Etched Facet Technology for Blue-Violet Lasers

CNF Project # 924-01
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Abstract:
A blue-violet (405 nm) emitting laser was fabricated using a new etched facet technology for GaN-based material. The technology can allow the fabrication of short-cavity lasers with higher yield than possible in cleaved facet lasers.

Summary:
Nichia Chemical first demonstrated GaN-based blue lasers on sapphire substrates in 1995 and has subsequently been able to produce commercially available CW lasers [1]. Nichia uses cleaving to form the facets of its blue lasers, but prices of such lasers have remained very high. There is tremendous interest in fabricating inexpensive 405 nm-emitting GaN based lasers for the next generation of DVD applications.

Cleaving to form mirror facets is the standard process for making edge-emitting lasers. An alternative to cleaving is to etch the laser facets. Etched facets with high quality were formed in GaAs through a process based on chemically assisted ion beam etching (CAIBE) at Cornell University [2]. These laser devices are characterized by precisely located mirror facets with quality and reflectivity equivalent to those obtained by cleaving.

The EFT allows lasers to be fabricated on the wafer in much the same way that integrated circuit chips are fabricated on silicon. Etched facet lasers are monolithically integratable with other photonic devices on a single chip [3] and can be tested inexpensively at wafer-level [4]. Facet reflectivity modification (FRM) can be used to modify the reflectivity of the etched facets through deposition of dielectric coatings with the wafer intact.

Early on in the development of GaN based blue lasers, CAIBE was applied to the fabrication-etched facets for blue lasers on sapphire [5], however, the reflectivity obtained from such etched facets were smaller than cleaved facets. The lower reflectivity was blamed primarily on roughness of the facet [6] as well as the deviation of the facet from vertical [7].

A key to obtaining high quality etched facets is high selectivity between the etch mask and the semiconductor material in the etching process. The etch facets formed in GaN were formed with a selectivity of better than 10:1 and the etch rate was higher than 0.25 µm/min.

Formation of a cavity in the GaN system through cleaving does not easily allow a cavity length below 500 µm. Since the material system has very high defect density (presently around 1x5 defects/cm² for the best available material), assuming a ridge width of 2 µm, a cavity of such length will on average contain at least 1 defect. As such, the GaN system provides additional incentive for using etched facets since much shorter cavities can be formed with relative ease. Assuming a cavity length of 50 µm with the same ridge width of 2 µm, the probability of a cavity with a defect is a factor of 10 lower. This leads to significantly increased yield.

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References:
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- Low-cost blue-violet emitting lasers for next generation DVD players.
- High defect density in GaN material severely impacts laser diode yield.
- Improved yield with short cavity etch facet lasers.

Figure 1: SEM image of an etched GaN facet.

Figure 2: Spectral characteristics of a blue-violet laser.