3D MICRO/NANO-SCULPTURES MADE OF SWCNT POLYMER MATRIX VIA TWO PHOTON POLYMERIZATION

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Two-photon polymerization (TPP) is a well-established method to fabricate intricate 3D micro/nano structures from polymers. These 3D structures have vast potential in applications such as MEMs and targeted drug delivery systems. However, it remains necessary to functionalize and enhance the properties of the polymer structures for practical applications. To this end, single-wall carbon nanotubes (SWCNTs) are critically acclaimed as ideal fillers to enhance mechanical, electrical, and thermal properties of the polymer due to their high Young's modulus (up to 1 TPa), high tensile strengths (up to 63 GPa), high aspect ratios (up to 10000000), and small diameters (~ 1 nm). In this presentation, we establish a novel way to evenly embed SWCNTs into 3D polymer structures by means of TPP. SWCNTs were dispersed into a photo-resin with a ratio 0.01 wt% by sonication. The mixture showed a large absorption peak around 400 nm, and some small peaks attributed to SWNTs in the range from 450 nm to the near infrared region. A 780 nm femtosecond pulsed laser beam was then focused onto the photo resin, and a nanometric volume of the resin photo-polymerized in the focus spot via two-photon absorption. The focus spot was three dimensionally scanned, dictated by a preprogrammed computer-aided design file, and various structures were created following the trajectory of the focus spot. After scanning, the unsolidified resin was washed away using acetone. Using this method, 3D microstructures such as an 8 micron length bull, a micro-lizard, and a 200 nm width nanowire were obtained. SWCNTs were evenly dispersed in 3D micro-sculptures, as indicated by Raman microscopy. Our method may potentially open the door to a variety of applications such as MEMs, sensors, and targeted drug delivery devices, which call for microstructures reinforced and enhanced by SWCNTs.

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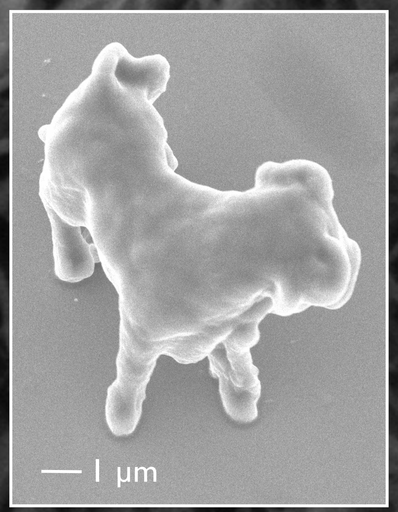
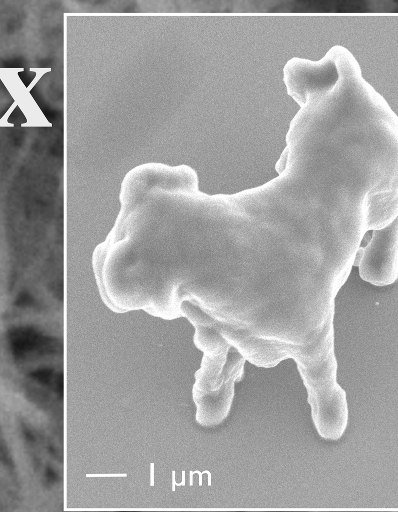


3D Micro/Nano-sculptures made of Single Wall Carbon Nanotube Polymer Matrix via Two Photon Polymerization



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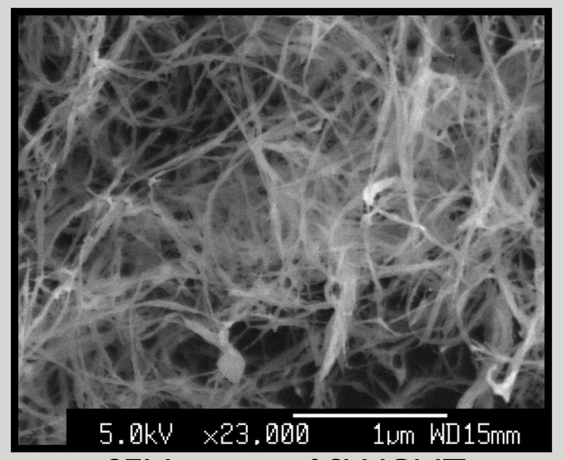
1. Marvelous Mechanical Properties of SWCNTs

