NDnano
Notre Dame Nanoscience and Technology

NDnano Summer Undergraduate Research 2022 Project Summary

1. Student name & home university: Stephanie Atampugre, University of Notre Dame

2. ND faculty name & department: Dr. Yanliang Zhang, Department of Aerospace and Mechanical Engineering

3. Summer project title: Scalable nanomanufacturing and hybrid printing of multifunctional devices

4. Briefly describe new skills you acquired during your summer research

   I had the opportunity to interact with and learn about two aerosol jet printers in the Advanced Manufacturing and Energy Lab. I learned how to assemble printer parts and run diagnostic and troubleshooting tests on both printers through which I became well acquainted with their working mechanisms.

   The bulk of the work I did involved printing devices using nanoparticle inks, and to do that successfully I spent a lot of time optimizing printing parameters, wherein I experimented with parameters such as sheath flow, aerosol flow, platen temperature and nozzle size to find out which combinations of these parameter values worked best for a given nanoparticle ink.

   In testing what parameters worked best for any print, I spent a lot of time with a microscope by which I was able to observe the finer features of the nanoparticle deposits and the printing substrate surface. I learned to identify characteristics about ink deposits such as overspray, coffee ring effect and nanoparticle distribution, which allowed me to draw conclusions about the stability of the nanoparticle ink and the viability of chosen parameters.

5. Briefly share a practical application/end use of your research

   The integrated strain and temperature sensor has sensing capabilities up to 550 °C and is to be used in nuclear power plants, but has additional applications in turbine engines and aircrafts.

6. 50- to 75-word abstract of project

   Conventional fabrication methods for integrated sensors involve manufacturing the sensors separately before integrating them into one device, a process which is complex, labor-intensive and time-consuming, making these integrated sensors cost-inefficient. Aerosol jet printing presents a fabrication process that is much more simplified with the ability to print on conformal substrates to produce flexible, micro-scale multifunctional sensors. Indium tin oxide (ITO) and gold's high thermal stability, conductivity and relatively high Seebeck coefficient when employed in thermocouple temperature sensing make them ideal for the fabrication of an integrated sensor for simultaneous strain and temperature sensing, sensing up to 550 ℃.

7. References for papers, posters, or presentations of your research:

8. One-page project summary that describes problem, project goal and your activities / results

Our goal for this project was to design and manufacture a sensor using aerosol jet printing for simultaneous temperature and strain sensing using gold and ITO, with sensing capabilities up to 550 °C.

The first step towards making the sensor involves preparing the printing substrate. Stainless steel sheets are cut into 6 in x 1 in strips which are then sanded, insulated with ceramic cement and polished, with the finest polishing paper used being 6000 grit applied in conjunction with 0.5 micron diamond solution. Insulation is necessary so as not to short-circuit the sensor since steel is electrically conductive. While substrates made of insulating material are available, stainless steel is particularly viable not only because the strips are bendable, which is relevant for testing strain when the strip is used as a cantilever beam, the metal has operating temperature up to 800 °C, which is useful for testing in extremely high temperatures. Other readily available substrates do not possess both characteristics simultaneously.

After the substrate is prepared, printing starts. Gold and ITO nano inks are fed into the Optomec Aerosol Jet 300 System to print the inks into the sensor geometry. The printer works by first aerosolizing the nano ink. The ink is then carried through a tube using nitrogen gas and then deposited through a nozzle head onto the substrate.

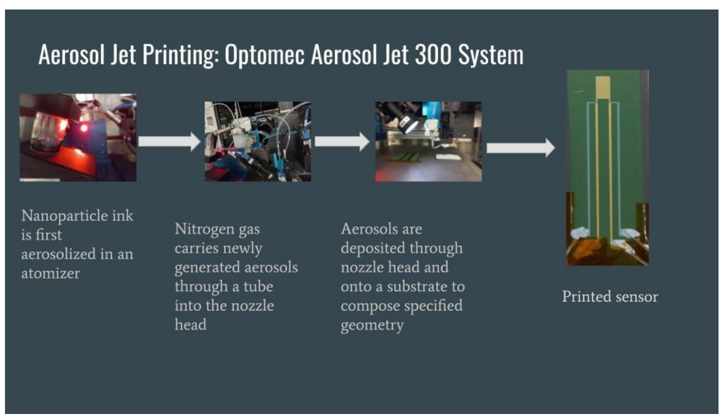

Figure 1. Aerosol jet printing process

The completed device is then sintered in a high temperature furnace at 800 ℃ for three hours. The process of sintering welds together the nanoparticles that make up the sensor, which ensures greater conductivity.

The final step in the process involves attaching the sensor to a measuring setup wherein a temperature gradient is applied to the sensor and the corresponding electric potential is measured. Data is collected regarding the relation between the difference in temperature and the voltage induced, with the operating principle being the Seebeck effect. To run measurements on the strain sensor, the cantilever beam is bent and the corresponding change in resistance in the strain sensor is measured.