Multi-material bio-printing facilities
Juhani Virtanen, Sampo Tuukkanen*
BioMediTech Institute and Faculty of Biomedical Sciences and Engineering, Tampere University of Technology (TUT), Finland. *sampo.tuukkanen@tut.fi

Dispenser printing provides a method to produce 2D and 3D patterns from basically any liquid phase material. Dispensing considered here is a form of extrusion of material through a narrow diameter needle. An advantage of dispensing technique over conventional printing techniques is the avoidance of complicated ink formulation, which generally requires hazardous organic solvents that may be harmful to biological objects. Dispensing also allows materials with rather different properties such as different viscosity to be printed in the same process. Combining the dispensing printing of liquid phase materials and 3D printing of solid materials, complex structures with new functional properties can be fabricated, which is very challenging if not impossible using conventional manufacturing techniques.

**Dispenser system for bio-printing**

Fig. 1 shows a dispenser robot (EFD Nordson) capable for printing liquid phase materials, e.g. hydrogel or nanocellulose dispersions. The robot is controlled by a PC software and the actual liquid volume with dispensing controllers (three dispenser seen in Fig. 1). The working area of this dispensing robot is 400x400x200 mm with a repeating accuracy of 10 µm. The needle diameter can be varied between 50 µm and 2000 µm. Figs. 2 and 3 show the dispenser-printed tracks of cellulose nanofibril (CNF) gel (Fig. 4).

**Nanocellulose printing & aerogels**

Aerogels can be prepared by freeze-casting or freeze-drying process. Freeze-casting is a method where aqueous dispersion is deposited and solidified by simultaneous freezing the water molecules (freezing-stage in Fig. 5). The solidified water crystals the retain the shape of the casting even though the solid material concentration is very low (~1 wt-%). After the structure is solidified by freezing water is removed with a freeze-drying process. If done properly the water removal won’t affect the solid components and an aerogel structure is remains (Fig. 6). Dispenser printed aerogel (Fig. 7) which has been freeze dried can be seen. Nanocellulose aerogels [1] are potential lightweight materials for example in biomedical or membrane applications.

**FDM 3D multi-material printing**

Figure shows a multi-material Fused Deposition Modeling (FDM) printer. This particular Prusa i3 Mk2 printer is capable of printing 4 different filament materials in a single print without operator interaction. Therefore it can be used to combine functional properties such as flexibility, electrical conductivity or visibility to the structure. The FDM prints can also be combined with the dispenser robot prints to enable even more complicated material combinations.

**Microscopic analysis of nanocellulose aerogels**

The prepared aerogels from cellulose nanofibrils (CNF) and cellulose nanocrystals (CNC) (Fig. 6) were imaged with three microscopic techniques, scanning electron microscopy (SEM, Figs. 11, 12), X-ray micro–computed tomography (µCT, Figs. 13,14) and He-ion microscopy (HIM, Figs. 15,16). SEM shows well the aerogel surface features, such as well distinguishable CNC particles, whereas µCT and HIM gives more information about 3D-structure of the aerogels. CNF aerogel appears as lamellar planes, whereas CNC aerogel forms a needle-like mesh.

**Nanocellulose based electronic devices**

Nanocellulose is an interesting material for electronic applications, such as supercapacitors [2] and piezoelectric sensors [3, 4] because of high surface area, entangled networks of cellulose nanofibrils (CNF) and permanent dipole moment of cellulose nanocrystals (CNC).

References