EXPLORING CERAMIC NANOPARTICLES FOR CONDUCTIVE ABS FILAMENTS IN ADDITIVE MANUFACTURING

UNIVERSITY OF DELAWARE | CENTER FOR COMPOSITE MATERIALS

Myles Wommack, (BME)[2] , Luke Ballenger, (BECE)[3], Prof. Mark Mirotznik[1,3]

University of Delaware | Center for Composite Materials[1] | Department of Mechanical Engineering[2] | Department of Electrical and Computer Engineering[3]

Introduction

The field of engineering constantly grapples with the dual challenges of cost-efficiency and budget constraints. Our research specifically addresses these issues by focusing on the development of high-K dielectric filaments for 3D printing. Presently, only two overseas manufacturers supply these filaments, each costing $700 per 750 grams. To mitigate these expenses, we have devised an in-house production process that involves dissolving ABS pellets in acetone, combining them with ceramic nanoparticles and plasticizers, and subsequently extruding the mixture to form filament.

Ensuring uniform dispersion of the ceramic nanoparticles within the ABS matrix and achieving consistent extrusion quality are critical factors we are refining. The high-K filaments developed through our process are expected to enhance the performance of electrical circuits by minimizing interference, thus improving overall efficiency.

Objectives

- Create a filament suitable for 3D Printing that has a high K dielectric constant.
- Ensure that the resulting filament is within the suitable diameter of 1.75mm (+/- 0.05mm) to be printed on a FDM 3D printer.
- Ensure that the filament is not too brittle so that it will not break when being printed.
- Make a filament that ideally costs less to produce than purchasing from a limited supplier

Process

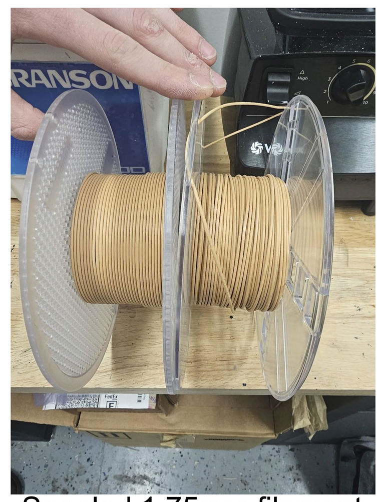
- A 3Devo Next filament extruder was used to turn processed, ceramic filled ABS pellets into usable 3D printing filament.

3Devo Next Filament Extruder Source: 3Devo

Strontium TItanate filled ABS pellets loaded into the 3Devo Next. Source: Luke Ballenger

- To start, A predetermined amount of ABS pellets are dissolved in acetone until a homogenous mixture is created.
- Once a homogenous mixture is created, Octyl Gallate, a surfactant and Dibutyl Phthalate, a plasticizer is added to the mixture.
  - Either barium or strontium titanate is then added to the mixture and hand mixed.
- The hand combined mixture is left in a sonicator filled with water for a minimum of 48 hours to ensure that most air bubbles are removed.
- The resulting mixture is stirred by hand to mix up any ceramic that settled over the 48 hour time period.
- PTFE release film is laid on a metal baking sheet to prevent the mixture from adhering to the sheet during the drying process.
- The mixture is spread thinly onto the sheet and allowed to dry inside of the fume hood until solid.
- Once solid, the sheets of plastic are broken by hand into smaller pieces to fit into a food dehydrator where it is left for 48 hours to remove any remaining moisture from the plastic.
- The dried sheets are then blended in a Vitamix blender to create small pieces of plastic that are roughly the same size to be fed into the filament maker.
- The 3Devo filament maker heats, measures, and spools the filament.
  - An optical sensor ensures that the filament remains in the appropriate diameter of 1.75mm with a +/- 0.05mm margin of error.

