Micro drilled ‘via holes’ in III-V semiconductors

Reactive ion etching is widely used for producing via-holes because of superior uniformity and control of etch rates compared with wet etching. However, in spite of the extensive use of ionised gases for etching III-V MMICs, there is still a demand for procedures producing via holes in III-V semiconductors at a low cost, high speed, without photo-resists and toxic gases. This contribution describes our preliminary results on the use of micro-drills for the fast and maskless fabrication of via holes in GaAs/AlGaAs 2-DEG heterostructures. Van der Pauw Hall measurements and X-ray analysis showed there to be no adverse effects of the drilling on the electrical and crystallographic properties of the heterostructures.

Implementation of backside via holes in GaAs MMICs enables low inductance grounding as well improving heat dissipation. Such via-holes are used for improving the high frequency performance of MMICs incorporating heterostructure bipolar transistors (HBT) and high electron mobility transistors (HEMT).

The authors’ main motivation for this research is to use via holes as a means of eliminating bonding wires used in Hall effect sensor devices which lead to external noise due to induction loops.

The typical procedure used for forming a via hole in a thinned GaAs substrate involves using reactive ion etching (RIE) or inductively coupled plasma etching (ICP) to etch holes in a photore sist windows to a depth of between 100µm-300µm so as to electrically connect the backside with grounding pads on the front surface. Chlorine based gases such as BCl3/Cl2, SiCl4/Cl2 and CCl2F2/CCI enable etch rates of 2µm/min ~15µm/min [1].

The main technological issues still to resolve are (i) high etch rate and thus improved throughput; (ii) simplification of the process by a ‘maskless’ approach; and low cost.

We used ‘micro-drills’ to physically cut via holes into GaAs/AlGaAs heterostructures. Vertical and tapered via holes were readily produced without thinning of the substrate or photolithography prior to processing. Via holes were...
drilled in HEMT structures with a sheet carrier concentration of 5x10¹¹ cm⁻²/Vs and electron mobility of 6500 cm²/Vs, at room temperature.

The samples were fixed onto glass holders using industrial wax. The glass slides were then fitted into the sample holder of a programmable drilling system. Dedicated software enabled adjustment of the drill’s position, rotation speed and depth of penetration. The x-y positioning mechanism of the drill system has a reproducibility of 5µm. The vertical axis of the drill shaft has a vibration deviation of ~0.8µm. The procedure for producing a typical set of four via holes using a single drill was completed within 30 seconds.

Figure 1 shows four tapered via holes in the backside surface of a GaAs substrate. As illustrated in Figure 2, the via holes were formed by first using a 700µm diameter drill (30,000 RPM) to produce holes to a depth of 300µm, followed by the use of a 60µm diameter drill with a tip angle of 60° (10,000 RPM) to form the tapered region that opens up to the front surface, with an aperture of ~100µm.

Figure 3 shows SEM images of the diamond drill used for producing the via holes shown in Figure 1, as well as the vertical via holes in Figure 4. Here the SEM images of via holes with vertical walls, are formed in a single action using the micro-drill of Figure 3. The size of the aperture in the surface of the GaAs was varied by adjusting the depth of drill penetration into the sample. The morphology of the aperture was smooth and suitable for evaporation or electrochemical deposition of metals.

Subsidiary peaks in XRD spectra from the GaAs/AlGaAs heterostructure were not detected, thus indicating that the drilling did not produce crystalline defects. Further, we did not observe any differences in the sheet carrier concentration and electron mobility of the HEMT structures before and after drilling via holes.

We are proceeding to use micro-drills during the fabrication of micro-Hall effect devices without bonding wires which will considerably reduce noise due to induction [2].

The use of this simple method for forming via holes is expected to have applications in the fabrication of MMIC as well as discrete III-V high frequency devices. We were able to achieve similar results for InP and Si substrates.

The use of micro-drills offers an efficient, inexpensive and environmentally friendly means of producing via holes in III-V as well as other semiconductors.

References
