Ion Beam Milling using SIMS monitoring/control and directional Reactive Ion Beam Etching profile control for optoelectronic devices

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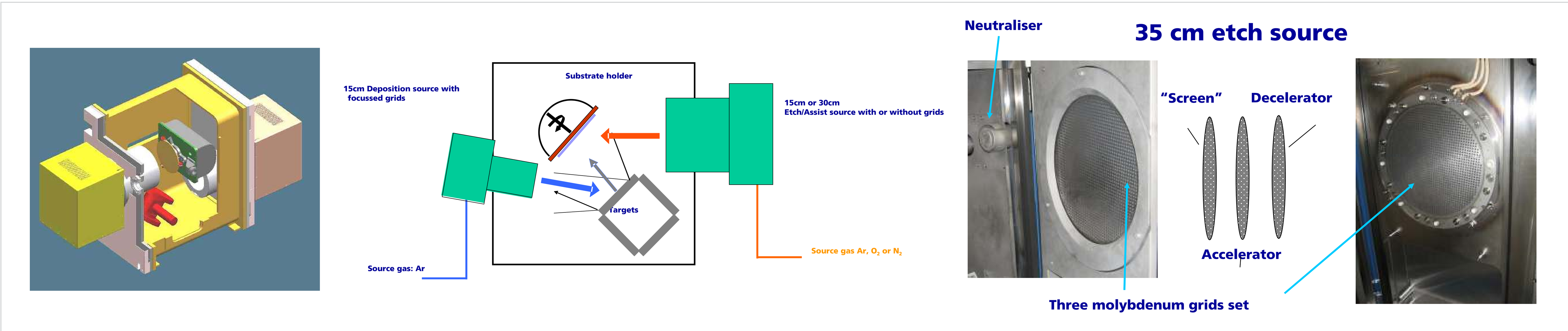
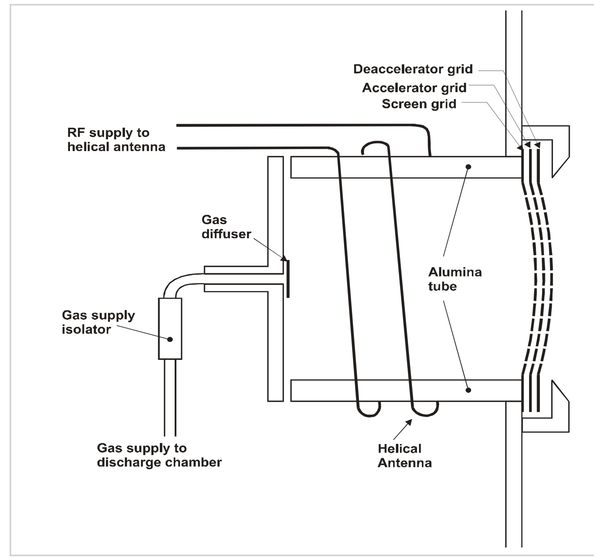
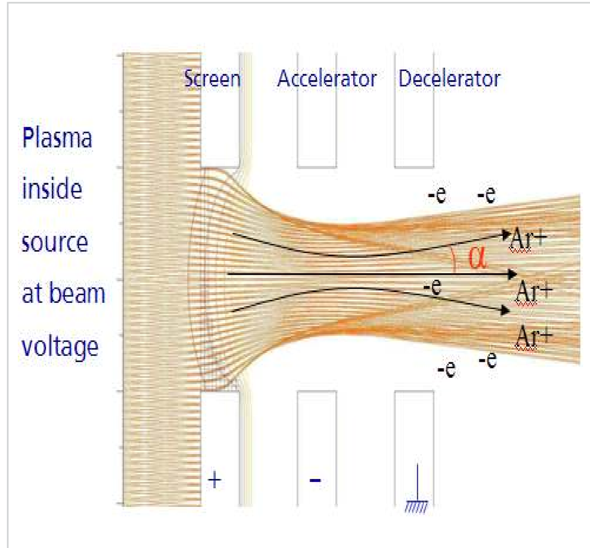
Etching/Milling using a Dual Ion Beam deposition/etch Ionfab®300 system





Electrostatic shield

- Triple molybdenum collimating grid set for low maintenance (reduce downtime)
- Screen grid: sets beam energy (+ voltage)
- Accelerator grid: helps to extract ions and provides focussing for ion beamlet (- voltage),
- Decelerator grid: helps beam collimation, electron backstreaming and sputter redeposition (grounded)
- Divergence α defined as: a cone encompassing 95% of the beamlet of angle $\pm\,\alpha$