Single wall carbon nanotubes (SWCNTs) are acclaimed as ideal fillers to enhance mechanical properties due to their:

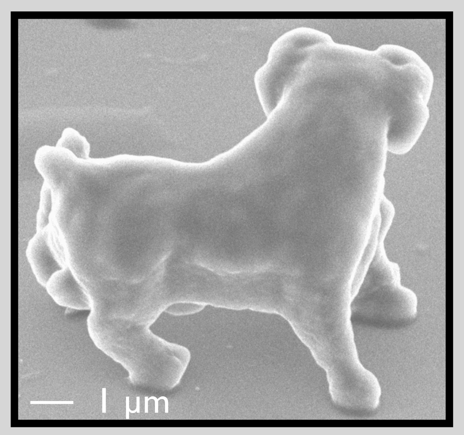
- high Young's Modulus (1 TPa)
- high tensile strength (63 GPa)
- high aspect ratio (up to 10000000)
- 1 nm diameter

J.N. Coleman et al. / Carbon 44 (2006) 1624–1652



SEM image of SWCNTs

Purpose: Fabrication of SWCNT Enforced Micro-sculptures



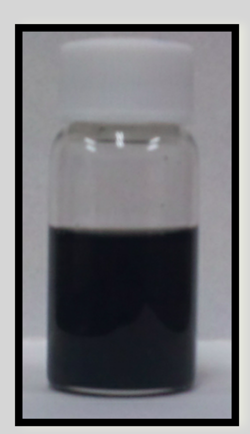
8 μm length micro bull made of SWCNT polymer matrix

We propose a novel approach to fabricate 3D micro-sculptures of a SWCNT enforced polymer matrix using two photon polymerization (TPP). We believe this will open the door to applications needing SWCNT enforced micro-structures such as drug delivery devices, sensors, and MEMs.

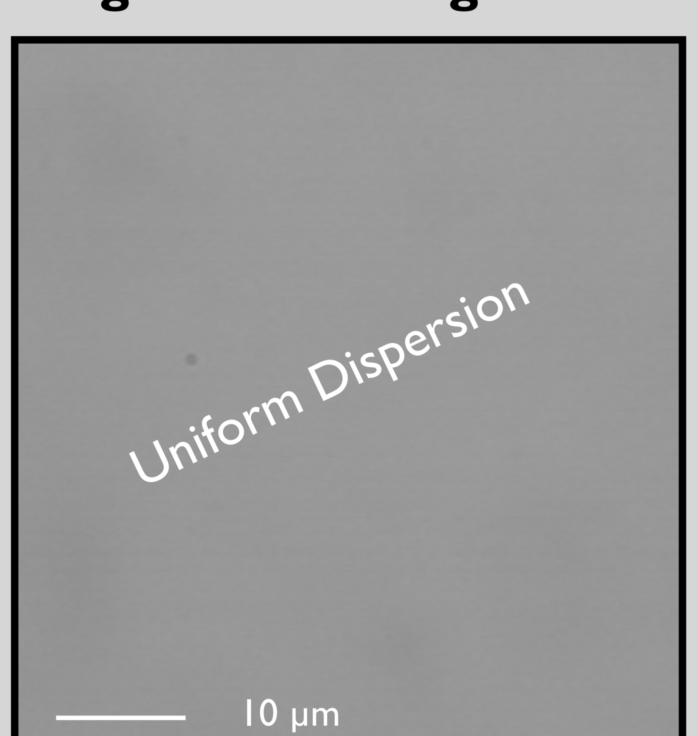
2. SWCNTs evenly dispersed in Photo-resin

Recipe of SWCNT dispersed photo resin

Ingredient	Single Wall Carbon Nanotube	R712 Monomer	Photo Initiator	Photo Sensitizer
Weight %	0.01	96.67	1.67	1.67