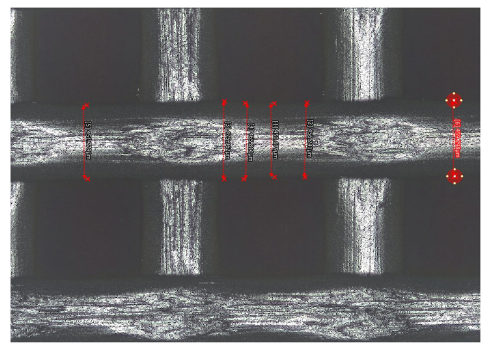
1.75mm ceramic filled filament Source: Luke Ballenger



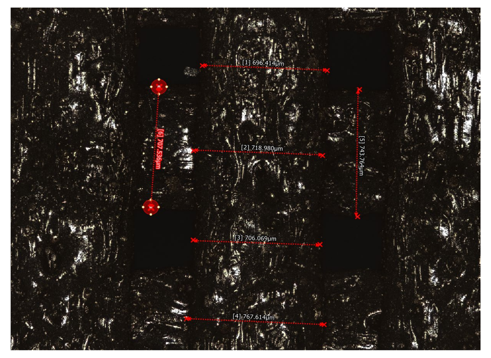
Spooled 1.75mm filament Source: Luke Ballenger

Testing

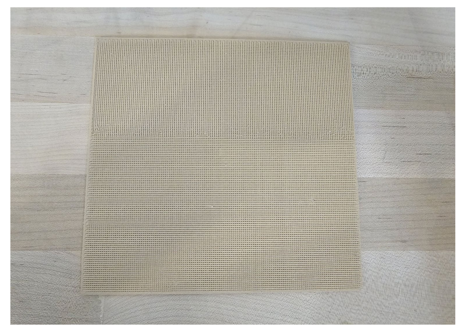
- The resulting spools of filament were loaded into the lab's Bambu Lab X1 Carbon with AMS to be printed into a test pattern called a logpile.
  - Using a slicer programmed in MATLAB, the logpile was generated with varying parameters to achieve a testable result.
  - Variables of hot end temperature, bed temperature, volume fraction, and extrusion multiplier were changed.
- Once printed, the samples were measured on a Keyence laser microscope to ensure that the diameters are correct.



Underextrusion shown through a microscope



Overextrusion shown through a microscope



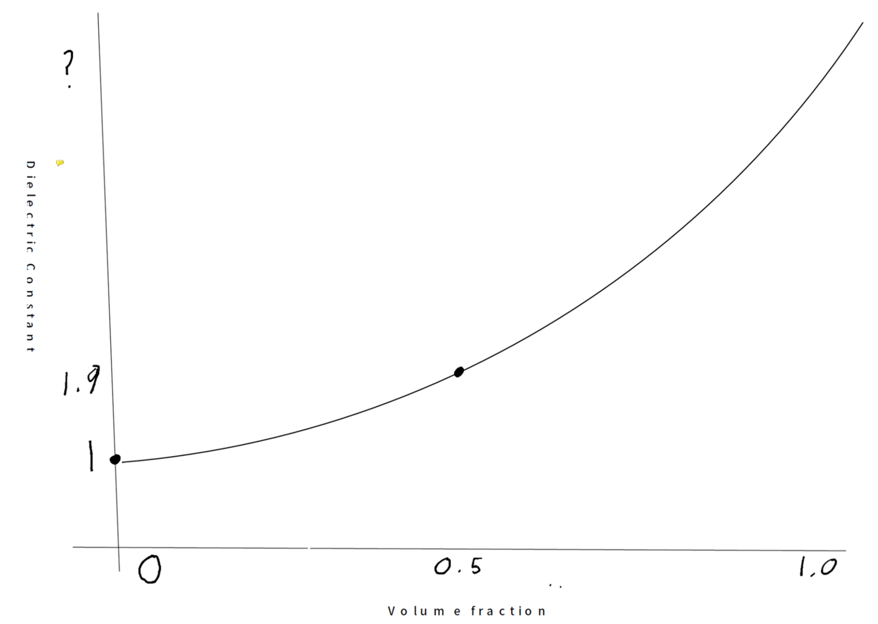
Logpile printed pattern 150mm x 150mm x 1.7mm

Results

- Initial testing through a Compass Microwave Focused Beam System shows that the dielectric constant of the custom material reads at just below 2 as its dielectric constant. The dielectric constant of air is 1, so the material has some properties, but is not completely where we want it to be.
- Further testing is required to determine the correct mixture to achieve a higher dielectric constant material than we have already created.

Compass Microwave Focused Beam System Source: Compass Technology Group

- The idea that the K dielectric constant increases as the volume fraction increases can be modeled to the Maxwell-Garnett Curve as shown in the graph below.



Acknowledgements

- *Department of Electrical and Computer Engineering*
- *Prof. Mark Mirotznik*