3D-Printing Pluronic F-127 Lattices to Spray with Methylcellulose Nanowires and Encapsulate with Agarose Gel

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Abstract

Pluronic F-127 gel lattices were printed on preheated silicon wafers using a modified 3D printer. The sample was then sprayed with a solution of methylcellulose to form methylcellulose nanowires, and hot agarose gel was poured on top of the lattice in order to encapsulate it. The agarose gel was then allowed to solidify and was carefully removed, leaving the impression of the lattice in the gel. The lattice structure was then printed directly onto the silicon wafer. The agarose wafer was then heated to 35°C and electrospray deposition was used to spray the sample, first with a 1 wt% shell solution, dyed with oil blue dye, to test the encapsulation process, and then later with an MC solution. Originally, the material was printed onto glass slides, which were then placed onto a silicon wafer before spraying, but we discovered that when the sample was printed directly onto the silicon wafer it was more conductive and allowed more material to be deposited during spray. The difference between the coating of a sample printed directly onto a silicon wafer and the coating of a sample printed onto a glass slide can be seen in Figure 2. Microscopic images of the samples were then captured to ensure that the Pluronic F-127 structure was coated by the spray material. Figure 3 shows microscopic images of the blue-dyed shell particles that were deposited onto the structure. While the optical microscope images could not resolve the spray morphology, optical scattering was taken as an indicator that nanoparticles and wires were being sprayed as opposed to dense films. Next, a hot 1 wt% agarose solution was poured over the structure and allowed to cool in order to create a mold of the printed structure. Because Pluronic F-127 gel solidifies when heated to a temperature between 25°C and 35°C, and the agarose solution gels between 34°C and 38°C, the complementary nature of the two gels facilitated encapsulation. The solid agarose was then peeled off, and an imprint of the Pluronic F-127 structure was left in it, along with the material sprayed onto the original lattice; this feature can be seen more easily when observing the encasulations that were made using the blue-dyed shell spray, as shown in Figure 1.

Research Conducted

The modified printer was used to print 10 wt% Pluronic F-127, made using a 2 wt% KCl and distilled water solution instead of plain distilled water. The salt in the solution was used to make the material more conductive. A lattice of this material was then printed directly onto a silicon wafer. The silicon wafer was then heated to 35°C and electrospray deposition was used to spray the sample, first with a 1 wt% shell solution, dyed with oil blue dye, to test the encapsulation process, and then later with an MC solution. Originally, the material was printed onto glass slides, which were then placed onto a silicon wafer before spraying, but we discovered that when the sample was printed directly onto the silicon wafer it was more conductive and allowed more material to be deposited during spray. The difference between the coating of a sample printed directly onto a silicon wafer and the coating of a sample printed onto a glass slide can be seen in Figure 2. Microscopic images of the samples were then captured to ensure that the Pluronic F-127 structure was coated by the spray material. Figure 3 shows microscopic images of the blue-dyed shell particles that were deposited onto the structure. While the optical microscope images could not resolve the spray morphology, optical scattering was taken as an indicator that nanoparticles and wires were being sprayed as opposed to dense films. Next, a hot 1 wt% agarose solution was poured over the structure and allowed to cool in order to create a mold of the printed structure. Because Pluronic F-127 gel solidifies when heated to a temperature between 25°C and 35°C, and the agarose solution gels between 34°C and 38°C, the complementary nature of the two gels facilitated encapsulation. The solid agarose was then peeled off, and an imprint of the Pluronic F-127 structure was left in it, along with the material sprayed onto the original lattice; this feature can be seen more easily when observing the encasulations that were made using the blue-dyed shell spray, as shown in Figure 1.

Results

While experimenting with spraying the prints, it was found that the structures printed directly onto silicon wafers were coated most effectively. The difference between the samples that were printed onto glass slides and those that were printed directly onto silicon wafers can be seen in Figure 2. Although the shellac particles were clearly deposited onto the Pluronic F-127 structure, as can be seen in the microscopic images, it is less clear whether the MC solution was efficiently deposited. The reason that the shellac particles are more easily seen than the MC may be because of the difference in their sizes. The thickness of the MC nanowires have been shown to be significantly less than 1µm. [4] The shellac droplets, on the other hand, are larger than that, as is shown in Figure 2. The comparison between the two samples can be seen in Figure 4 below. The agarose gel encapsulated the lattice structure and was able to maintain its shape after being removed from the structure, as seen in Figure 1. When removed, the blue-dyed shellac could be seen in the grooves of the imprint in the agarose. Our results show that the structure should be printed directly onto the silicon wafer to improve the coating of the lattice and that the silicon wafer should also be preheated to 35°C to ensure that the Pluronic F-127 gel remains firm during the printing process.

Conclusion and Future Work

Pluronic F-127 lattices were successfully printed using modified 3D printer. These lattices were printed directly onto a silicon wafer, which was then sprayed with either a shellac or MC solution using ESD. The structure was then encapsulated with agarose gel, and when the encapsulant was removed, an imprint of the structure was successfully captured in it. The shellac solution was successfully deposited onto the lattices, and the prints sprayed with shellac also successfully deposited the shellac into the imprint of the agarose, as can be seen in Figure 1. More investigation into spraying with the MC solution is recommended, as it is less clear whether the MC solution was efficiently deposited; using longer spray times and imaging the sample before and after spray might make the changes on the sample easier to observe. While mechanical peeling was used in this case, solvent etching would likely be better for removing the 3C or shellac, but this will require us to use water and also form chemical crosslinks, like gelatin methacrylate. [1] In the future, this work could lead to the construction of detailed models of vascular structures and creating artificial human organs using 3D printing techniques.

Acknowledgments

Figure 4: Pluronic F-127 lattices sprayed with the blue-dyed shellac (left) and the MC solution (right), both imaged at 20x magnification. Both scale bars indicate 50µm.

References