

Epitaxial liftoff technology

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ABSTRACT

Epitaxial liftoff permits the integration of III-V films and devices onto arbitrary material substrates. This paper will review Bellcore's work on opto-electronic integration of III-V optical transmitter and receiver devices onto LiNbO₃, glass, Silicon and sapphire substrates.

INTRODUCTION

In the field of electronic materials there has been a persistent interest in the integration of high quality epitaxial thin film semiconductor layers with arbitrary crystalline or glass substrates. For example, thin film GaAs layers on crystalline Silicon substrates would allow the combination of the two technologies. This has led to a massive effort on lattice mis-matched heteroepitaxial growth. Recently, however, a new and more flexible approach¹ has been attracting increasing² attention.

In this new approach, perfect epitaxial quality AlGaAs thin films are lifted off lattice-matched GaAs growth substrates by means of an ultra-thin AlAs release layer. Advantage is taken of the extremely selective etching ($\geq 10^7$) of AlAs in dilute Hydrofluoric acid, permitting large area (cm²) epitaxial AlGaAs films to become undercut. The GaAs substrate is left intact and can be re-used if so desired, while the epitaxial thin film can be cemented or "Van der Waals bonded" by surface tension to any arbitrary substrate. In this paper we report the implementation of examples of this technology involving the marriage of a number of different opto-electronic devices and materials.

Among the devices and material systems which have been demonstrated are double heterostructure GaAs thin film lasers on glass and Silicon substrates³, MESFET's on glass⁴, InGaAs strained quantum well HEMT's on Silicon and glass², GaAs LED's on Silicon⁶, InGaAs/InP p-i-n photodetectors on sapphire⁷, GaAs photodetectors integrated with LiNbO₃ and glass waveguides^{8,9}. In addition, the regrowth of quantum wells on GaAs on Silicon has been shown to be feasible.

Unlike lattice mis-matched heteroepitaxy, there is no compromise in the epitaxial quality¹ of the liftoff films. We anticipate that the epitaxial liftoff approach will find use wherever there is a desire to combine thin film III-V semiconductor crystals with other materials and substrates. In particular, monolithic integration of minority carrier III-V devices onto pre-processed Silicon chips from a foundry should be feasible in the near term.

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REFERENCES

1. "Extreme Selectivity in the Lift-Off of Epitaxial GaAs Films", E. Yablonovitch, T. Gmitter, J. P. Harbison, R. Bhat, Appl. Phys. Lett. 51, 2222 (1987).
2. "(AlGa)As/(InGa)As Strained Quantum Well on Silicon Dioxide by Selective Device Liftoff as an Alternative to Hetero-epitaxy", D. R. Myers, J. F. Klem, J. A. Lott, Tech. Dig. of the 1988 Int. Elec. Dev. Mtg. (IEEE, Piscataway, N.J., 1988)
3. "Double Heterostructure GaAs Thin Film Lasers on Glass Substrates", E. Yablonovitch, E. Kapon, T. J. Gmitter, C. P. Yun, R. Bhat, IEEE Phot. Tech. Lett. 1, 41, (1989)
4. "MESFET Liftoff from GaAs Substrate to Glass Host", C. Van Hoof, W. D. Raedt, M. Van Rossum, G. Borghs, Electron. Lett. 25, 136 (1989)
5. "Regrowth of GaAs Quantum Wells on GaAs Liftoff Films 'Van der Waals Bonded' to Silicon Substrates", E. Yablonovitch, K. Kash, T. J. Gmitter, L. T. Florez, J. P. Harbison and E. Colas, Electron. Lett. 25, 171 (1989)
6. "Integration of GaAs LED's on Si by Epi-lift-off", I. Pollentier, P. De Dobbelaere, F. De Pestel, P. van Daele and P. Demeester, Proceedings of ESSDERC '89 (Berlin, 1989)
7. "A High-Speed InP/InGaAs Photodiode on a Sapphire Substrate", H. Schumacher, T. J. Gmitter, H. P. LeBlanc, R. Bhat, E. Yablonovitch and M. Koza, Elec. Lett. 25, 1653 (1989).
8. "Grafted GaAs Detectors on Lithium Niobate and Glass Optical Waveguides", A. Yi-Yan, W. K. Chan, T. J. Gmitter, L. T. Florez, J. L. Jackel and E. Yablonovitch, IEEE Phot. Tech. Lett. 1, 379 (1989).
9. "Optical Coupling of GaAs Photodetectors Integrated With Lithium Niobate Waveguides" W. K. Chan, A. Yi-Yan, T. J. Gmitter, L. T. Florez, J. L. Jackel, E. Yablonovitch, R. Bhat and J. P. Harbison, IEEE Phot. Tech. Lett. 2, 194 (1990).