3D Microfabrication of Boron Nitride Nanotube/Polymer Composites by Two-Photon Polymerization Lithography

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We report the fabrication of arbitrary three-dimensional microstructures with boron nitride nanotube (BNNT)/polymer composites using two-photon polymerization lithography. Potential applications include micro/nano actuators, sensors, photonics devices and nanoelectromechanical systems based on BNNTs. Our preferred method using two-photon polymerization (TPP) allows fabrication of three-dimensional microstructures with sub-diffraction limit resolution. Along with mechanical properties comparable to carbon nanotubes', BNNTs possess distinguishable electronic properties independent of chiralities, higher thermal stability (900°C) and transparency in the visible region, most advantageous for TPP. BNNTs could not be dissolved in MMA, the standard monomer for TPP fabrication, even with inclusion of various surfactants. An acrylate monomer (R712) proved to be utmost suitable for dispersion. Raman imaging presented unclear spectra and was inefficient for verifying the presence of BNNTs. Distribution of BNNTs in the sample was ensured by dark field imaging. The stable range is 0.01-0.1-wt% BNNT. Optimization of the protocol for increased ratio of the nanotubes based on dispersion results occurred concurrently with fabrication of BNNT-R712 composite 3D structures. We anticipate this can demonstrate BNNTs can enhance properties of microstructures fabricated by two-photon polymerization.

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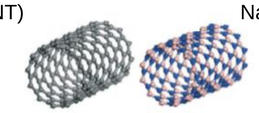
Introduction

Boron Nitride vs. Carbon Nanotubes

Carbon Nanotube (CNT) | Boron Nitride Nanotube (BNNT)



BNNTs similar to CNTS

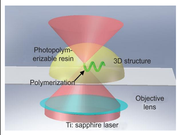
Advantages of BNNTs :

- Thermal Stability high up to 900 ° C
- High Young's Modulus up to 1. 3TPa
- Transparency in Visible Range

Purpose:

Develop 3D microfabrication method of BNNT composites for diverse potential applications for example sensors, photonic devices, actuators etc. based on BNNTs

Two Photon Polymerization (TPP) Lithography

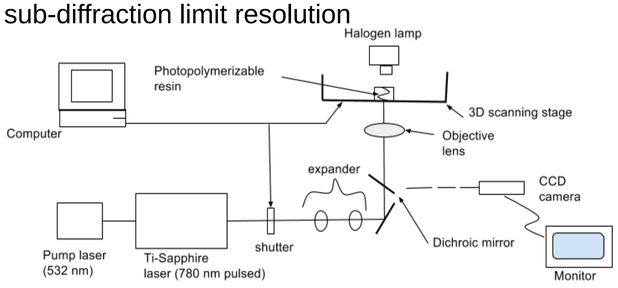


780nm laser excites photopolymerizable resin

Nanometric volume of photo-polymerizable resin is solidified at the focus spot

3D scanning of focus spot for Fabrication of 3D microstructures

- Two photon absorption: non linear process for sub-diffraction limit resolution



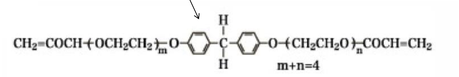
TPP Fabrication Setup

Results

BNNTs incorporated in Photopolymerizable Resin

BNNT+ R-712 monomer+ photoinitator(Benzil) +photosensitizer

Molecular structure



- R-712 monomer showed best dispersion

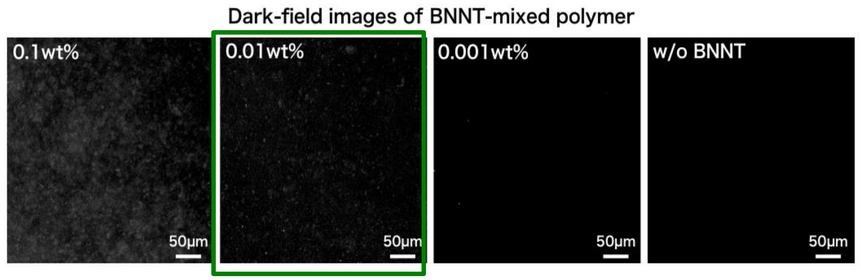
Possible explanation: Benzene rings of R-712

Attempted methods for dispersion:

x Sodium Dodecyl Sulfate (SDS)
Dimethylformamide (DMF)
DMF/acetone
Methyl methacrylate monomer (MMA)

0.01wt% BNNT-R-712 Sample with Photoinitiator and Photosensitizer

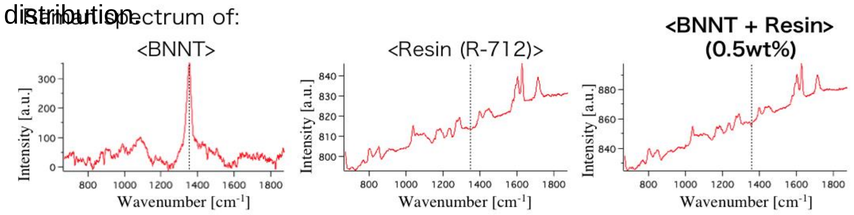
Analysis of dispersion of BNNTs with Dark Field Imaging



- 0.01wt%-0.001wt% : most stable range for aggregations

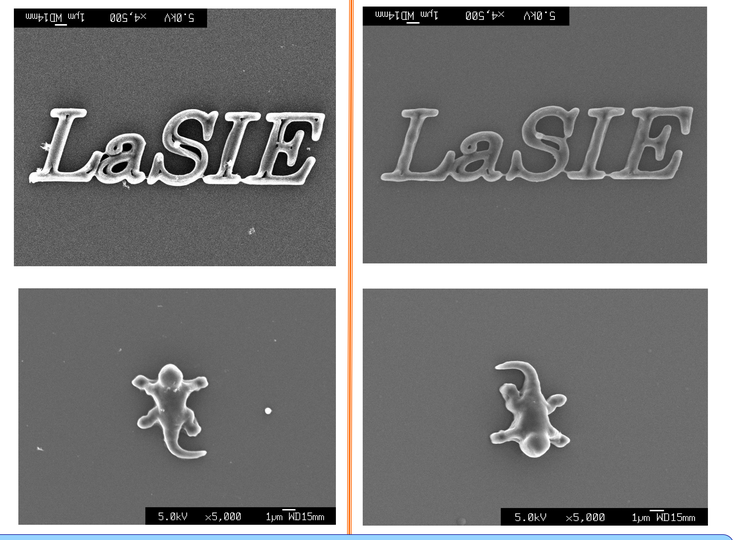
Note for Raman Spectra: clear BNNT signal could not be detected in mixed BNNT/R-712 samples. Dark Field Imaging was used to analyze distribution.

Raman Spectrum of:



SEM Images of 3D Microfabrications

With 0.01% BNNTs | W/O BNNTs



Conclusion

0.01wt% BNNTs can be dispersed in an R-712 monomer and used for 3D microfabrication of arbitrary structures using the TPP technique.

Future Work:

- Measurement of spring constant
- Measurement of the index of refraction

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