SIMS monitoring and control of Ion Beam Milling (IBM) processes

Count per second against time sample D906

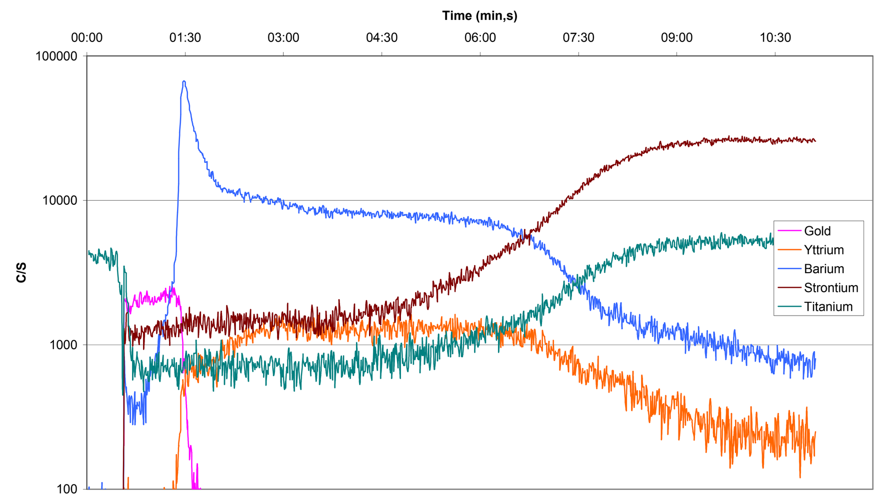


***Figure 1**: SIMS traces for Ar IB milling of an Au(32nm)/ $YBaCu_3O_7$(40nm) bi-layer on $SrTiO_3$*

This sample took the form of a 5 x 5 mm square located in the centre of a 150 mm Si carrier wafer. The sample material was Strontium Titanate ($SrTiO_3$) coated with a bi-layer stack: Au(32nm)/$YBaCu_3O_7$(40nm).

The ion milling parameters for this process were:

- Substrate angle to beam: 90°
- Beam voltage (energy): 250V
- Beam current density (intensity): 0.51 mA/cm²

Count per second against time while etching GaAs/AlGaAs (40/61nm) multilayers stack

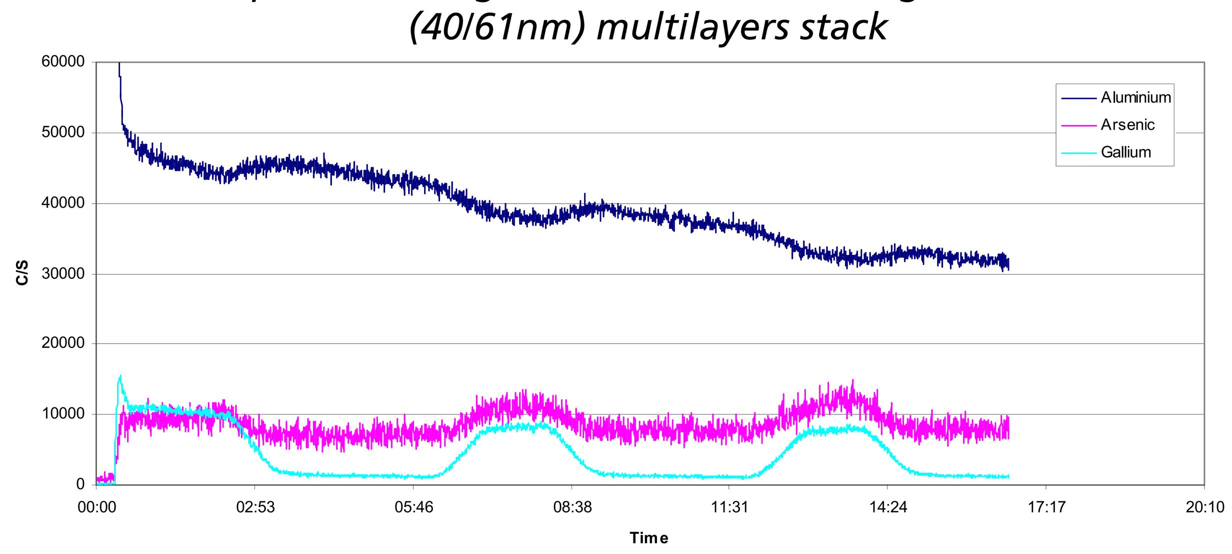


***Figure 2**: SIMS traces for Ar IB milling through a GaAs(40nm) /AlGaAs(61nm) multilayer*

This sample took the form of a 10 x 10mm square located in the centre of a 150 mm Si carrier wafer. In Figure 2, the transition between the GaAs and AlGaAs layers can clearly be seen, in particular from the Ga signal. The As signal is also varying in the same manner between the two layers showing the reduced amounts of these two elements in the AlGaAs alloy. The Al signal shows a high background level due the presence of aluminium in chamber components and some coating which is progressively being etched away, but the variation from one layer to the next can still clearly be seen.

