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Nitride-on-Silicon microdisk lasers covering the blue to UV-C spectral range

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Ultra-violet semiconductor lasers have numerous applications for optical storage, biochemistry, sterilization or optical interconnects. The usual design of deep UV-emitting ridge lasers relies on complex buffer layers or expensive substrates for the growth of the nitride heterostructures [1]. UV microlasers can also be developed following a simpler approach with a better compatibility with nanophotonic circuits and their thin waveguides.

In this work we demonstrate a series of nitride-on-silicon microdisk lasers covering a broad spectral range, from the blue (λ=470 nm) to the deep ultra-violet (λ=275nm), and operating at room temperature. They rely on the controlled growth of thin AlN buffer layers on silicon substrates, followed by the growth of GaN/AlN or InGaN/GaN multiple quantum wells (MQWs) with a high radiative efficiency up to T=300K. We exploit the possibility to under-etch selectively the silicon substrate in order to form nitride membranes for photonic resonators; this has allowed many demonstrations of microdisk and photonic crystal cavities with quality factors larger than 1000, ranging from the near-IR [2] to the near-UV spectral range [3,4], now expanding to the UV-C [5].

Following the demonstration of a UV-C microlaser operating at λ=275 nm and at room temperature [5], the figure 1 presents the emission characteristics of a series of nitride-on-silicon microdisks with different active layers grown on a thin AlN buffer layer. Their whispering gallery modes are probed under continuous wave excitation at 266 nm with a 15 µm laser spot (Figure 1.b); the photoluminescence is collected from the edge of the microdisks. The chosen microdisk diameters in panel (b) are 5-6 µm in order to properly exhibit the modes, except for the 3 µm microdisk emitting at 275 nm. In all cases, the sharpest peaks are observed in the low energy tail of the PL spectrum where the absorption of the active layer is limited. The measured Q factors exceed 1000, and reach 4000 in the best resonators. The lasing operation is obtained under pulsed quasi-resonant optical pumping (266nm, 400ps pulses) with a threshold excitation density ranging from 2 to 40 nJ/pulse (Figure 1.a). The dependence of the lasing threshold on the QW design will be discussed.

In the UV-B and UV-C spectral ranges, these demonstrations underline the interest of simple binary GaN/AlN MQWs, grown on a thin AlN buffer on a silicon substrate, in order to obtain efficient active layers providing optical gain up to room temperature. The microdisk lasing in the visible spectral range, based on more mature InGaN/GaN MQWs, proves the versatility of the nitride-on-silicon photonic platform, that can embed a broad range of integrated sources.

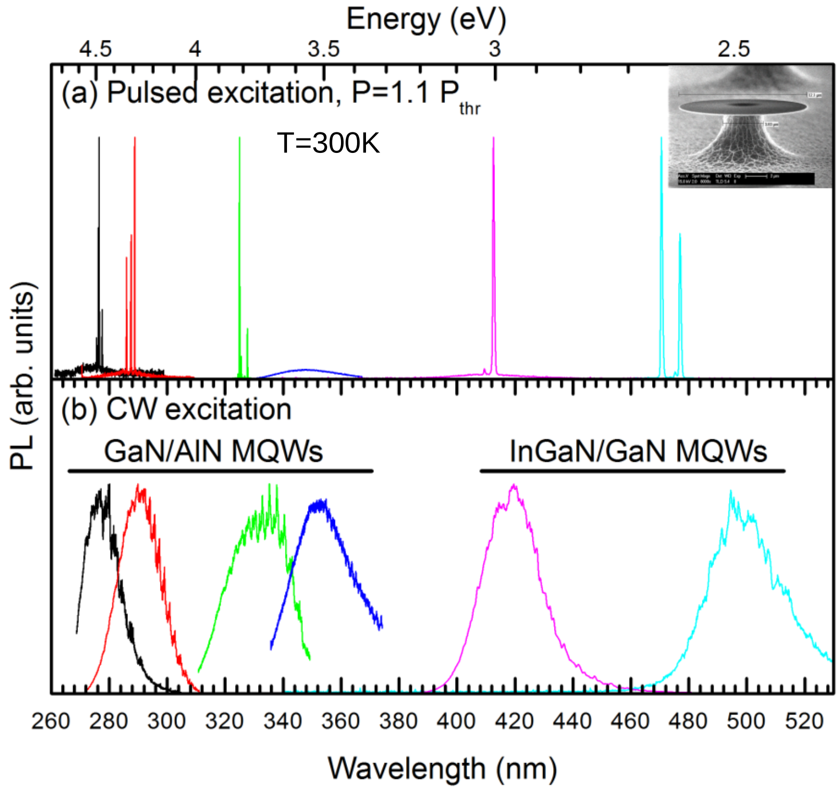

Figure 1: Edge-collected photoluminescence under top optical excitation from a series of microdisks embedding GaN/AlN MQWs (Nominal thicknesses 0.7 nm, 0.8 nm, 1.2 nm, 1.8 nm from left to right) and InGaN/GaN MQWs (11% and 20% indium content respectively, same thickness 2.2 nm). (a) Under pulsed excitation with an excitation power 10% larger than the laser threshold (except for the 1.8 nm GaN/AlN MQWs, not lasing); b). Under continuous wave excitation. Inset : Scanning electron micrograph of a 12µm microdisk.

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