

Optimization of 3D Printing Parameters for Conductive Polymer Nanocomposites

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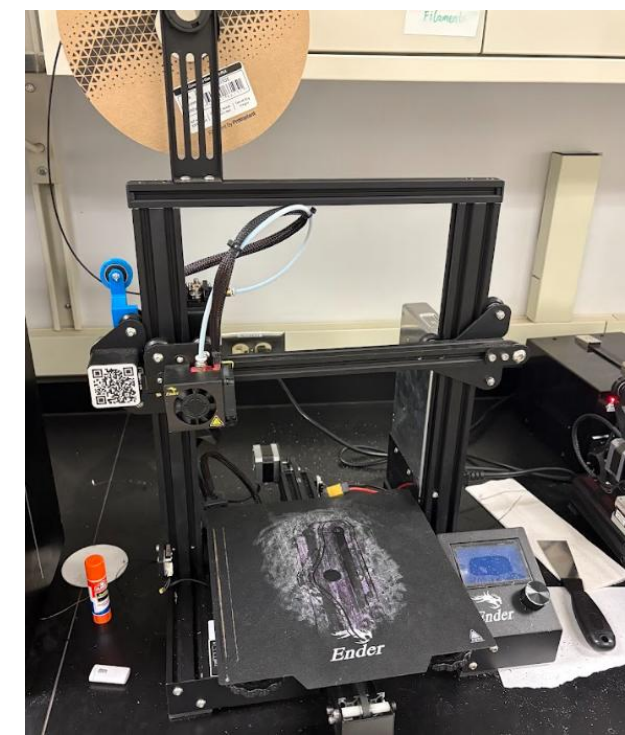


Introduction and Objectives

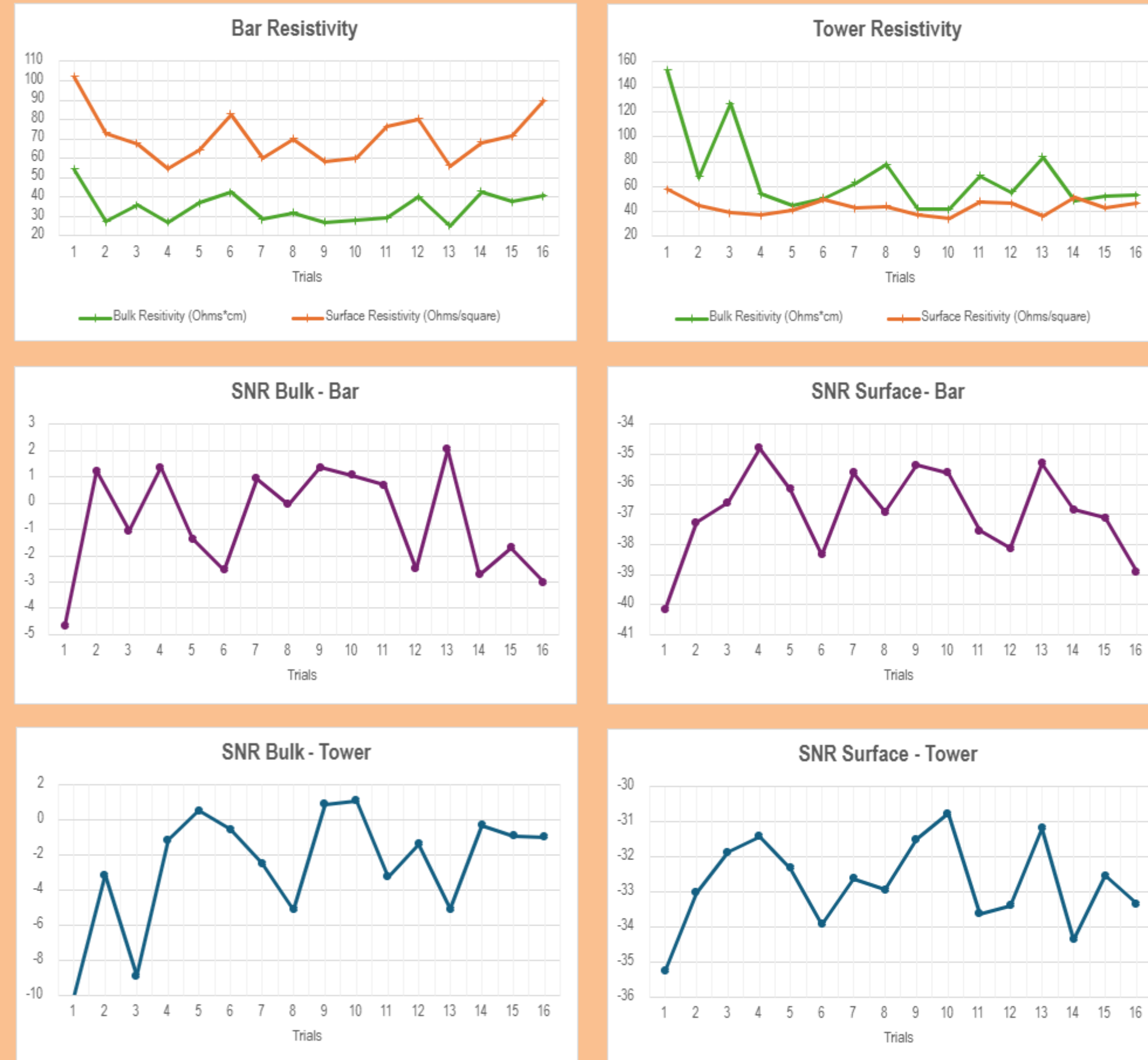
As conductive filament is only suited for low-power applications on small sensors and circuit boards, achieving the most consistent conductance of printed filament is critical to maximize its relatively low conductivity in electronic devices.

