Surface/interface engineering InAs quantum-dot based edge-emitting LED for III-V/SiN photonic integrations

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Edge-emitting LEDs (ELEDs) possess a high brightness, a high coupling efficiency/tolerance to optical fibres compared with surface-emitting LEDs; whilst a simple structure for fabrication with a low cost compared with their coherent counterparts (i.e., lasers).[1] Therefore, it is a good candidate for short-reach optical communications, optic gyroscopes, gain material for external-cavity lasers, and photonic integrated platforms. Recent breakthrough in InAs quantum-dot (QD) grown on various substrates with emission wavelength in O-band range enables the development of high-brightness ELEDs,[2] including super-luminescent LEDs.[3] In order to efficiently couple the emitting light out of an ELED, an anti-reflection coating (ARC) layer is required. Ideally, the ARC layer is also expected to be a passivation layer to reduce non-radiative recombination and to enhance the device lifetime, which is especially important for the edge-coupling scheme. In this case, the materials are requested to have both the desired refractive index and correct chemical property.

In this work, we investigated the SiN_x as an ARC and surface passivation layer, as it is excellent dielectric material for low-loss Si photonics, with its refractive indices continuously adjustable from 1.7-3.0 in telecom range by changing N/Si ratio.[4] From our FDTD simulations, a SiN_x with n=2.5 (Si-rich SiN_x) and thickness of 130 nm is required as an ARC between 1.3 μm QD optical active layer and a stoichiometric SiN waveguide on Si to minimize the retroreflections. In order to perform a systematic study of the surface/interface passivation, we fabricated three ELEDs, with Si-rich SiN_x coating (A), with N-rich SiN_x (B) coating and without surface coating (C). Before deposition of the surface coating layer, the sidewalls are treated with citric acid and diluent ammonia to reduce the surface defects. By investigating both the optical properties and electrical transport properties by photoluminescence, electroluminescence, and photocurrent generation. We concluded that the device A exhibits a best performance with the highest stability, whilst device C shows surface recombination and aging problems. The results are explained by the reduction of surfaces/interface states and prevention of oxidation of the surface in air with Si-rich SiN_x.

Our findings are not only applicable in ELED/SiN coupled structures, but also eligible for InAs QD lasers and nanophotonic devices integrated with SiN components.

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