Precision Manufacturing of Laser-Fabricated Nanofoam

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Femtosecond laser machining enables light-matter interactions that may not be possible for nanosecond and longer pulses. Presented here is a method for the targeted fabrication of nanofoam via 250kHz repetition rate, 4μJ femtosecond pulses. Previous work explored the laser parameters [1] and demonstrated fabrication of nanofoam inside a hollow capillary [2].

Here, the nanofoam was fabricated by raster-scanning a 5μm diameter laser focus over a silica substrate with scan speed of 1mm/s, and 5μm separation between adjacent scanned lines. The high repetition rate laser pulses produce a plasma that expels jets of molten material, which can solidify into ~100nm diameter nanowires, hence creating a high-porosity nanofoam. Typically, the top ~1μm of the material is sacrificed to produce ~100μm deep nanofoam. As shown in Fig. 1a), a computer-controlled shutter blocked the incident laser pulses at pre-determined times in order to irradiate specific regions on the sample, hence enabling targeted fabrication of nanofoam. Here, a QR code [3] was fabricated via 210 raster-scanned lines, and encoded with the string “50.935018, -1.399512” corresponding the latitude/longitude of the Physics building at the University of Southampton.

As illustrated in Fig. 1b), a Huawei P9 smartphone was used to image the silica substrate and enabled the accurate recovery of the information from the nanofoam QR code. Fig. 1c) shows the image recorded by the smartphone and d) shows the location corresponding to the recovered information. Detection via smartphone was enabled by the presence of the highly scattering ~100nm diameter nanowires that formed the nanofoam, which resulted in significant scattering of incident light, hence making the fabricated regions appear white. The QR code, at approximately 3mm by 3mm, was the smallest nanofoam QR code reliably recognisable via the smartphone, without additional optics.

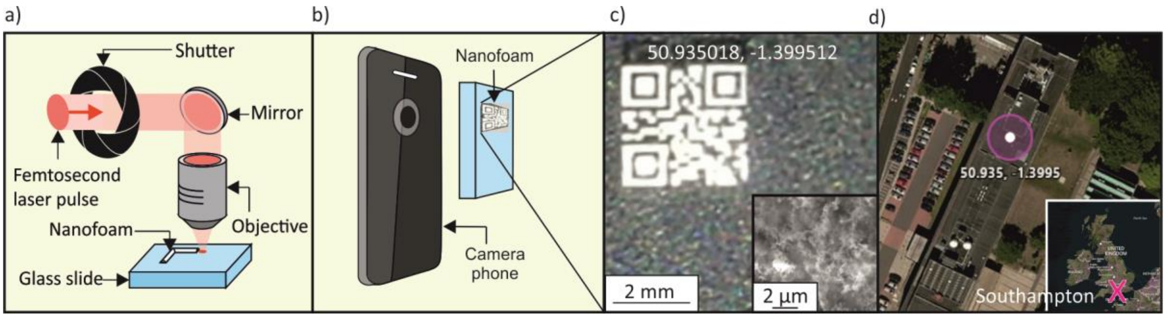

Figure 1: Showing a) schematic for fabrication of QR code, b) method for extraction of encoded text string from QR code, c) image recorded on smartphone (inset showing SEM image of a region on the sample) and d) the location corresponding to the recovered string.

Nanofoam offers several advantages when compared to surface marking via direct ablation. We have already shown that nanofoam can be produced inside sealed geometries [2], due to the multiphoton nature of the process, hence offering the potential for labelling inside finished products. In addition, our recent results indicate that the nanofoam is effective as a particulate capture device, therefore showing potential for an airborne pollution sensor or a biological filtration device that also contains smartphone-readable information.

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[2] A. F. Courtier, et al. (2017) "Laser-Based Fabrication of Nanofoam inside a Hollow Capillary." MSA 8.12: 829.
[3] J. Rouillard, (2008) "Contextual QR codes." Computing in the Global Information Technology. ICCGI'08.