Optimized set of parameters must provide:

- Minimized bulk resistance in print
- Minimized surface resistance on print
- Low variance (Creality Ender 3 Pro)



Results



Experiment #	Layer Height (mm)	Flow Rate (%)	x1	x2	Bulk Resistivity (Ohms*cm)	Surface Resistivity (Ohms/square)
1	0.25	104	-1	-1	46.61	92.4
2	0.275	104	0	-1	35.12	77.94
3	0.3	104	1	-1	36.52	81.04
4	0.25	107	-1	0	34.36	99.58
5	0.275	107	0	0	41.66	91.64
6	0.3	107	1	0	41.41	79.17
7	0.25	110	-1	1	39.38	72.13
8	0.275	110	0	1	44.58	80.24
9	0.3	110	1	1	44.58	88.5

Experiment #	Layer Height (mm)	Flow Rate (%)	x1	x2	Bulk Resistivity (Ohms*cm)	Surface Resistivity (Ohms/square)
1	0.25	104	-1	-1	61.57	52.92
2	0.275	104	0	-1	56.35	53.17
3	0.3	104	1	-1	61	49.33
4	0.25	107	-1	0	65.76	52.73
5	0.275	107	0	0	96.92	146.07
6	0.3	107	1	0	72.41	113.14
7	0.25	110	-1	1	91.51	130.92
8	0.275	110	0	1	86.37	85.4
9	0.3	110	1	1	69.94	50.37

Experimental Design/Methodology

Taguchi L16b Orthogonal Design (TOA)

ANOVA Test (Analysis of Variance)

Response Surface Methodology (RSM)

Find Signal to Noise Ratios for calculated Resistance

$$S/N = -10 \cdot \log_{10} \left(\frac{1}{n} \sum_{i=1}^n y_i^2 \right)$$

Perform ANOVA test and find % Contribution

$$\% \text{Contribution} = \left(\frac{SS_{\text{factor}}}{SST} \right) \times 100$$

Fine-tune key factors with regression modeling and plotting

ANOVA identified flow rate and layer height as the most influential factors affecting variance; consequently, RSM was used to develop a predictive model that calculates bulk/surface resistivity to narrow down the best combination of the two parameters and for future improvements.

Bar: Bulk $\hat{y} = 39.13 + 0.36x_1 + 1.72x_2 + 0.02x_1^2 + 1.99x_2^2 + 3.82x_1x_2$
 Bar: Surface $\hat{y} = 88.67 - 2.57x_1 - 1.75x_2 + 2.20x_1^2 - 8.09x_2^2 + 6.93x_1x_2$
 Tower: Bulk $\hat{y} = 84.71 - 2.58x_1 + 11.48x_2 - 9.51x_1^2 - 7.24x_2^2 - 5.25x_1x_2$
 Tower: Surface $\hat{y} = 117.30 - 3.96x_1 + 18.55x_2 - 19.98x_1^2 - 33.63x_2^2 - 19.24x_1x_2$

The combination of layer height = 0.3 mm and flow rate = 104% was shown to be optimal in 3 out of 4 RSM model equations.

Optimized Parameters based on RSM and TOA data:

- Layer Height = 0.3mm
 - Flow Rate = 104%
 - Temperature = 220 C
 - Speed Rate = 30mm/s
 - Infill Density = 100%
- (Additional TOA trials or further RSM adjustments may improve accuracy)