# Effect of strain of template on current injection efficiency for AlGaN-based deep-ultraviolet light-emitting diodes

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AlGaN-based deep ultraviolet (DUV) light-emitting diodes (LEDs) have attracted an increasing attention as an effective method for disinfection and sterilization, especially to kill the coronavirus (COVID-19). However, the wall-plug efficiency (WPE) of DUV-LEDs is still very low (< 8%). The low current injection efficiency (CIE) is one factor that limits the WPE of AlGaN-based DUV-LEDs under electrical injection.[1] It is well known that the strain plays a crucial role in the performance of the DUV-LEDs. A number of studies focused on strain effects on the radiative recombination efficiency due to the quantum-confined Stark effect (QCSE) of the quantum wells (QWs). The strain effects on the light extraction efficiency via the modulation of the photon polarization have also been investigated extensively. In this talk, we report a theoretical simulation of the CIE dependence on strain of AlN template in AlGaN-based DUV-LEDs.

A one-dimensional drift diffusion model was used for the carrier transport simulations when taking the strain-induced piezoelectric effects into account. The simulation structure consisted of a first AlN layer, n-$Al_{0.6}Ga_{0.4}N$ layer with Si doping concentration of $3\times10^{19}$ $cm^{-3}$, three $Al_{0.4}Ga_{0.6}N/Al_{0.55}Ga_{0.45}N$ QWs, followed by p-$Al_{0.8}Ga_{0.2}N$ electron blocking layer (EBL), p-$Al_{0.75}Ga_{0.25}N$ hole injection layer, and p-GaN ohmic contact layer. The Mg concentration in p-$Al_{0.8}Ga_{0.2}N$ and p-$Al_{0.75}Ga_{0.25}N$ were $5\times10^{18}$ $cm^{-3}$ and $2\times10^{19}$ $cm^{-3}$, respectively.[2] We assumed that the strain was unrelaxed (i.e. pseudomorphic growth) in all epilayers, except for the EBL. The strain in EBL was assumed to be relaxed in case of a tensile strain (the in-plane lattice constant of tensile-strained AlN template is larger than that of p-$Al_{0.8}Ga_{0.2}N$ EBL). The dislocation density in active region was assumed to be identical in all cases with a special focus on the band diagram changes under strain. It was shown that the strain state in AlN template can strongly affect the current injection efficiency. As shown in Fig. 1, a small compressive can enhance CIE, but it reached a maximum when the compressive in-plane strain was approximately -1.0%. In contrast, a tensile in-plane strain in AlN template can significantly improve the CIE.

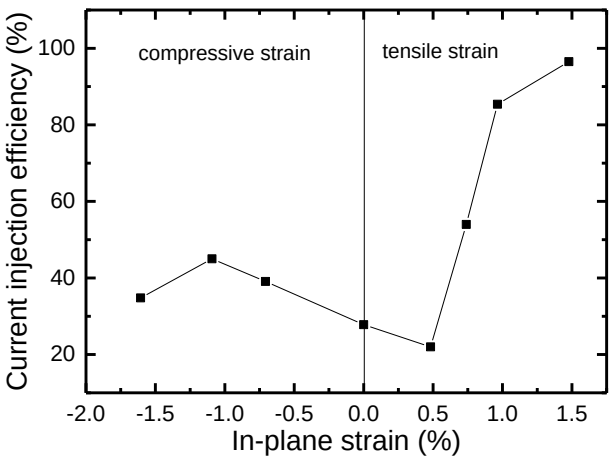


Fig. 1 Current injection efficiency as a function of in-plane strain in AlN template

[1] G. D. Hao, N. Tamari, T. Obata, T. Kinoshita, and S. Inoue, Opt. Express **25,** A639 (2017).

[2] G. D. Hao, M. Taniguchi, and S. I. Inoue, J. Phys. D: Appl. Phys. **53,** 505107 (2020).