Fabrication and MBE Regrowth of First Order, High Contrast AlGaAs/GaAs Gratings

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In this paper, we present the fabrication and regrowth of first order, high contrast, AlGaAs/GaAs Bragg gratings for short-wavelength applications. The gratings are employed as reflectors in a distributed Bragg reflector (DBR) laser emitting at 980 nm. We first present a novel immersion holography technique used to fabricate the first order short-wavelength gratings. Next, we discuss a matrix of regrowth experiments used to overgrow high contrast gratings. Solid source Molecular Beam Epitaxy (MBE) was used for regrowth, and atomic force microscopy (AFM) and scanning electron microscope (SEM) were used to characterize the gratings and quality of overgrowth. Finally, results of these gratings monolithically integrated into a DBR laser are presented.

High contrast, first order gratings are important technologically because of the high reflectivity with a small footprint. There are two main methods of patterning diffraction gratings—direct e-beam writing and holography. Standard holography is attractive due to its ease of fabrication, high throughput, and low cost. In our holography setup, a HeCd laser emitting at 325 nm was used as the source. However, to achieve the short grating pitch of ~150 nm necessary for our first-order 980 nm gratings, the wavelength of the laser source was reduced via a prism. Xylene was used to adhere the sample to the prism and also act as an index-matching fluid. This immersion holography technique was thereby effective in patterning uniform gratings at a shorter pitch. The exposed grating pattern is then transferred directly to the semiconductor via dry etching, and the sample is cleaned and prepared for regrowth.

MBE regrowth has generally been considered a difficult or impractical growth technique for smooth overgrowth of gratings. Chemical vapor deposition is more commonly used due to the high mass transport properties [1]. In this work, MBE regrowth has been successfully achieved on patterned gratings. The gratings were targeted to have a high coupling coefficient, $\kappa \sim 650\ cm^{-1}$. Therefore, $Al_{0.75}Ga_{0.25}As$ was used to overgrow GaAs gratings that were ~300 Å deep. Similar to work performed by Pickrell, et. al., we find that a slow growth rate is effective in overgrowing the gratings [2]. By growing at a slow growth rate, pitting defects are greatly reduced. Finally, substrate temperature and Arsenic overpressure were optimized to achieve both smooth overgrowth in non-grating regions as well as filled overgrowth over grating regions.

The high contrast, first order gratings were monolithically integrated into a DBR laser to evaluate its performance as a mirror [3]. The devices demonstrated single mode lasing at 978 nm with >30 dB side mode suppression. The lasers had a threshold current of 9 mA, and had output powers >5 mW.

In summary, first order, high contrast, AlGaAs/GaAs diffraction grating have been developed and implemented into a DBR laser emitting at 980 nm. A novel immersion holography technique has been developed to fabricate highly uniform gratings. Optimum regrowth conditions were found to overgrow and fill in the gratings. These gratings were successfully integrated in a DBR laser structure resulting in single mode emission at 980 nm.

References

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