Etching of Antimonide-Based Semiconductor Materials

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Introduction
Light emitting diodes (LEDs) fabricated on narrow bandgap semiconductors such as AlInSb and GaInSb offer a cheap and compact solution for developing gas sensors in the 3-5 μm wavelength range [1]. Fabrication of these devices requires a precisely controllable etching method to build mesa structures. This project aims at optimising the dry etching of AlInSb and GaInSb materials.

Experiments
The wafers with designed structures were grown on semi-insulating GaAs substrate by molecular beam epitaxy (MBE). Dry etch process of AlInSb/GaSb p-n diode and AlSb/GaAs/GaSb, distributed Bragg reflector (DBR) structures was investigated. One major limitation is that wafer temperature cannot exceed 120°C during the fabrication process to avoid performance degradation.

Chlorine (Cl) based etchant (a) and table pressure (b) are introduced.

Chlorine Based Etch
Due to the local accumulation of the by-product InCl3 polymer on the surfaces, chlorine based etchings showed rough etched surfaces although it provided high etch rate. Moreover, the temperature dots also indicated that the actual wafer temperature was over 200°C which is beyond the maximum temperature tolerated by this layer structure.

Methane/Hydrogen Based Etch
Results on the CH4/H2 based recipe show that etch rate is less than 100nm/min but gives low damaged sidewalls and smooth surfaces. ICP power is used to generate and control plasma density. RF bias power accelerates the plasma dynamic energy to physically bombard material. The etch rate therefore increases with increasing of ICP power due to the larger quantity of plasma introduced into the chamber. However, high ICP power leads to rough surfaces because the substantial polymer deposition cannot be completely removed by the slow physical reaction. High RF bias power gives a high etching rate as well as smooth surface morphology, while, excessively high bias power causes rough surface by physical bombardment and it also reduces selectivity through erosion of the masks.

The chamber pressure and table temperature also affect the etch rate and mesa sidewall profiles. A low chamber pressure results in sidewalls with positive slope but etch rate is decreased significantly. The table temperature influences the volatility of the polymer and therefore affects both sidewall and surface profiles. As the table temperature is increased the etch rate increases and the sidewall slope changes from positive to vertical and even shows a slightly undercut at 120°C.

Conclusion
In conclusion, it was found that chlorine based recipes are not suitable to etch antimonide semiconductor material under low temperature conditions. The optimum recipe is a CH4/H2/O2 chemistry with a ratio of 6/50/2 sccm, ICP/bias power=350/150W. Pressure=20mTorr, Table temperature=110°C that provides vertical sidewalls and smooth surfaces on the diode structure with an etch rate of 50nm/min. It was also found that reducing the chamber pressure causes a sidewall with a positive slope but decreases the etch rate. The same recipe without O2 and the power increase to 400/200 W appears to be promising for achieving vertical profiles in the DBR structure.

References:

Fig. 1 Wafer layer structure
Fig. 2 Schematic diagram of inductively coupled plasma enhanced reactive ion etching (ICP-RIE) machine [3]
Fig. 3 Cl based etch results (a)(b) diode and DBR sample (c), (d) diode and DBR etched with recipe: BCl3/Cl2/Ar=7.5/2.5/5sccm, ICP/bias power=2000/200W, Pressure=700mTorr, Table temp=100ºC.
Fig. 4 Etch rate vs ICP power (a) and RF bias power (b), CH4/H2/O2=6/50/0.2, chamber pressure=20mTorr
Fig. 5 Etch rate vs chamber pressure (a) and table temperature (b), CH4/H2/O2=6/50/0.2, ICP/bias power=350/150W
Fig. 6 Effect of O2 on diode sample (a) and DBR sample (b)