Nanocomposites by Stereolithography: a Literature Review

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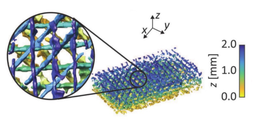
ABSTRACT

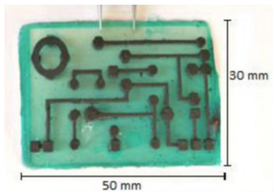
Nanocomposites are widely used to improve material properties. Nanoscale reinforcement materials in stereolithography resins improve the hardness, tensile strength, impact strength, elongation and electrical conductivity of the printed products. A literature review was conducted on the effects of reinforcement materials on nanocomposite properties. Additionally, pre-processing techniques, printing processes, and post-processing techniques of nanocomposites were reviewed. The nanocomposite properties are discussed based on their application in the mechanical, electrical and magnetic, and biomedical industries. To improve the properties of printed nanocomposites, future directions of the equipment and material are proposed.

Applications of Nanocomposites

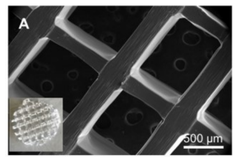
Mechanical	Electrical /Magnetic	Biomedical
•Rapid Prototyping	•Magnetic Sensors	•Cell Manipulation
•Rapid Manufacturing	•Resistors	•Dental Implants
•Surface Coating	•Capacitors	•Reconstructive Tissue
•Tailored Anisotropy	•Printed Circuits	•Scaffolds



Greenhall, J. and Raeymaekers, B., 2017. 3D Printing Macroscale Engineered Materials Using Ultrasound Directed Self-Assembly and Stereolithography. *Advanced Materials Technologies*, *2*(9), p.1700122.



Gonzalez, G., Chiappone, A., Roppolo, I., Fantino, E., Bertana, V., Perrucci, F., Scaltrito, L., Pirri, F. and Sangermano, M., 2017. Development of 3D printable formulations containing CNT with enhanced electrical properties. *Polymer*, *109*, pp.246-253.



Lee, S.J., Zhu, W., Nowicki, M., Lee, G., Heo, D.N., Kim, J., Zuo, Y.Y. and Zhang, L.G., 2018. 3D printing nano conductive multi-walled carbon nanotube scaffolds for nerve regeneration. *Journal of neural engineering*, *15*(1), p.016018.

Pre-Processing

•Homogenously disperses reinforcement material

•Reduces agglomerations

Methods: Manual Mixing, Magnetic Stirring, Sonication

Post-Processing

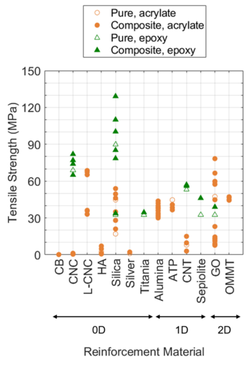
Soaking—Removes excess resin

Curing—Further polymerizes the printed object

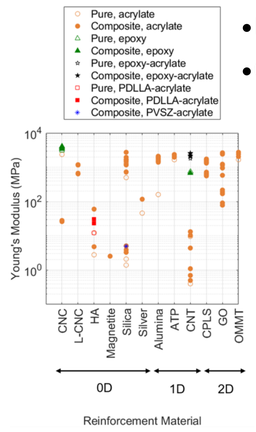
Annealing—Reduces internal stresses in the printed object

Mechanical Properties

Tensile Strength



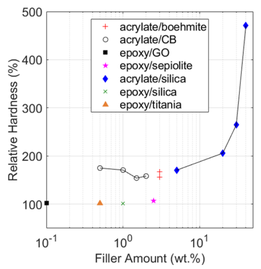
Young's Modulus



Influences on Nanocomposite Properties:

- Base Resin
- Reinforcement Amount
- Processing Conditions
- Curing Power and Time

Hardness



- OD: Nanoparticles
- 1D: Nanorods
- 2D: Nanoplatelets

Electrical Properties

Electrical Conductivity:

- Increased by thermal post-processing in a vacuum
- Decreased by UV light exposure

Magnetic Intensity:

- Incorporation of magnetic nanoparticles causes greater deflections compared to electroless plating

Biomedical Properties

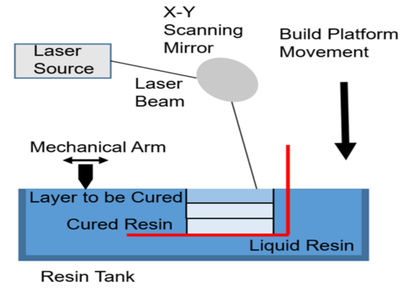
Cell Manipulation:

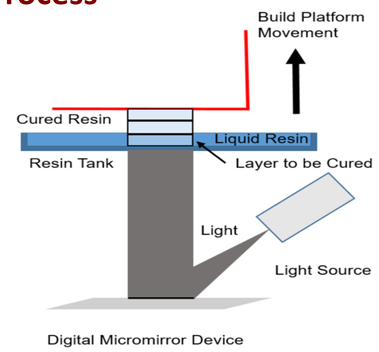
- Improves the metabolic activity of endothelial cells
- Changes the cell's rounded morphology to an outstretched morphology

Scaffolds:

- Delivery method for therapeutic agents
- Improve cell adhesion for bone tissue engineering

Printing Process



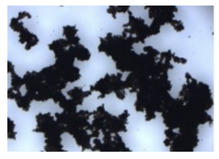


System Configuration:	Top– Down	Bottom-Up
Scanning Strategy:	Serial Scanning	Flood Exposure

Future Work

Material Improvements

- Correlation between aging and post-processing
- Materials that decrease volumetric shrinkage and agglomerations
- Photoinitiators that have high absorbance at the same wavelength of the light source



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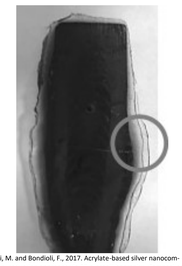
Equipment Improvements

- Sensors that detect when a layer is fully polymerized
- Resin tank agitator to reduce settling and agglomeration
- Temperature control of resin tank to control



Sciancalepore, C., Moroni, F., Messori, M. and Bondioli, F., 2017. Acrylate-based silver nanocomposite by simultaneous polymerization–reduction approach via 3D stereolithography. *Composites Communications*, *6*, pp.11-16.

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