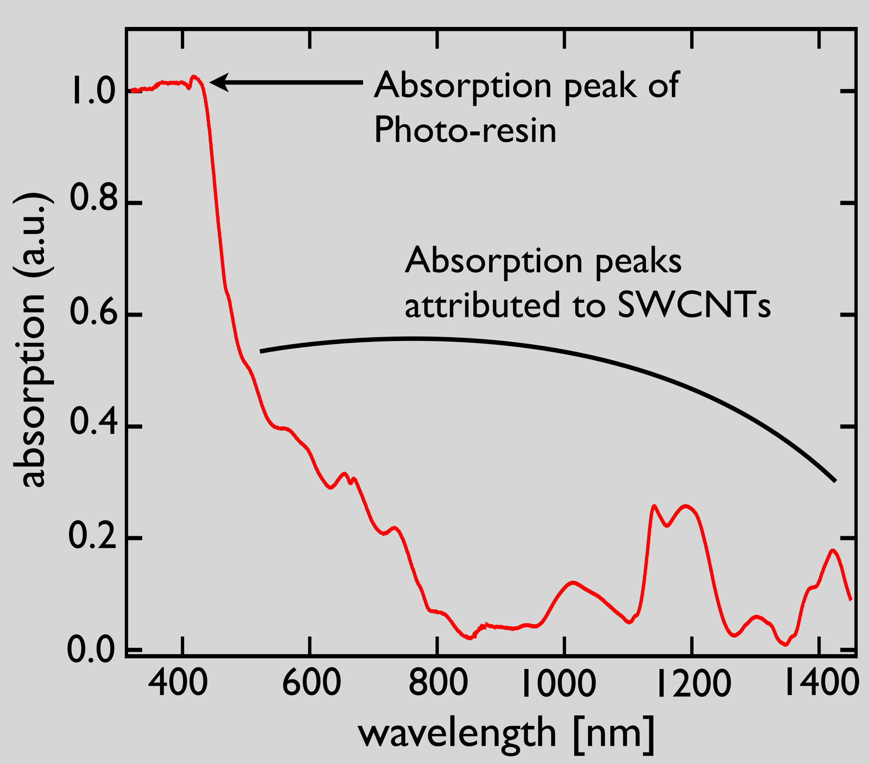


Bright field image



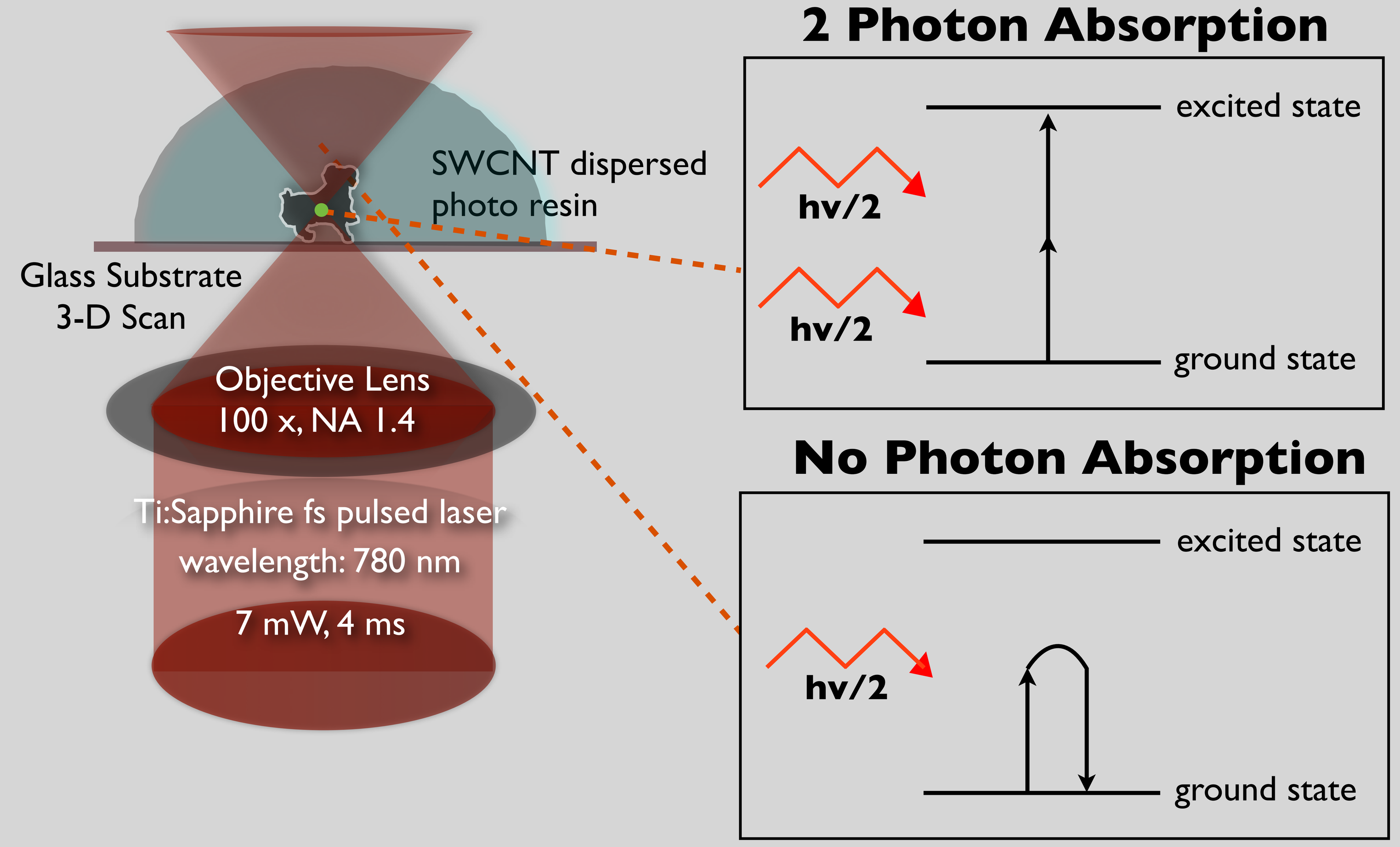
There were no aggregated SWCNTs in the bright field image, which indicates that SWCNTs were evenly dispersed in photo-resin.

Absorption of the resin



The photo-resin exhibits high absorption below 390 nm and low absorption in NIR region rendering the resin photopolymerizable for TPP.

