Surface and Bulk Properties Modification of 3D Printed Samples Using Atmospheric Jet Plasma

Mechanical Engineering/Electrical and Computer Engineering

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Abstract

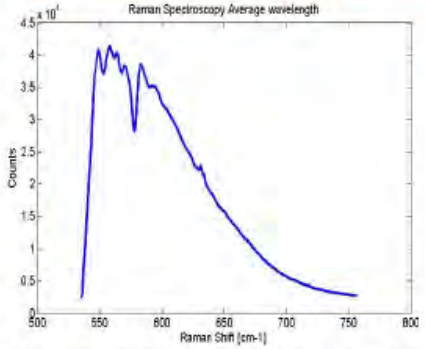
The goal for this project was to increase a model's material strength in the Z-axis and eliminating post processing. This was accomplished by retrofitting a 3D printer with a micro-plasma device (jet plasma). Further accomplished in this project is the integration of the 3D printer and plasma jet into using a Raspberry Pi 2 Model B controller. Python code was used to develop the software. Results of this project were verified using varying testing methods; tensile tests, microhardness tests, scanning electron microscope imaging (to study the topography), spectroscopy (to study the molecular structure of the cured prints).

Tensile/Hardness Testing

Tensile tests were performed using an MTS tensile test machine. For this test we compared yield strength of the treated and untreated specimens with different infills. These specimens have a complex shape that resemble a dog bone per the ASTM standard D638. A plot shows the treated specimens have a higher yielding point than the untreated specimens.

Microhardness testing was done by a Rockwell hardness machine. We compared the hardness of the treated and untreated specimens with different infills. The samples are 1"x1"x.25". This is per the ASTM standard D785. As expected, the treated specimens are harder than the untreated specimens as shown in the plot.

Raman Spectroscopy



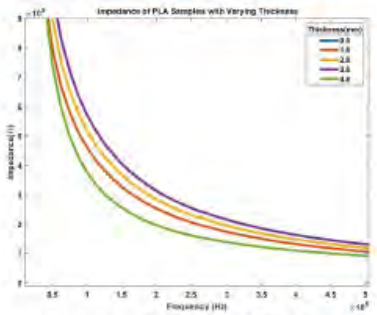
Average Raman Spectroscopy curve of ten 3D printed PLA samples

- 532nm Raman laser wavelength was used.
- Local Maxima occurs at Raman Shift 556.25, 561.25, 564.5, 566, 566.75, 584.25, and 631.5.

Design

- The frame design is based on the Ender 3 and was constructed using 2020 T-slot extrusions opposed to 2040 and 4040 slots
- The mount for the x-axis is completely different from the Ender 3 extruder and fan mount since the main purpose is to hold the plasma discharge and not the extruder. The mount will be manufactured using 10-gauge steel for strength.
- The X-axis was modified to use a threaded ACME rod to translate the plasma mount from side to side. The original design however used a belt driven system. This change was made to combat weight issues.

Impedance Spectroscopy



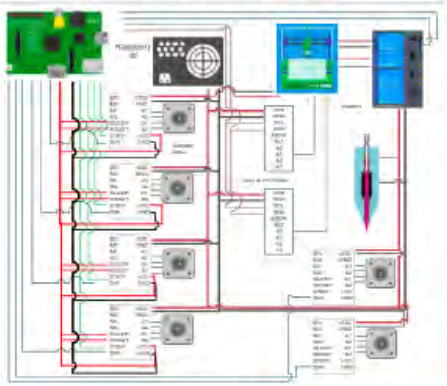
Impedance Test Measurements of 5 PLA Samples

- Frequency from 20 MHz to .5 MHz
- Impedance is in the order of $10^6\Omega$
- Sample thickness was varied from 0.8mm to 5.8mm
- In the future the impedance will be measured using the thickness of 4.8 mm which showed the lowest impedance.

Electrical Components

1. Raspberry Pi 2B
2. Nema 17 bipolar stepper motor (6)
3. End-stop switches (5)
4. Heaters (hot bed & extruder)
5. ADC chips [ADS1115] (2)
6. Temperature sensors [100K NTC 3950] (2)
7. Stepper motor drivers [A4899] (6)
8. Relay module (4)
9. Breadboard
10. Jumper cables
11. Capacitor [100 µf] [6]
12. Resistors [100K] (2)
13. Fans (2)
14. Ethernet cable
15. Power supply

Electrical Circuit Layout



Logic & Code

- The printable object is designed in SolidWorks. The STL design files from solid works get converted to G-Code through CURA software. The G-Code is then passed to the raspberry pi media drive. The program designed in python reads the G-Code and prints the design files. After every layer of filament (Polylactic acid), the plasma machine runs over the layer making the design stronger.
- The circuit above shows the internal workings of the 3D printer. five motors controls the X, Y, Z motion of the extruder and the plasma gun. The sixth motor controls the PLA flow from the extruder.
- The Heaters use a PID logic to keep the temperature consistent. The temperature is read via temperature sensor that uses a voltage divider circuit to read the voltage and convert to temperature using the "**Steinhart-Hart equation**":

$$\frac{1}{T} = \frac{1}{T_o} + \frac{1}{B} * \ln\left(\frac{R}{R_o}\right)$$

T = Heater temperature
To = Room temperature
B = Thermistor constant (3950)
R = Reference resistance
Ro = Thermistor resistance

Conclusion

The final Plasma Mount design integrated the design of the Ender 3 with several modifications. The controller integrated both the Ender 3 and Plasma Mount. The Raman shift for the impedance of the PLA was identified to have shifts at six points and the impedance was identified to be in the order of $10^6\Omega$. Future work includes comparing plasma processed samples to the control samples. It is expected that future samples' impedance decrease, and a change in Raman Shifts to be detected.

Sponsors

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