Laser-assisted transfer for rapid additive micro-fabrication of electronic devices

M. Feinaeugle*, B. Mills, D. J. Heath, C. L. Sones and R. W. Eason

[1]*Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, UK*

*Mailing Address: Matthias.Feinaeugle@soton.ac.uk

Abstract

Laser-based micro-fabrication techniques can be divided into the two broad categories of subtractive and additive processing. Subtractive embraces the well-established areas of ablation, drilling, cutting and trimming, where the substrate material is post-processed into the desired final form or function. Additive describes a manufacturing process that most recently has captured the news in terms of 3-d printing, where materials and structures are assembled from scratch to form complex 3-d objects. While most additive 3-d printing methods are purely aimed at fabrication of structures, the ability to deposit material on the micron-scale enables the creation of functional, e.g. electronic or photonic, devices [1].

Laser-induced forward transfer (LIFT) is a method for the transfer of functional thin film materials with sub-micron to few millimetre feature sizes [2,3]. It has a unique advantage as the materials can be optimised beforehand in terms of their electrical, mechanical or optical properties. LIFT allows the intact transfer of solid, viscous or matrix-embedded films in an additive fashion. As a direct-write method, no lithography or post-processing is required and does not add complexity to existing laser machining systems, thus LIFT can be applied for the rapid and inexpensive fabrication or repair of electronic devices. While the technique is not limited to a specific range of materials, only a few examples show transfer of inorganic semiconductors. So far, LIFT demonstration of materials such as silicon [4,5] have undergone melting, and hence a phase transition process during the transfer which may not be desirable, compromising or reducing the efficiency of a resulting device.

Here, we present our first results on the intact transfer of solid thermoelectric semiconductor materials on a millimetre scale via nanosecond excimer laser-based LIFT. We have studied the transfer and its effect on the phase and physical properties of the printed materials and present a working thermoelectric generator as an example of such a device. Furthermore, results from initial experiments to transfer silicon onto polymeric substrates in an intact state via a Ti:sapphire femtosecond laser are also shown, which illustrate the utility of LIFT for printing micron-scale semiconductor features in the context of flexible electronic applications.

References

1. Photonics Revolutionising our World, http://photonicsuk.org, Date accessed: 28.02.2014

2. Arnold, C.B., Serra, P. & Piqué, A., 2007. Laser Direct-Write Techniques for Printing of Complex Materials. MRS Bulletin, 32(1), pp.23–32

3. Banks, D.P. et al., 2006. Nanodroplets deposited in microarrays by femtosecond Ti:sapphire laser-induced forward transfer. Applied Physics Letters, 89(19), p.193107

4. Zywietz, U. et al., 2014. Laser printing of silicon nanoparticles with resonant optical electric and magnetic responses. Nature communications, 5, p.3402

5. Toet, D. et al., 2000. Experimental and numerical investigations of a hydrogen-assisted laser-induced materials transfer procedure. Journal of Applied Physics, 87(7), pp.3537–3546