Reflow transfer: extending planar micro- and nanolithography to 3-dimensional substrates.

G. Zabow
National Institute of Standards and Technology, Boulder, Colorado, 80305
gary.zabow@nist.gov

While optical lithographies provide detailed micro- and nanopatterning capabilities, such high-resolution patterning is traditionally limited to only planar, rigid surfaces, and to only those substrate sizes and materials classes that are compatible with cleanroom processing environments. Some of these limitations have been overcome in recent years through the development of various transfer microprinting techniques that can lift nanopatterns or structures from the surfaces on which they are originally made and transfer them onto a secondary, receiving surfaces that need not necessarily be completely planar nor completely rigid, enabling patterning or structuring of gently curved and/or soft substrates. Nevertheless, existing transfer techniques are still unable to pattern surfaces of arbitrary geometry and/or curvature. Existing techniques rely on either solid transfer carriers with limited flexibility for conformally mapping to an underlying substrate, or liquid transfers that cannot accurately position or preserve the ordering of the transferred patterns. Here, a new surface micropatterning approach is suggested based on a new microprinting technique that transfers micropatterns using thermally reflowable materials [1]. It is shown that such reflow transfer provides for accurate transfer positioning and patterning while at the same time providing high flexibility for conformal mapping onto truly 3-dimensional receiving substrates of arbitrary shape and dimension. The micro- or nanopatterns and structures transferred in this way can then either form the surface patterning itself or be used as temporary templates for further structuring through patterned chemical or physical processing of, or deposition onto, the underlying surface.

The reflow process requires only low operating temperatures and uses materials that are cheap and fully water soluble. This allows for chemically and physically gentle surface structuring without any harsh or contaminating solvents, making the process compatible with a broad array of materials and environments. Examples include micropatterning and structuring of both traditional planar and non-planar substrates made from an array of materials including semiconductors, metals, glass, plastics, elastomers, hydrogels and paper. This presentation explains the new reflow patterning process and shows example surface patternings that can be realized via this new approach, two of which are shown in figs 1 and 2 below.

[1] G. Zabow, *Science* 378, (2022)

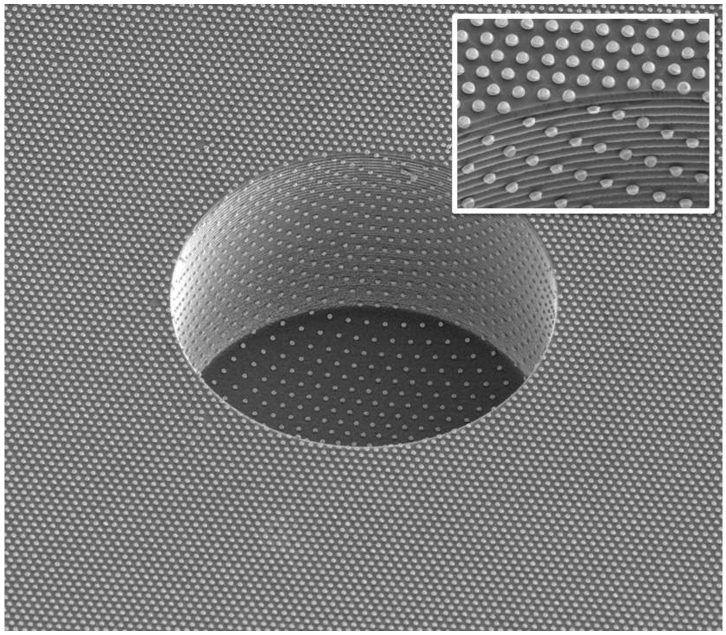

Figure 1: Micropatterning recessed surfaces: SEM showing reflow transfer patterning over a surface with deep recessed hole. Inset shows magnified view of transfer over the top edge of the recessed hole. For scale, patterned disks are 1 micrometer in diameter.

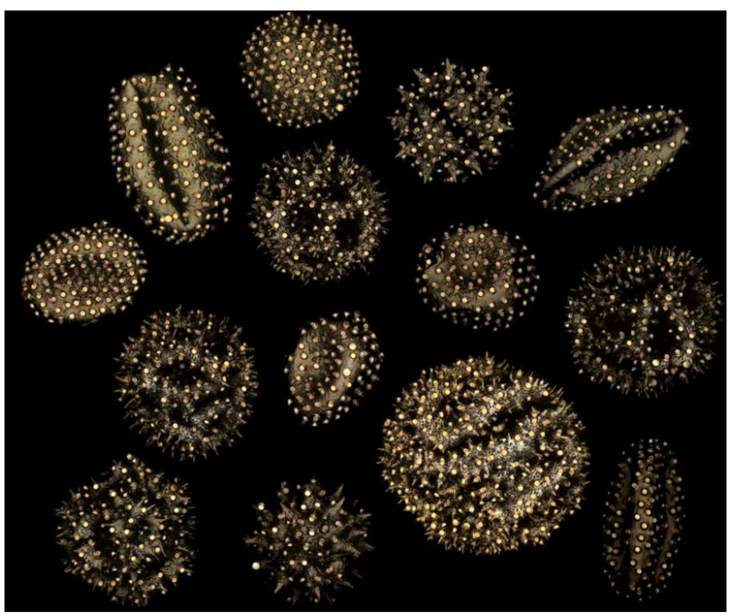

Figure 2: Micropatterning 3D micro-objects: Collage of laser confocal micrographs showing individual grains of pollen, micropatterned with arrays of gold disks using the reflow transfer process. For scale, patterned disks are 1 micrometer in diameter.