Mechanics of Nanostructures and Nanocomposites

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The topics to be discussed: (i) Experimental studies by my group of carbon nanotubes and nanocoils, boron and metal boride nanowires, and carbon nanotubes projecting from the fracture surface of CNT composites (a) subjected to tensile loading (b) driven into mechanical resonance by mechanical or electrical excitation. (ii) The ideal strength of materials & fracture in nanostructures (a) ab initio calculations of ideal strength (b) experimental work on nanostructure fracture (c) modeling of the fracture strength of nanostructures with 0, 1, 2 adjacent, 3 adjacent, …, n adjacent defects (d) following this summary of prior work, a new theory (developed with Nicola Pugno, Politecnico di Torino) for fracture of nanoscale structures will be presented: Quantized Fracture Mechanics.

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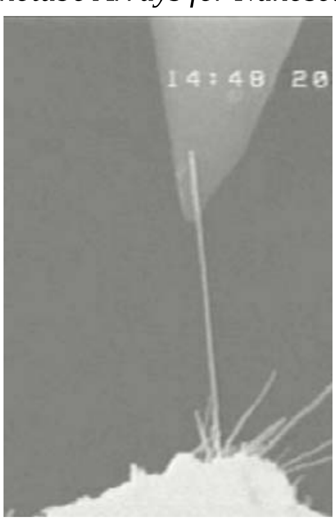

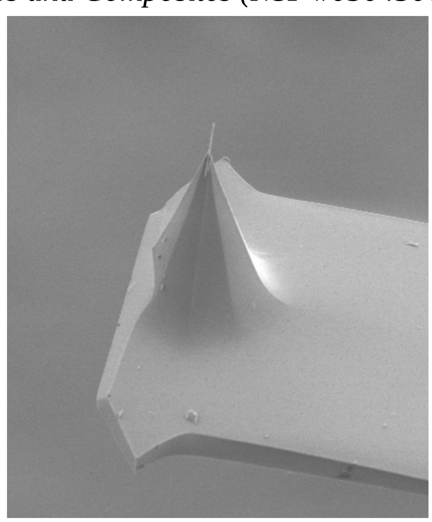

Figure 1. Scanning electron microscope image of an AFM cantilever tip contacting a carbon nanotube, and the nanotube subsequently mounted on such a tip, by the Ruoff group.

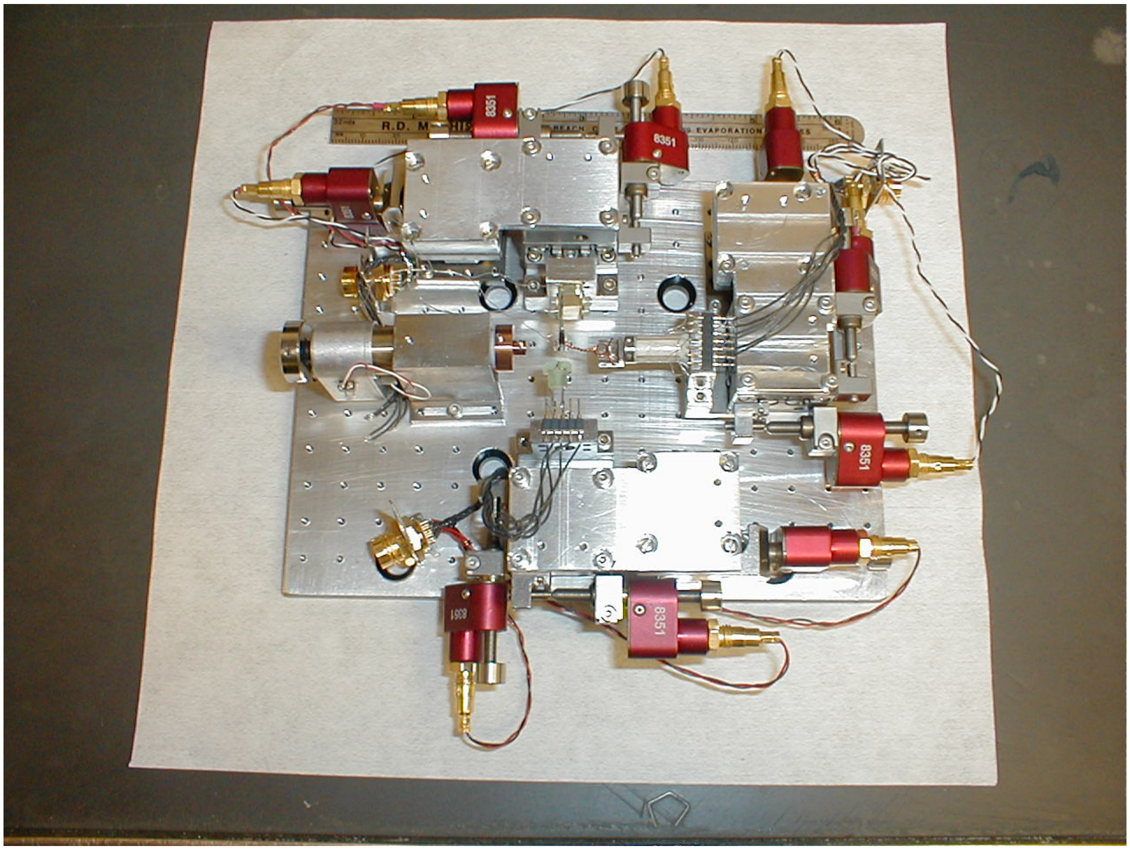

Figure 2. A ten degree-of-freedom nanomanipulation/assembly device built by the Ruoff group, that operates inside of a scanning electron microscope such as the Leo1525 FEG SEM at Northwestern University.

