3D プリンタマスクプロセスによる CNT メタマテリアル加工
CNT Metamaterial Fabrication 3D Printing Mask Process

1) Florida International University, 2) Kochi University of Technology,
Jose Rivero[1,2], Rebekah Arias[1,2], Yuto Sawada[2], Tomu Yamato[2], Nezih Pala[1] and Hiroshi Furuta[2]
Email: jrive387@fiu.edu, furuta.hiroshi@kochi-tech.ac.jp

Introduction:
The demand for clean energy is rising alongside the global population. Renewable energy sources such as solar will play a key role in the years ahead. Solar energy has a key problem with energy storage as the energy produced during peak solar hours must be used immediately or stored in a battery. Carbon Nanotubes (CNTs) have unique electrostatic properties similar to metals capable of producing and storing electric energy in the form of a capacitor. The CNTs are to be arranged in a pattern using 3D printing to generate a Split Ring Resonator (SRR) metamaterial. Past research has shown generating CNT SRR patterns are possible using a Focused Ion Beam (FIB). FIB allows for limited sample size to be patterned for CNT growth. On the other hand, 3D printed shadow masks allows for SRR patterns on a larger sample size. Today's 3D printing technology cannot achieve the same resolution as FIB patterning yet capable of producing a larger sample.

Method: In the present research, a 3D model of a shadow mask with the desired SRR pattern was created using Fusion 360 and printed using Phrozen Sonic Mini 8K 3D printer. For the CNT synthesis process, first, heated treated Silicon Oxide substrate was placed into a RF magnetic sputtering to deposit the first catalyst film of Aluminum Oxide using Argon plasma. The sample then was removed from the chamber to place the mask on and placed back in to sputter an Iron catalyst layer. The sample was then taken to a thermal catalytic chemical vapor deposition (CVD) chamber in which it was annealed to 730° C and afterwards exposed to acetylene gas to generate CNTs.

Results and Discussion: It was confirmed that after deposition the iron film pattern was too thin with a 3D printed mask to synthesize CNTs. FIB samples can be made of a size of 1 mm^2 with a long patterning time. Shadow mask method has an initial 3D printing time, but the printed mask can be reused for multiple samples, significantly decreasing the SRR patterning time. The spatial resolution of the features on the 3D printed mask can be as small as 100 µm allowing very fine patterns. Hence, a mask can help in producing large area metamaterials with small features. We will discuss the tuning of iron deposition to grow CNTs.

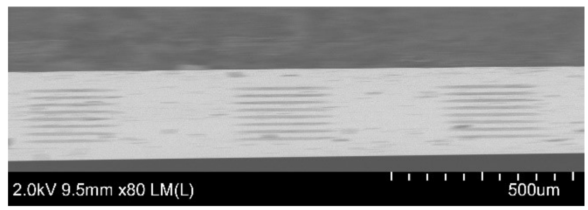

Fig. 1. Bird-view Iron catalyst sputtering pattern deposited using 3D-printed shadow mask.

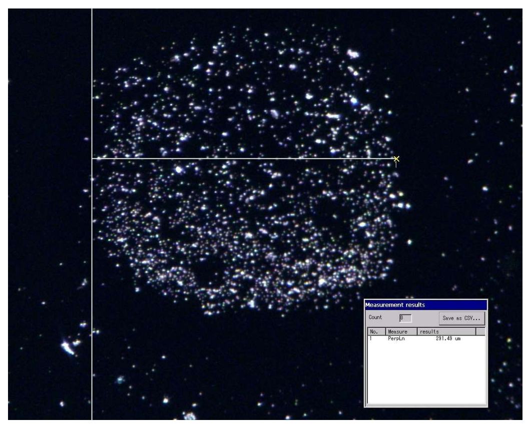

Fig. 2. Iron catalyst deposition measurement. The measured width is 291.5 µm.

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[1] A. Pander, K. Takano, A. Hatta, M. Nakajima, and H. Furuta, "Shape-dependent infrared reflectance properties of CNT forest metamaterial arrays," Opt. Express 28, 607-625 (2020).