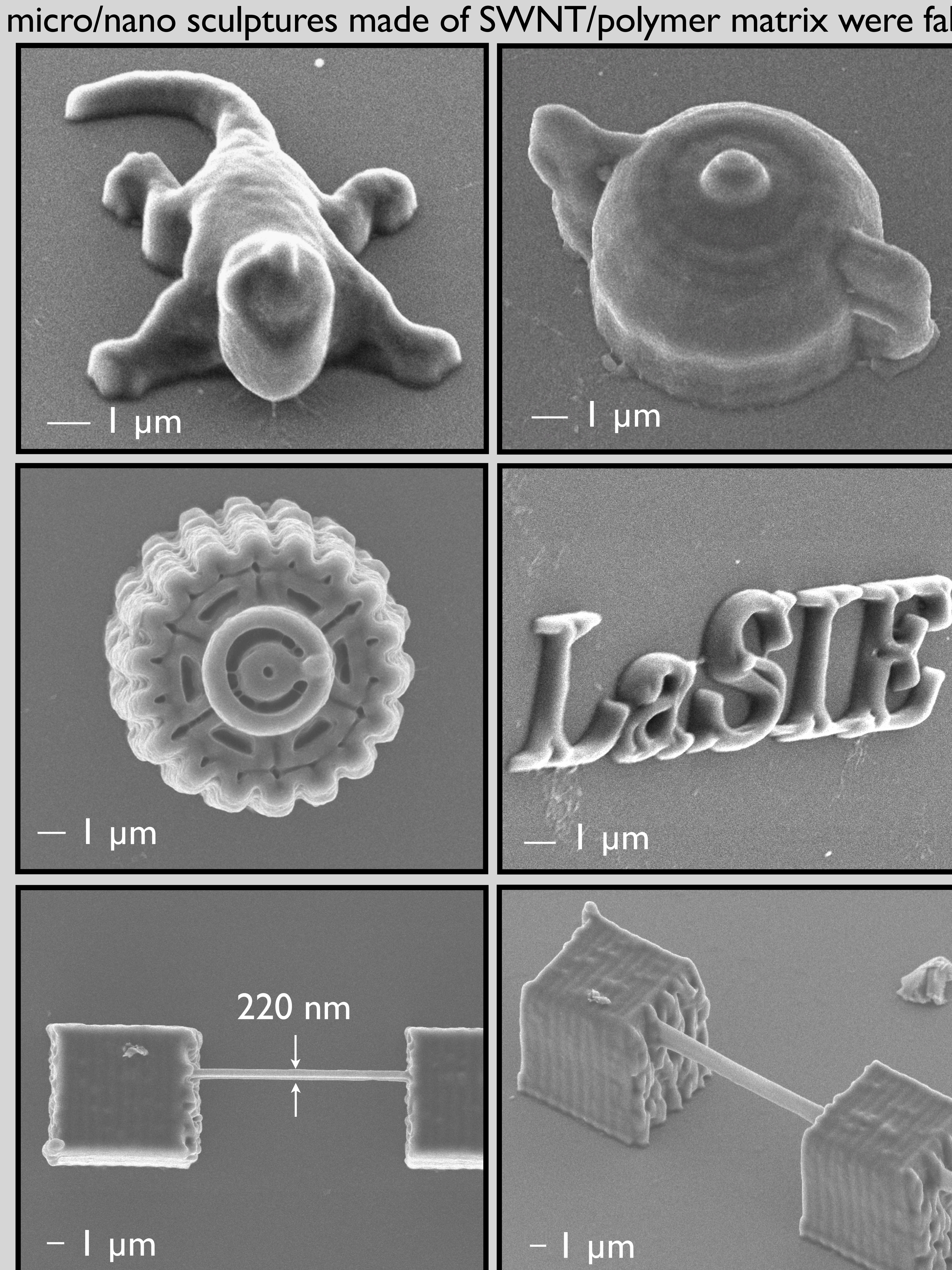
3. Two Photon Polymerization for Fabricating Sculptures



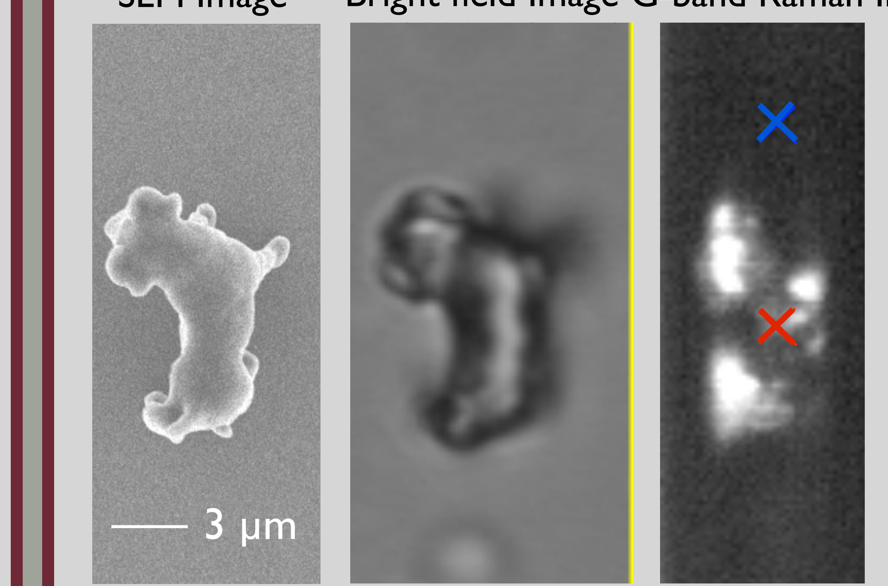
Fs pulsed laser at 780 nm excites 2 photon absorption on a UV photo polymerizing resin, initiating polymerization which only happens at the focus spot. 3D scanning creates SWCNT enforced micro-sculptures.

