Damage Detection In 3D Printed Parts Using Optical Properties of Gold Nanoparticles

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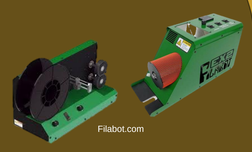
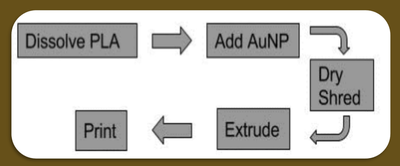
Background and Motivation

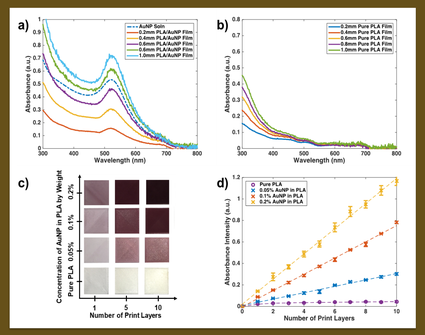
- **Many structural health monitoring (SHM) applications require physical sensors and infrastructure and complex algorithms for effective use**
- **Large scale SHM applications typically focus on the detection of large defects, such as cracking**
- **Demand in public and private sectors for efficient and effective damage detection to increase the overall service life of a structure**
- **The objective is the development of a damage detection and communication methodology to detect and communicate external loads and information about the material state**

Experimental

AuNPs were synthesized[1] and incorporated within dissolved polylactic acid (PLA). This solution was then dried, shredded and extruded using the apparatus to the right. This material was then 3D printed into various geometries (including square and rectangular shapes) with a varying number of print layers and concentrations (See Fig. Below).

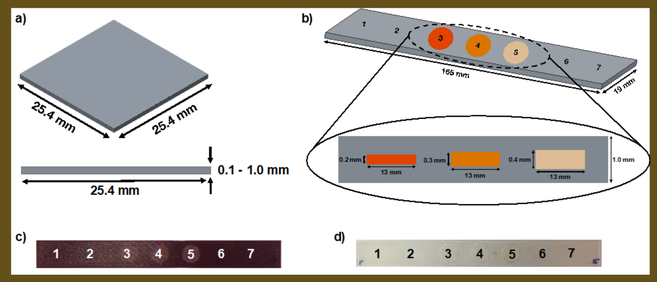






(a, b) Absorbance spectrum of 3D printed PLA/AuNP and pure PLA films with increasing thickness, respectively; (c) 3D printed films with increasing concentrations of AuNPs in PLA by weight. (d) Number of print layers vs. absorbance intensity at 521 nm.

Results

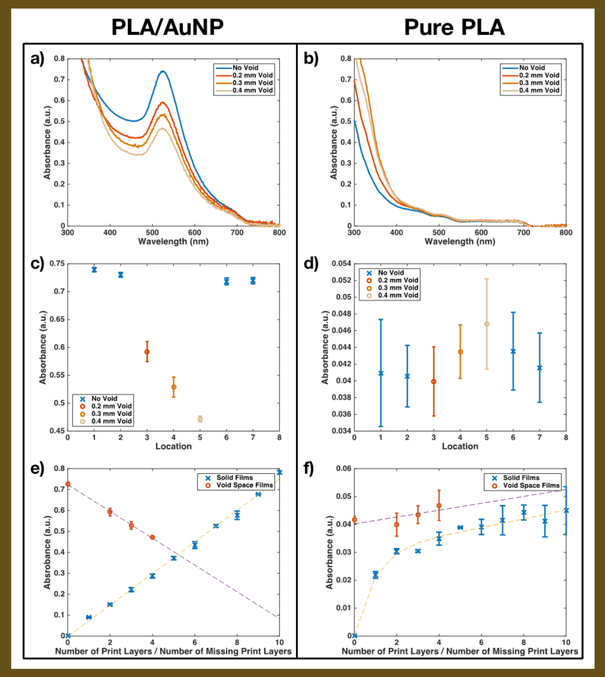


(a) Dimensions of 3D printed thin films; (b) Dimensions of 3D printed void space samples; (c,d) 3D printed PLA/AuNP and pure PLA samples with void spacings, respectively.

*PLA with AuNPs showed a linear trend in absorbance based on the number of print layers in the 3D printed structure (similar to **Beer-Lambert Law**). Using this trend, we were able to successfully identify and quantify the number of missing print layers and material defects in 3D printed structures based on the optical response of AuNPs alone.*

$$A = \epsilon l c$$

Where A is absorbance (a.u.), ε is molar absorptivity coefficient ($M^{-1}cm^{-1}$), l is path length (cm) and c is concentration (mol/L)



Representative absorbance spectra (a,b) and intensity (c, d, e, f) of pure PLA and PLA/AuNP films at locations with no void, 0.2 mm void, 0.3 mm void and 0.4 mm void.

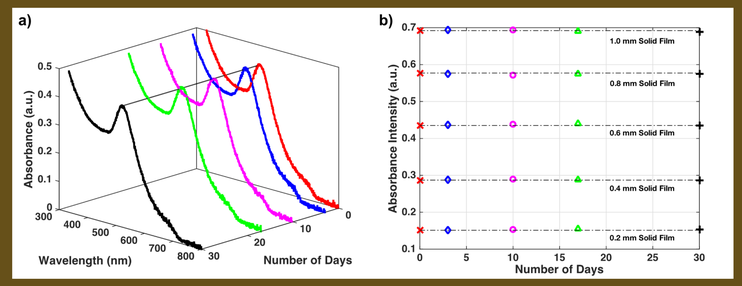
3D Film Response

Comparison between absorbance response for solid films and absorbance response for samples with voids.

Solid Films		Void Spacing		% Difference
Number of Print Layers	Absorbance	Number of Print Layers Missing	Absorbance	
10	0.7522	0 (No Void)	0.7269	3.77
8	0.6012	2 (0.2 mm Void)	0.5926	0.85
7	0.5256	3 (0.3 mm Void)	0.529	1.19
6	0.4501	4 (0.4 mm Void)	0.4718	3.84

Based on optical response of Gold nanoparticles alone, as few as two missing print layers were able to be identified.

Temporal Response



Temporal Response of PLA/AuNP films over a period of 30 days with 3D representation of absorbance spectrum.

Conclusions

- Presence and relative size of the void defects can be localized and quantified based on absorbance intensity of gold nanoparticles as indicated in *Beer-Lambert Law.*
- Optical response of Gold nanoparticles was observed to remain constant over a period of 30 days.
- Beyond defect detection, the optical response of AuNPs may allow for detecting and monitoring the growth of cracks and material defects through optical properties alone.

Acknowledgements and References

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• [1]Lawrence, J.; Pham, J. T.; Lee, D. Y.; Liu, Y.; Crosby, A. J.; Emrick, T. ACS Nano 2014, 8 (2), 1173–1179.