ELO MBE of II-VIs at Heriot-Watt

There has over recent years been much discussion of the practical application of the epitaxial lift-off or ‘ELO’ technique. Often this has been in connection with the III-nitrides but it has attractions for other compounds too. A topical example is a UK project where ELO has been applied to the MBE growth of II-VI heterostructures using a novel MgS release layer.

A couple of years ago *TFR* reported on how workers at the School of Engineering and Physical Sciences, Heriot-Watt University, in Edinburgh, were developing a new growth method for the heteroepitaxial growth of thin films of magnesium sulphide (MgS) on GaAs substrates. By way of an update on progress, TFR spoke to Dr Kevin Prior.

“This project is some joint work between our MBE group and the Nano-Optics Group** here at Heriot-Watt. The growth is basically a modification of standard MBE growth which we have developed for MgS and MnS thin films.

“As I said last time we spoke, this has great promise for a whole range of new devices - but one of our particular interests today is in taking it a stage further with epitaxial lift-off for ZnSe/ZnCdSe and MgS/ZnCdSe quantum well structures. Because it is highly reactive we have been able to use MgS as the sacrificial layer. The technique works thanks to a huge contrast in etch rates between the metastable MgS release layer and the II-VI QW materials. Typically we see the ratio between MgS and ZnSe etch rate is some $10^8$.

“The growth of MgS basically employs fairly standard equipment, which has been adapted to suit the required conditions, notably low background sulphur pressure. The twin chamber VG Semicon V80H is fitted with conventional K-cell elemental sources for growth of ZnSe and CdSe. But for the sulphide layers a K-cell incorporating high purity zinc sulphide compound is used. There is no other source of sulphur in the chamber.

“Another modification is a liquid nitrogen cooled shutter to keep background sulphur as low as possible. This stops sulphur leaking into the chamber contaminating the GaAs substrate. Multilayers of various II-VI materials have been grown. Growth conditions include a temperature range of 230-270°C and growth is always on a thin ZnSe buffer layer, not directly on GaAs.”

Structures grown specifically for ELO comprise a buffer layer of ZnSe then the MgS release layer followed by the structure of interest. “Not only is etch selectivity important but also it is crucial to stress the epilayer. This causes it to bow up slightly which keeps an open channel for the etch to proceed - we do this by applying a layer of black wax. When cooled to room temperature, the wax is under tension and the substrate under compression, so, as the MgS is etched away the thin film curls up slightly, thus aiding the lift-off process, which is completed in approximately 30 min. This compares with having to wait several weeks if we need to have the substrate removed by conventional mechanical polishing.”

By comparing the PL from wafer material both with and without a MgS release layer, the team
conclude that the MgS release layer has no quantifiable effect on the energy, emission efficiency and linewidth of the ZnCdSe/ZnSe QW PL.

PL measurements were made on a lift-off layer on a glass substrate and on a piece of original wafer material under exactly the same conditions with PL excitation from a 400 nm GaN laser diode.

"In this sample the ZnSe buffer layer was deliberately doped with manganese so that we could identify it. PL experiments clearly indicate the removal of the Mn doped buffer layer. From this we could confirm that the luminescence efficiency of the QW isn’t changed within the measurement uncertainty of about 10% by the ELO.

"The PL peaks differ by at most 6 meV, showing that the strain in the QWs is virtually unchanged on lifting off the epilayer. The broad emission peak at 2.3 eV is, however, considerably weaker, which is exactly as expected as the Mn doped buffer layer is no longer present in the heterostructure."

**Future directions**

"Such results could be very important for a number of research areas," says Kevin’s colleague, Dr Richard Warburton of the Nano-Optics Group: ‘For example, MgS/ZnSe QW structures, have demonstrated the possibility of stable excitonic transitions at room temperature, but it is difficult to combine these with MBE grown epitaxial mirrors. By using ELO, we can transfer the MBE grown layers onto a conventional dielectric Bragg mirror in order to investigate II-VI polariton parametric amplification.

"Furthermore, because magnetic atoms can be incorporated into the II-VI semiconductor lattice without introducing doping, interest has been renewed in these materials for spintronics applications. This ELO technique should offer valuable advantages in combining these novel structures with ferromagnetic layers."


**The Nano-Optics Group is a new group formed at the Physics Department at Heriot-Watt University, for more information please visit:**

Web: [www.phy.hw.ac.uk/resrev/nano-optics/](http://www.phy.hw.ac.uk/resrev/nano-optics/)