping power, even up to 500 kW/cm^2.

In the UVC range, planar SK-QDs achieve a power conversion efficiency of 0.5-1% under electron beam pumping, without requiring any surface treatment to enhance light extraction. We will also discuss the impact of the QD geometry and the presence of extended defects on the broadening of the emission line.

References

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