XeF_2 gas-assisted focused-ion-beam etching of InSb quantum wells for rapid prototyping of semiconductor nanodevices

D. K. Shearer[1], M. Masteghin[2], D. C. Cox[2], S. K. Clowes[1]

[1]Advanced Technology Institute, Department of Physics, University of Surrey

[2]Advanced Technology Institute, Department of Electrical and Electronic Engineering, University of Surrey

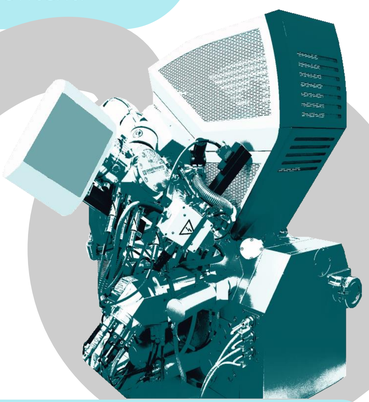
Aim: To develop a novel fabrication technique for **rapid prototyping of nanodevices** from InSb quantum wells

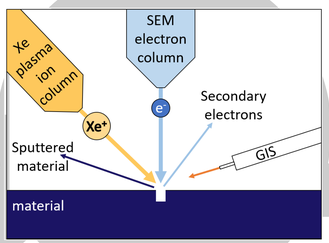
Background

Standard fabrication techniques for making nanodevices from semiconductors are **complex**, **time-consuming** and require photomasks which are **expensive**. We explore the use of **focused ion beam (FIB)** lithography for the nanomachining of devices from InSb quantum well materials. The FIB instrument uses a beam of ions to remove atoms from the sample surface. This flexible technique is a **'direct-write'** method, making fabrication quick as well as allowing for the testing of different etching chemistries and electrical properties in-situ[1]. This makes the FIB ideal for rapid-prototyping of novel devices within the R&D context.

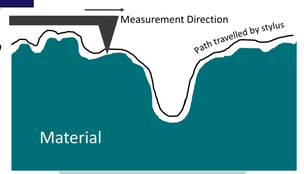
Methods

- The Xe plasma FIB was used to **etch trenches** into the InSb quantum wells
- Various **beam parameters** and the addition of a **fluorine chemistry** (XeF_2) was explored
- After etching, **scanning electron microscope images** were taken and the surface scanned using a **profilometer** to assess etch depth and quality



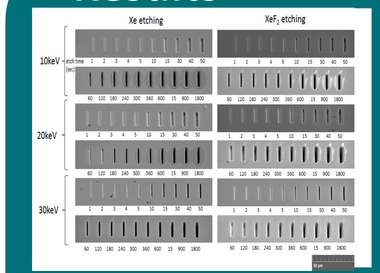


Focused Ion beam etching

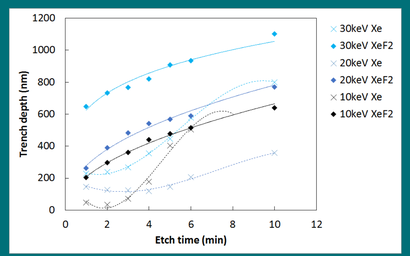


Stylus Profilometry

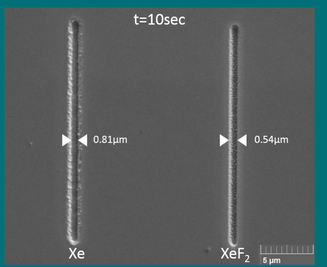
Results



SEM images taken at a 55° angle of etches made using Xe plasma FIB milling with a beam energy of 10keV, 20keV, 30keV without (right) and with (left) fluorine gas injection.



Trench depths taken from the pofilometry results



SEM image of trenches made using Xe (left) and XeF_2 (right) etching. Etching parameters were 30keV beam energy, 100pA beam current, and 10 sec etch time

XeF_2 chemistry increases etch rate, produces higher resolution features and less sputtered material compared with just the Xe beam

Resolution of 540nm trench width achieved with XeF_2 , 100pA beam energy & 10sec etch time

Conclusions

- XeF_2 is a suitable ion beam etching regime for InSb/ InAlSb quantum wells for making nanodevices
- The fabrication toolkit developed can produce resolution comparable to conventional lithography techniques with the advantages of the FIB system for R&D applications

Future Work

This study lays the groundwork for developing InSb-based nanoscale quantum devices. InSb has low effective mass, high mobility, and strong spin-orbit coupling making it an ideal material for applications such as spintronics[2], but until now fabrication challenges[3,4] have slowed the development of innovative InSb-based spintronics devices.

References

[1] A. A. Tseng, "Recent developments in micromilling using focused ion beam technology," Journal of Micromechanics and Microengineering, vol. 14, pp. R15-R34, Jan 2004.

[2] I. Zutic, J. Fabian, and S. Das Sarma, "Spintronics: Fundamentals and applications," Rev. Mod. Phys., vol. 76, pp. 323-410, Apr 2004

[3] M. Levinshtein, S. Rumyantsev, and M. Shur, Handbook Series on Semiconductor Parameters. WORLD SCIENTIFIC, 1996.

[4] J. W. Lee, R. J. Shul, G. A. Vawter, C. R. Abernathy, S. J. Pearton, and Y. B. Hahn, "Reactive ion beam etching of In-containing compound semiconductors in an inductively coupled Cl2/Ar plasma," Japanese Journal of Applied Physics, vol. 42, pp. 38-43, Jan 2003

Get in contact

Daisy Shearer

d.shearer@surrey.ac.uk