The ion milling parameters for this process were:

- Substrate angle to beam: 90°
- Beam voltage (energy): 500V
- Beam current density (intensity): 0.64 mA/cm²

SIMS detection of an MTJ multilayer stack

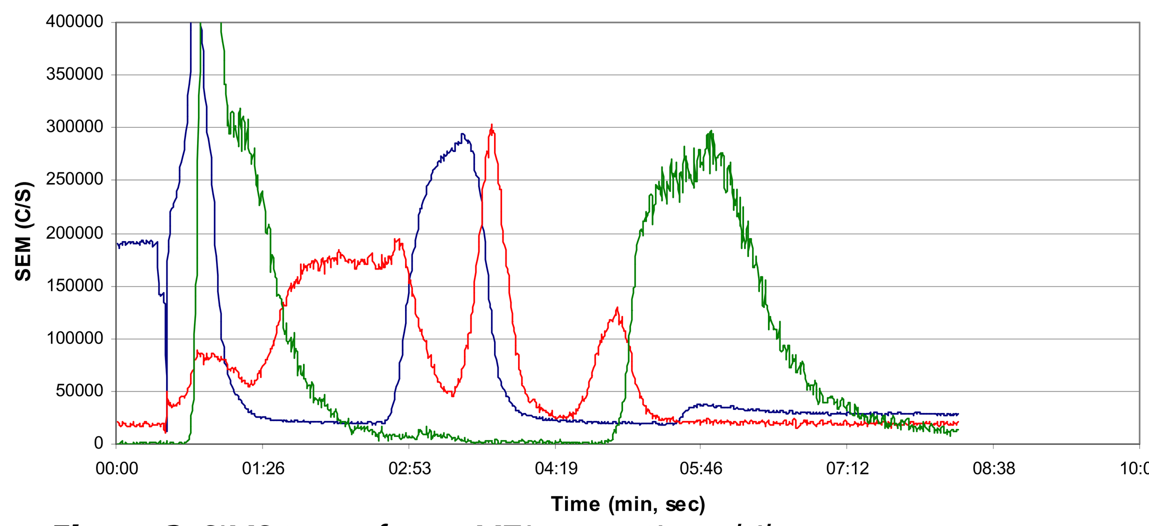


Figure 3**: SIMS traces for an MTJ magnetic multilayer: **Ta(5nm)/ Co(15nm)/ Al2Ox(2.3nm)/ Co (3.5nm)/ FeMn(10nm)/Co(5nm)/Ta(5nm) /SiO2(2mm)/ (Si substrate)

IBE of MRAM multilayers with SIMS probe
This example is the SIMS-controlled milling by Ar IBE of a TMR (tunnelling magneto-resistive) magnetic multilayer for MRAM applications on our Ionfab300+ tool. This tool was also supplied with a cryo-cooled chuck capable of reaching -170C in 14mins from room temperature.

The ion milling parameters for this process were:

- Substrate angle to beam: 90°
- Beam voltage (energy): 250V
- Beam current density (intensity): 0.51 mA/cm²

Reactive Ion Beam Etching (RIBE) process applications in optoelectronics/photonics

Blazed grating and laser diode fabrication

Figure 4 shows some examples of the application of the **Ionfab**300 etch tool in the optoelectronics/photonics area to the fabrication of a blazed grating and laser diode structures. The 'blaze angle' can be accurately determined by the capability of the tool for substrate positioning relative to the well-defined ion beam direction.

These processes are by RIBE using reactive gases SF_6 and CHF_3 for silica etch and Cl_2 for GaAs etch mixed in optimised ratios with Ar. The SEM pictures show static etching at 30° and 45° to the ion beam incident direction.

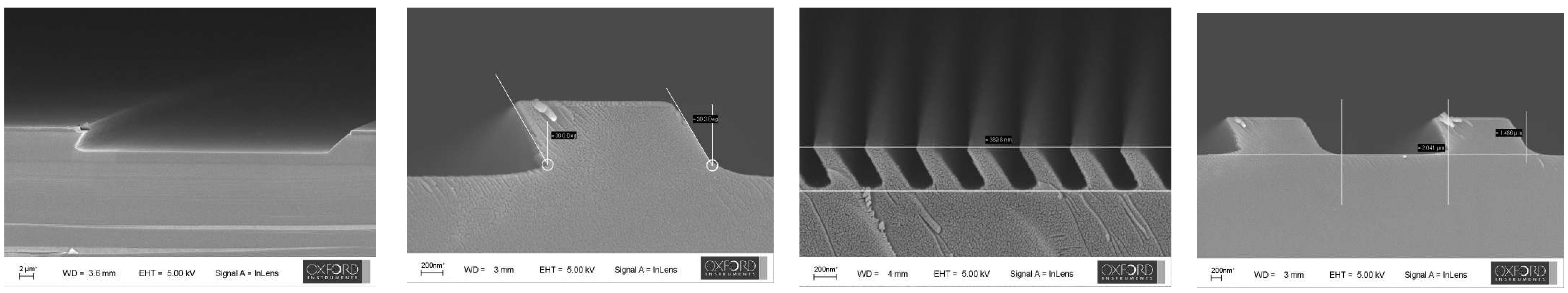


***Figure 4:** Blazed grating etch in quartz and laser diode structure etch in GaAs*

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