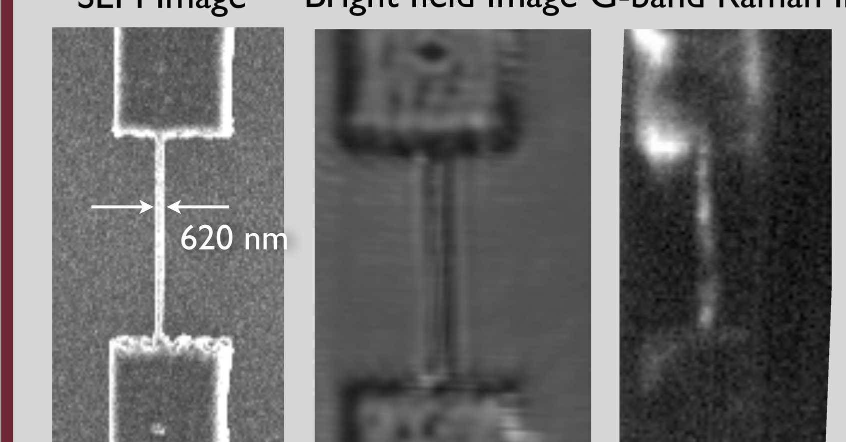
4. 3D Micro/Nano Sculptures of SWCNT Polymer Matrix

3D micro/nano sculptures made of SWNT/polymer matrix were fabricated.

