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Vapor Phase Epitaxial Liftoff of GaAs

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1. Introduction

A modified Epitaxial Liftoff (ELO) technique which deposits GaAs thin film devices onto Si circuitry is reported. An array of discrete thin film LED's is uniformly separated from its substrate and transferred onto a transparent sapphire disk for further manipulation. Etching channels are defined in a thick photoresist spacer layer to efficiently liftoff large arrays of devices. The liftoff process has now been adapted for vapor phase etching of the AlAs channels. Aqueous HF vapor is adequate for undercutting the GaAs thin film circuits.

The lifted-off films are then bonded onto a Si wafer using a thin polyurethane adhesive layer. This newly developed ELO process greatly improves the manufacturibility of ELO technique to a practical level suitable for wafer-scale integration. The performance of the transferred LED's shows no degradation but an enhancement in the output luminescence when bonded on Si substrates.

2. Results and Discussion

The separation of GaAs thin films from their mother substrate and subsequently transfer and bonding onto new host substrates has drawn great attention in recent years due to potential applications in the field of semi-monolithic opto-electronic integrated systems (OEIS). One of the major applications which is now being intensely investigated is the integration of GaAs and Si. Such an integration will enable the design of high performance systems that utilize the best attributes of both Si and GaAs technologies. In the last few years, research has focused on Epitaxial Liftoff (ELO) technique to integrate GaAs thin films with Si substrates while maintaining the ultimate performance of both. The essence of the ELO process is the manipulation of thin films and their transfer back-and-forth between different substrates and support carriers. This is done by using a variety of thin films supporting materials (e.g. Apiezon black wax, polyimide), selective etching acids (e.g. hydrofluoric acid, HF), and selective organic solvents, which release one layer but leave another layer unaffected.

Since the epitaxial liftoff etching process is a diffusion-limited reaction, it requires hours of etching to separate a continuous millimeter-size GaAs film from its substrate. Therefore, it limits the feasibility of implementing such a process scheme for wafer-scale hybrid integration. This problem can be circumvented by patterning a big and continuous GaAs sample into an array of smaller discrete devices before the ELO process, thus greatly decreasing the overall HF etching time. However, when the array becomes too large, problems arise regarding the handling of the lifted-off films as well as their accurate positioning onto new host substrates. Although the alignment problem has been addressed and partly solved by transferring lifted-off samples from Apiezon black wax to an intermediate transparent membrane, the use of black wax in the process makes it unacceptable for standard microelectronics processes.

Hence, in order to satisfy the current need for high throughput and efficient integration, the following criteria have to be met:

(1) The processing materials have to be compatible with standard microelectronics fabrication techniques
(2) The etching and bonding processes have to be more efficient
(3) Transparent and robust thin films carriers should be implemented
(4) The process should be scaleable to wafer-scale integration

3. Conclusion

We report the development of a new manufacturable ELO and bonding technique. Arrays of discrete GaAs thin film light emitting diodes (LED's) are separated from their substrates by HF vapor exposure of etching channels defined in a thick photoresist spacer layer. The sapphire disk is used as a thin film carrier during the liftoff and transfer processes. The thin films are then "flipped" and bonded onto a Si wafer coated with a thin layer of polyurethane. This integration process presents several advantages; first, black wax is eliminated and replaced by a more robust and transparent sapphire carrier. In addition, it can be reused for further ELO process; second, it improves not only the robustness of ELO process but its efficiency; third, this process has great potential for full wafer-scale integration.