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Multimaterial Aerosol Jet Printing of Passive Circuit Elements

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Inductor Design

- Inductors store charge in a magnetic field with a coil of wire around a magnetic or dielectric core
- Due to magnetic leaking in the ends of solenoidal (cylindrical) inductors, toroidal (disk) inductors have higher inductance
- Inductance related to coil density and cross section
- Applications in signal filtering and power, but bulky structure motivates strategies for printed microinductors

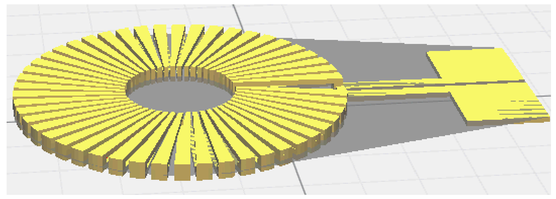

Figure 1: 3D model of toroidal inductor

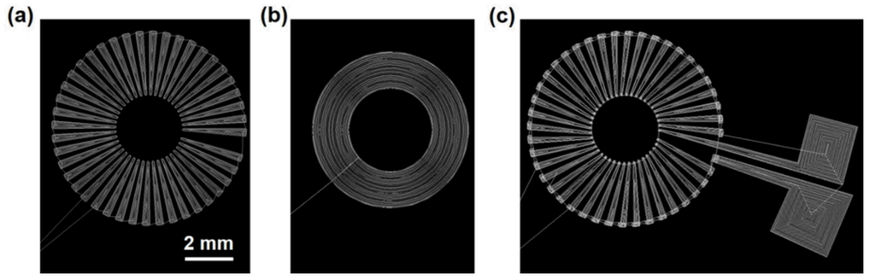

Figure 2: Toolpath design for inductor layers 1-3 in (a)-(c), respectively

Toolpath/Manufacturing

- Layers 1 and 3 are made with silver nanoparticle ink using the aerosol jet printer to creating the coil of the inductor
- Layer 2 generates the dielectric core of the inductor and is made from a polyimide precursor ink
- Future plans include printing a magnetic material for Layer 2 to increase overall inductance

Motor Accuracy

- Toolpath intricacy and limited resolution of the X and Y axes motors lead to inconsistency in width of the sections in Layer 1
- The individual coil sections exhibit overlap and under-filling in the top left and b right during printing
- This can result in electrical shorting and poor conductivity
- Adding servo's with a 7:1 turning ratio on both the X and Y axes motors improve resolution solving precision issue

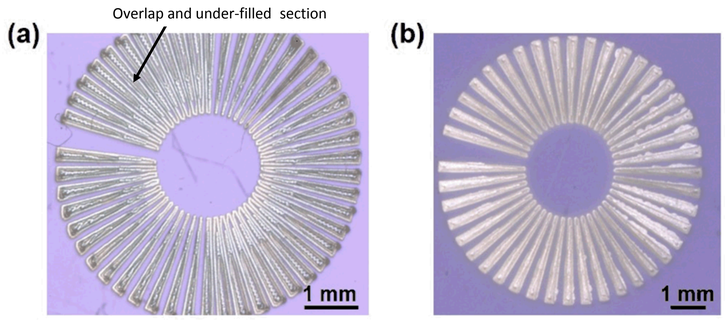

Figure 3: Layer 1 printed without (a) and with (b) added servos

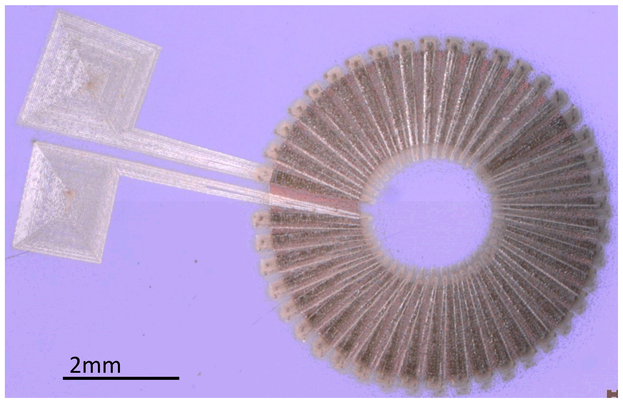

Figure 4: Microscope image of complete print with all three layers

Results/Future Research

- Inductors were successfully printed with the aerosol jet printer
- Printed inductors had an outer diameter of 6mm and inner diameter of 2mm
- Six successful prints exhibited an average inductance of 1.2 µH, compared to the designed inductance of 2 µH
- Further improvements in inductance will be pursued by increasing core height, developing a high permeability core material, and adding more coil turns
- Future plans include using printable ferromagnetic material for the core to maximize inductance
- This research will further the multi-material fabrication of integrated systems, allowing smaller and more easily incorporated electronics components.

Aerosol Printing

- The aerosol jet printer deposits functional liquid inks following atomization and aerodynamic focusing to achieve high resolution patterns
- Aerosol jet printing allows integration of multiple materials
- For this research, silver nanoparticle and polyimide precursor inks were used to additively manufacture inductors
- Ink formulation and print parameters are designed for reliable printing, including aerosol and sheath gas flow rates, atomizer voltage, print speed, and temperature
- Pneumatic shutter requires a delay of ~0.5 s for well defined starting and stopping

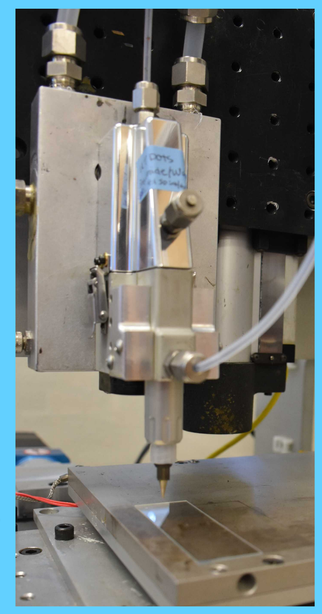

Figure 5: Photograph of the aerosol printer with a 25x75x1mm glass slide below

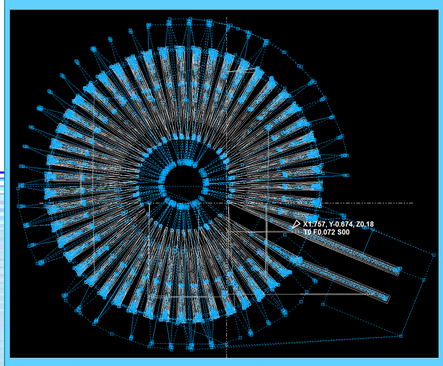

Figure 6: Failed toolpath design

Toolpath Generation

- Intricacy and size of the part presents a challenge for toolpath generation (slicing) from model
- Ideally the toolpath should minimize movement and shuttering to avoid lengthy and failed prints
- Toolpath shown in Figure 6 had many unnecessary movement and shuttering steps, causing bad parts and many failed attempts
- Final successful toolpaths shown in Figures 2 have the fewest unnecessary movement and shuttering steps
- The final toolpath was created using Simplify3D software

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