Fabrication of templates for large area patterning and the replication of "Motheye lenses" using Step and Flash Imprint Lithography (S-FIL)

J.Kettle [a,b], R.T. Hoyle [b] , R. M. Perks [c], S.Dimov [c]

[a] *Microelectronics and Nanostructures group, School of Electrical and Electronic engineering, The University of Manchester, PO Box 88, Manchester M60 1QD, UK*

[b] *Microbridge Services ltd., c/o Cardiff University, The Parade, Newport rd., Cardiff, CF24 3AA, Wales*

c Manufacturing Engineering Centre/School of Engineering, Cardiff University, Cardiff, CF24 3AA, Wales

An important consideration during the fabrication of micro and nano structures using Step-and Flash imprint Lithography (S-FIL) is the preparation of the templates. Conventional, patterning of a quartz S-FIL templates can be achieved using Electron Beam Lithography (EBL) followed by dry etching. As discussed by Kettle *et al* [1], Focused Ion Beam (FIB) lithography offers an alternative technique for patterning quartz templates due to its flexibility and relative simplicity. Whilst, S-FIL is commonly used for 2D patterning, few examples of S-FIL replication of complex 3D structures have been reported. One of the reasons for this is that the commercially-available (Monomat™) material is known to contract after UV curing [1]. Whilst this has been shown not to be a significant a problem for relatively simple 3D structures such as microlenses it is a challenge for complex 3D structures with a very high surface to volume ratio. Often, replication problems arise due to shrinkage, etc.

In this paper, the fabrication and characterisation of 2D and 3D structures using FIB onto templates for S-FIL is discussed. It has been discovered that the 2D line width and height is closely related to the ion dose. However, FIB milling is generally accompanied by re-deposition of the milling by products. This can be a hindrance to densely patterned structures required in most NIL applications. To reduce these re-deposition effects, xenon difluoride (XeF_2) FIB etching was applied. This process increases the material removal rates in comparison to ion sputtering. The effect of using XeF_2 gas during milling is highlighted in fig. 1. The XeF_2 gas assisted etching, FIB structuring has been used to fabricate <100nm structures onto quartz S-FIL templates. The presence of XeF_2 considerably enhances the etching rate of quartz without any significant negative effects on the spatial resolution of the FIB lithographic process.

Furthermore, we introduce a method to overcome the problem of polymeric resist contraction for complex 3D patterns, using a "multilayer" imprinting technique and apply this technique to the fabrication of "Motheye" lenses. With respect to the imprinted replica, we show that by using this approach, high fidelity can be achieved with the imprinting of complex 3D structures. Motheye lenses can therefore be consistently replicated when employing the S-FIL technology (see fig. 2).

[1] J. Kettle, R.T. Hoyle, S. Dimov, R.M. Perks, *J. Vac. Sci. Technol. B,* 26, 5, pp. 1794-1799 (2008)

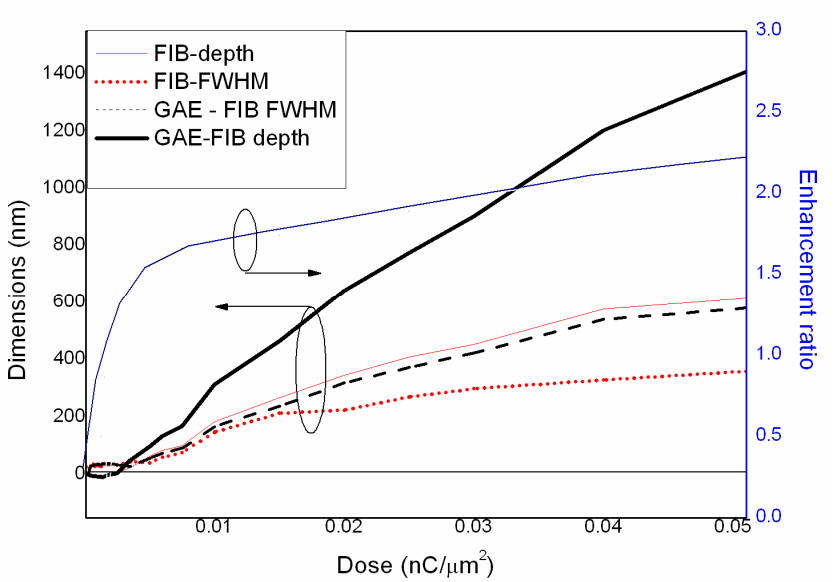

Figure 1. Change in height and FWHM as a function of ion dose for FIB milling into a quartz template, for both the case of Gas Assisted Etching (GAE) using XeF2 and relying on direct sputtering without Gas assisted Etching (non-GAE). Included is also the etch enhancement ratio of the depth as a function of ion dose.

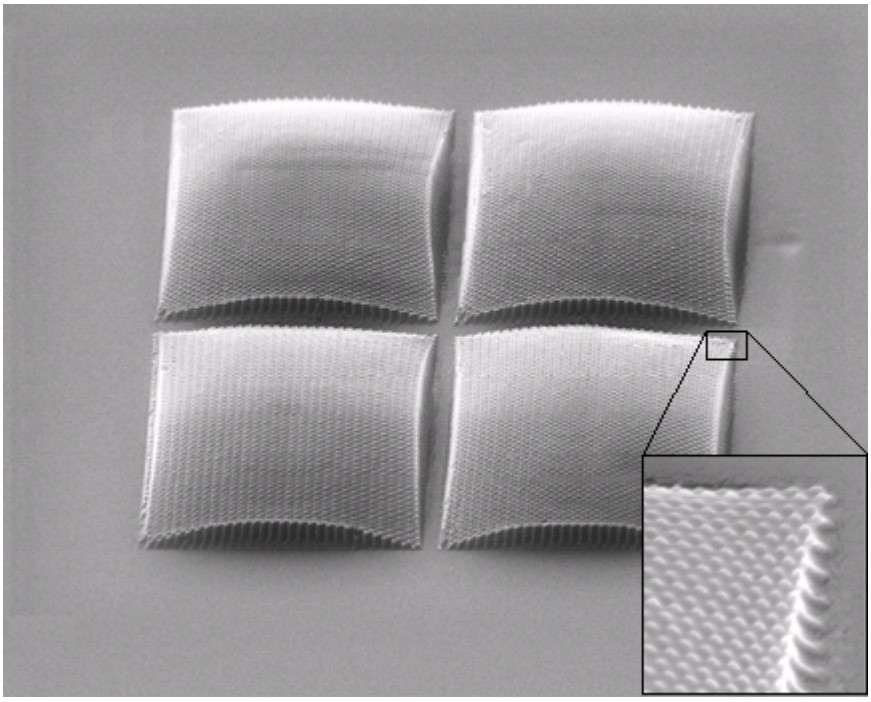

Figure 2. SEM image of S-FIL replication of the Motheye lenses after adopting the "multilayer" imprinting approach with (inset) showing 80nm lenses on the surface of the larger lens