Large area flexible conductive scaffolds by direct laser writing

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Two photon polymerization (2PP) is a direct laser writing technique used to fabricate complex micro/nano structures of different light sensitive materials. 2PP is a non-linear optical process that enables the simultaneous absorption of two photons in a photosensitive material known as photoresist. This initiates a polymerization process by activating so called photo-initiators in the photoresist by converting them into radicals and enables the polymerization of the resist locally. The limitations of the existing high numerical aperture focusing lens for two photon polymerisation processes impede scalable high speed production of the scaffolds. This issue is addressed by developing an ultrashort laser scanning, direct write, process with the ability to manufacture the scaffold templates with custom architectures. Two-dimensional (2D) polymer-based scaffolds with the ability of being easily detached from the host substrates are prepared by direct laser writing. An ultra-short laser is used to write the structures. These highly flexible scaffolds can be easily removed from the substrate. The process can produce features down to a few microns in size over large areas -up to 50 mm x 50 mm within minutes.

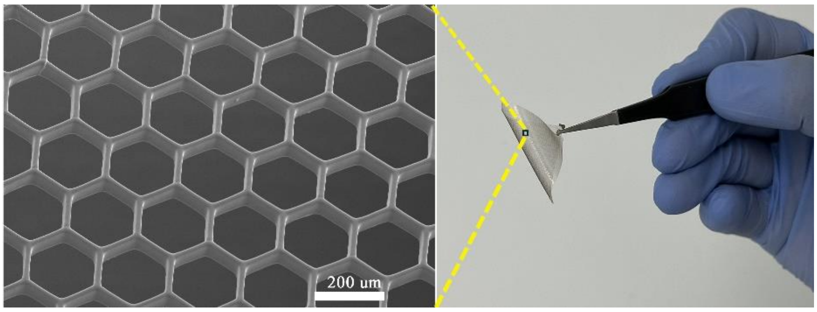

Figure 1: Flexible hexagonal structures scaffolds with good surface quality.

To make the scaffold electrically conductive is also challenging as the metallisation typically requires elevated temperatures (> 600^{o}C) to acquire the appropriate crystallisation to achieve the required electronic conductivity. Such elevated temperatures would destroy the micron-sized features forming the polymer scaffold. We developed low temperature sputter-coated process to add nanometre-thin gold layer on the scaffold structures. These coated non-conductive/highly resistive scaffolds are then annealed with ultra-short laser pulses at controlled and very low fluences.

Scaffolds can be rolled or folded with extremely small radii of curvature to produce three dimensional (3D) scaffolds. Mechanical measurements of the scaffold confirm that the effective elastic modulus of the scaffolds can be tuned by the geometric structure which is written into the scaffold. Non-isotropic structures give rise to non-isotropic mechanical properties. Preliminary interaction of the scaffolds with endothelial cells, cardiomyocytes, and clusters of cells known as vascular organoids have been examined and show promising first results. The development of reconfigurable structures can be tailored to suit the mechanical properties and size of the cell or vascular organoids of specific interest. This enables their potential to be deployed as a cardiac patch by minimal invasive surgery.