Progress on the MOCVD of GaInP Stranski-Krastanov Islands on GaP/Si Substrates

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Future generations of microchips will be required to meet demands for increased data transmission rates as well as reduced power consumption. Current technology dictates that this improvement in computational capacity come from adding more metal-line interconnects in parallel. However, the resistance, capacitance, and inductance associated with these lines will limit chip performance, making it increasingly important to develop a new technology for off-chip communications. One approach that has become attractive is the use of an optical databus. Various methods, including multi-chip modules, flip-chip bonding, and wafer bonding, have been developed that successfully integrate lasers with silicon and produce viable optical interconnects. Still, it would be more desirable to use a technology that could be applied to all of the devices on a chip simultaneously. The epitaxial "growth" of an optical material on the silicon substrate is one such method. However, this approach has been limited by the lack of a high-quality light-emitting material that can be monolithically integrated with silicon.

Our group is researching a method by which direct bandgap GaInP may be deposited on silicon by selective area metal organic chemical vapor deposition (MOCVD). Previous results indicated that smooth GaP could be grown epitaxially on patterned silicon substrates.[1] Additionally, it was shown that GaInP deposited on GaP substrates by MOCVD produced samples with efficient luminescence at room temperature.[2,3] It was found that the GaInP layer grows via the Stranski-Krastanov (S-K) mechanism and consists of strain-induced islands of ordered, direct bandgap GaInP which form type I quantum wells above a wetting layer of disordered, type II GaInP; this material system results in interesting structural properties and recombination physics that will be explained. By combining the GaP/Si and GaInP/GaP technologies, optical material has been deposited successfully on silicon substrates. Photoluminescence results from GaInP/GaP/Si structures will be presented for the first time.(Figure 1)

Additional research has focused on techniques to improve the quality of the luminescence from GaInP islands grown on GaP substrates and to test the potential of this material system in device structures. The performance of light-emitting diodes (LEDs) fabricated from this material was measured at room temperature. The pulsed light output versus current (L-I) data indicated that light emission from the GaInP islands does not saturate even at current densities as high as 15kA/cm2 (Figure 2), indicating the robustness of this system for device construction. Laser structures consisting of a GaInP active region surrounded by AlGaP/GaP barrier/cladding layers have also been fabricated. The gain characteristics of these structures have been measured using a nontraditional method that utilizes electrical pumping of the sample.

An interesting phenomenon that has been observed during testing of the GaInP/GaP samples is the degradation in luminescence intensity that occurs when the films are irradiated with UV light from an argon laser (wavelength = 363.8 nm) or a HeCd laser (wavelength = 325 nm) at low power densities (<100 W/cm2). Photoluminescence spectra will be presented that show a dramatic decrease in emission over time as the sample is exposed to the UV beam.(Figure 3) Reasons for this behavior and the effect on this decay of cap layer thickness above the active region will be discussed.

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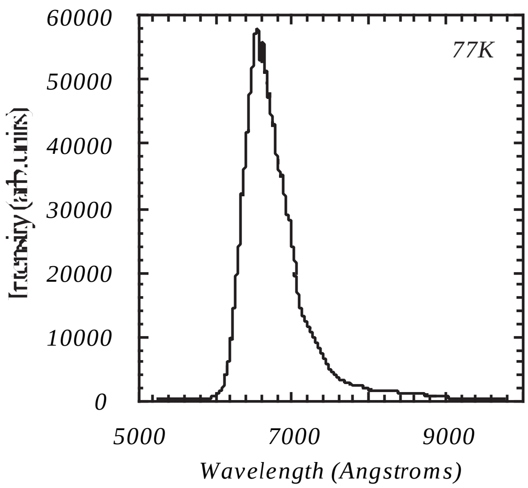

Figure 1: Photoluminescence spectra from GaInP/GaP/Si layer structure.

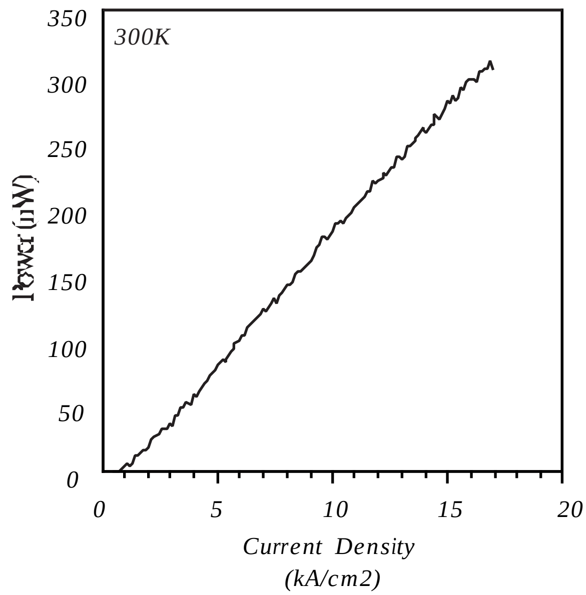

Figure 2: Pulsed L-I data indicating that light emission from GaInP islands does not saturate at current densities as high as 15 kA/cm^2.

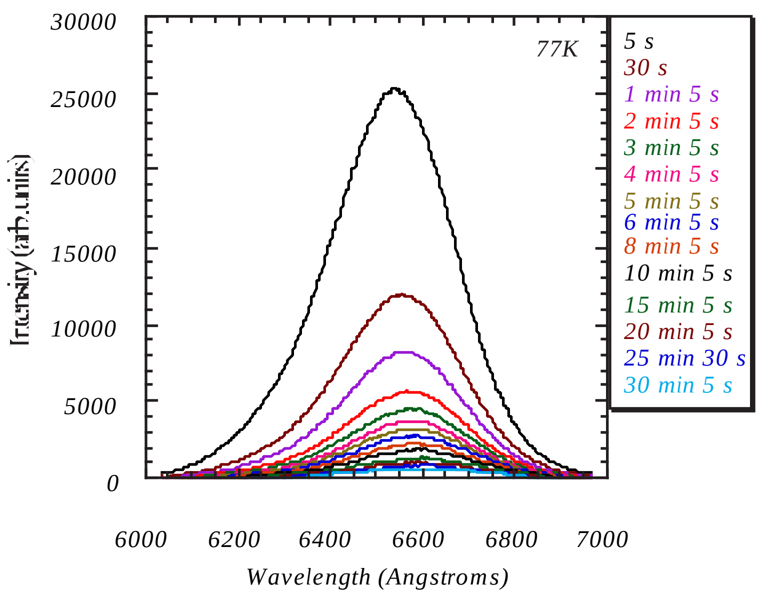

Figure 3: Decay in photoluminescence intensity as a function of UV exposure time. (excitation source=325 nm line of HeCd laser, incident power = 15 W/cm^2, cap layer thickness = 50 Angstroms.)