Laser-Based Rapid Manufacturing Technique for Nano/Micro-Scale Features

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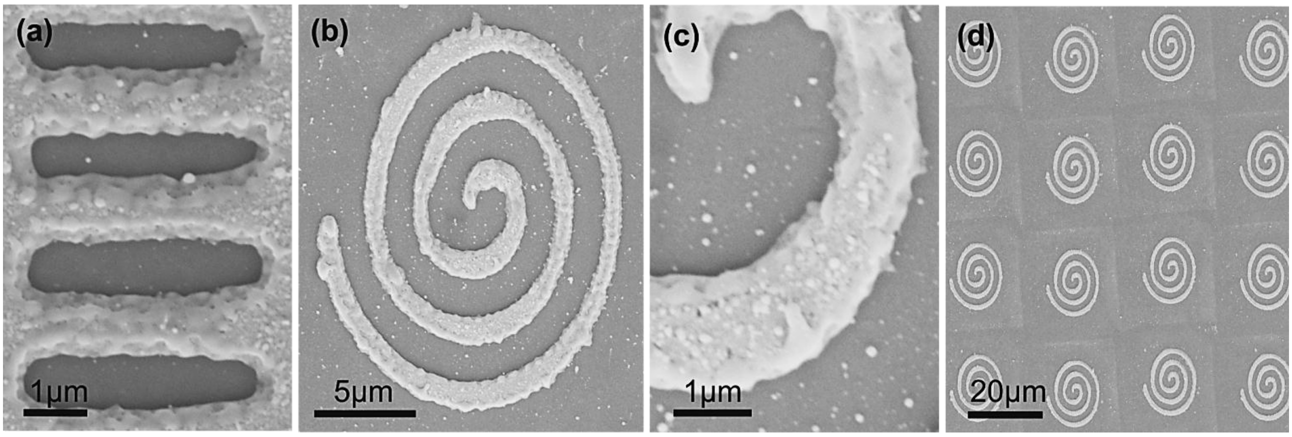
Abstract: Femtosecond laser ablation via a digital multi-mirror device has been used to fabricate micron-scale 2D features made of bismuth-selenide. Multiphoton ablation means this technique is applicable to materials transparent for the IR and visible spectrum.

There exists a wide range of techniques for the fabrication of nano-scale metamaterials, including electron beam lithography, focused-ion beam (FIB) milling and direct laser writing. Whilst techniques such as FIB provide resolution in the tens of nanometre range, manufacturing time is certainly an issue and fabrication of either large arrays or patterns within the µm to mm scale can prove problematic.

We demonstrate here that femtosecond ablation, via use of a digital multi-mirror device (DMD, Texas Instruments DLP3000 [1]), can be used to pattern large areas of a sample with sub-micron resolution and minimal localised damage. The DMD itself consists of an array of 680 by 608 10.6µm wide mechanical flip mirrors, which can rapidly switch between 'on' and 'off' positions at a rate greater than 1kHz. By illuminating the DMD with 800nm femtosecond laser light and subsequently imaging the projected intensity at large values of demagnification with a 50x objective, we have been able to produce binary spatial intensity profile that can be used to directly ablate complex patterns onto a substrate, which as a first demonstration was a 300nm thick bismuth selenide chalcogenide film sputtered onto a glass substrate. The figure shows a) ablation of 1µm wide lines, b) ablation of all material that is not part of a spiral pattern hence leaving just a thin spiral profile on the glass substrate, c) close up of the same image, and d) an array of near-identical structures. Single shot ablation is possible hence enabling rapid manufacturing; sample coverage of 1mm by 1mm, with submicron resolution, has been achieved in ~20 minutes through the use of a 1kHz repetition femtosecond laser, and typical edge quality is measured to be ~100nm. Through careful control of the intensity, we have achieved line widths of ~400nm (λ/2). Due to the high intensities on the sample (~10^{10} W/cm^2), ablation via multiphoton absorption is readily observed, hence enabling this technique to be applied to the manufacturing of materials that do not absorb either in the IR or visible spectrum [2].



[1] Texas Instruments (2012) http://www.ti.com/lit/ds/symlink/dlp3000.pdf (last accessed 8/10/2012)
[2] R. R. Gattass and E Mazur (2008) Nat. Phot. 2 219