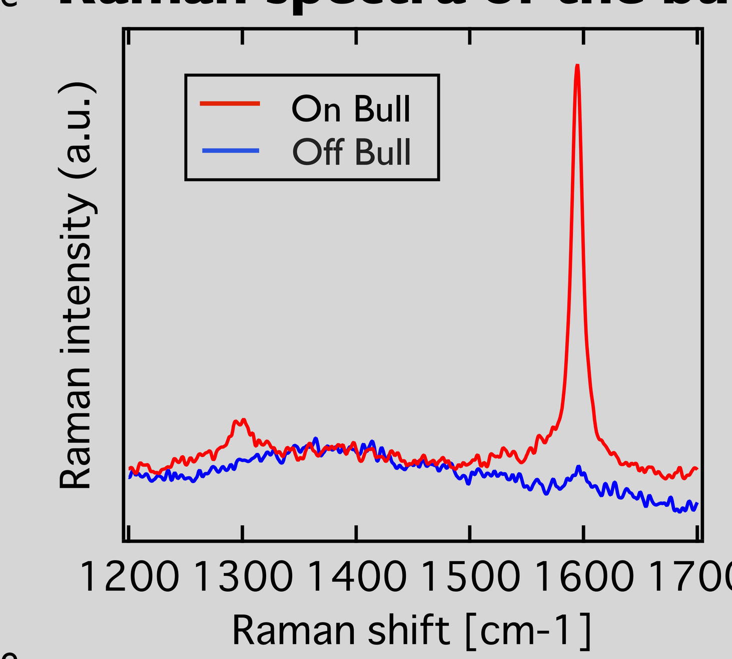


5. SWCNTs Embedded in Micro Structures





Raman spectra of the bull

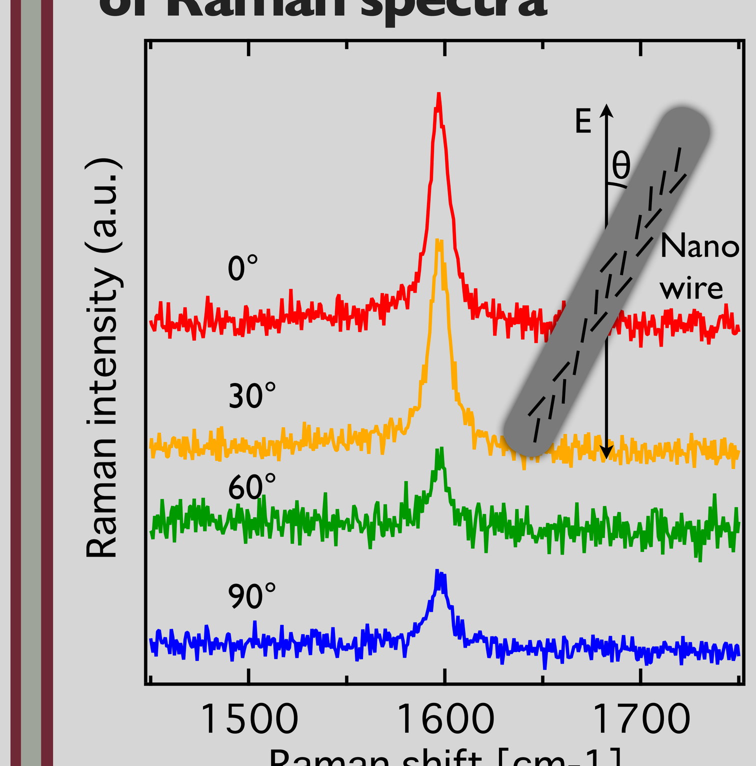


SWCNTs were embedded in micro-sculptures, which is seen by comparing the G-band Raman images to the bright field and SEM images.

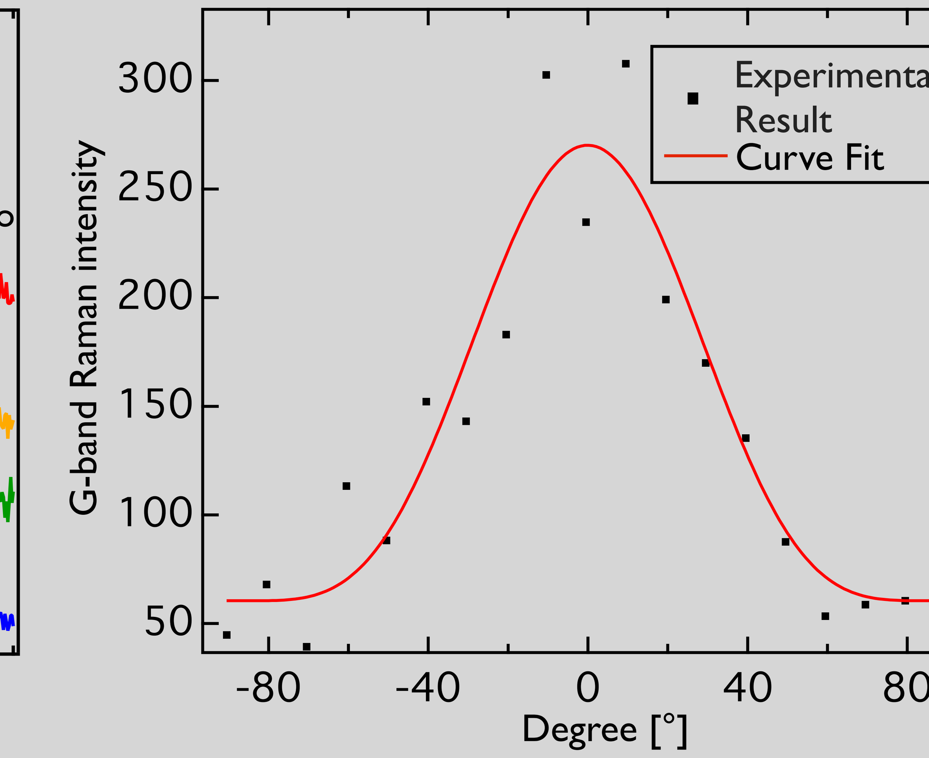
laser: 785 nm, 10 s, 0.56 mW; objective lens: 100x NA 0.9

6. SWCNTs are Aligned along Nano-wire axis

Polarization angle dependence of Raman spectra



Polarization angle dependence @ G-band intensity



SWCNTs were aligned along the nano-wire axis. Polarized Raman microscopy shows that the strongest Raman signal occurred when the nano-wire was parallel to laser polarization, and lowest signal occurred when nano-wire was perpendicular. This alignment is potentially produced by the spatial confinement. M. Ichida et.al., Appl. Phys. A 78, 1117–1120 (2004)

7. Conclusion

We have demonstrated 3D micro/nano fabrication of SWCNT polymer matrix. We elucidated that SWCNTs were embedded in micro structures, and aligned along nanowire axis.

Acknowledgements

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