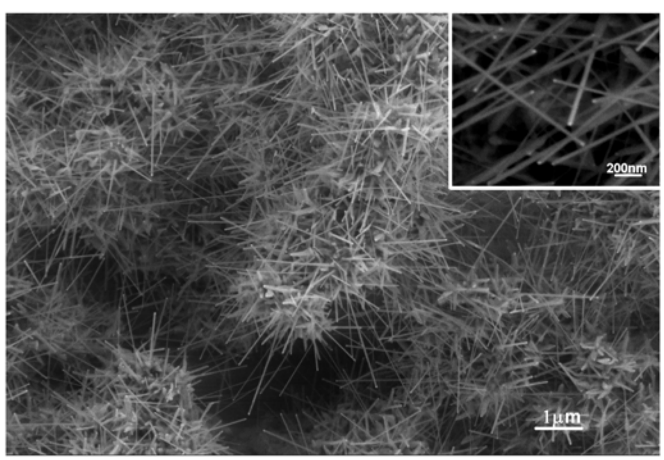

Figure 3. SEM micrograph of as-synthesized CaB_6 nanowires. The inset shows an enlarged view of the nanowires. Catalyst particles (bright white) can be observed on the nanowire tips. T.T. Xu, J-G Zheng, A.W. Nicholls, S. Stankovich, R. Piner, and R. S. Ruoff*, Single Crystal Calcium Hexaboride Nanowires: Synthesis and Characterization. ***Nano Letters* 4(10), 2051-2055 (2004).**

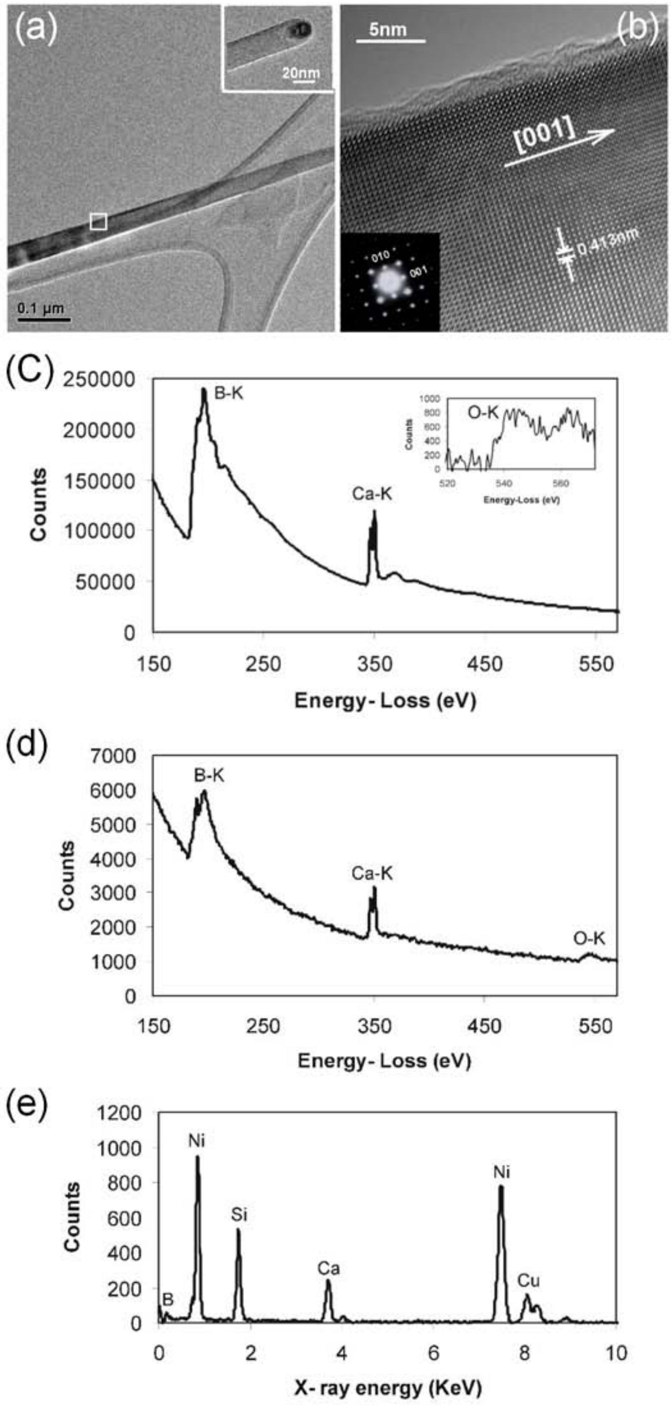

Figure 4. (a) TEM micrographs of a portion of one nanowire. The inset shows a catalytic particle on the tip of the nanowire. (b) HR-TEM image of the section enclosed by the white square in Figure 2(a), showing a crystallized structure and preferential growth along the [001] direction. An amorphous layer (1-2 nm thick) is clearly identified as the outer shell. The inset is a representative diffraction pattern recorded along the $[\bar{1}00]$ zone axis. (c) An EELS spectrum recorded at the center of one nanowire shows the high-intensity B and Ca K-shell ionization edges at ~188 eV and 346 eV, respectively. The inset shows the weak-intensity O K-shell ionization edge at ~532 eV. (d) An EELS spectrum recorded from the edge of one nanowire, showing B, Ca and O K-shell ionization edges. Note: The O K-shell ionization edge is more obvious in this spectrum. (e) An EDX spectrum recorded from the catalytic particle, showing the presence of Ca, B, Ni and Si. T.T. Xu, J-G Zheng, A.W. Nicholls, S. Stankovich, R. Piner, and R. S. Ruoff*, Single Crystal Calcium Hexaboride Nanowires: Synthesis and Characterization. ***Nano Letters*** **4(10), 2051-2055 (2004).**

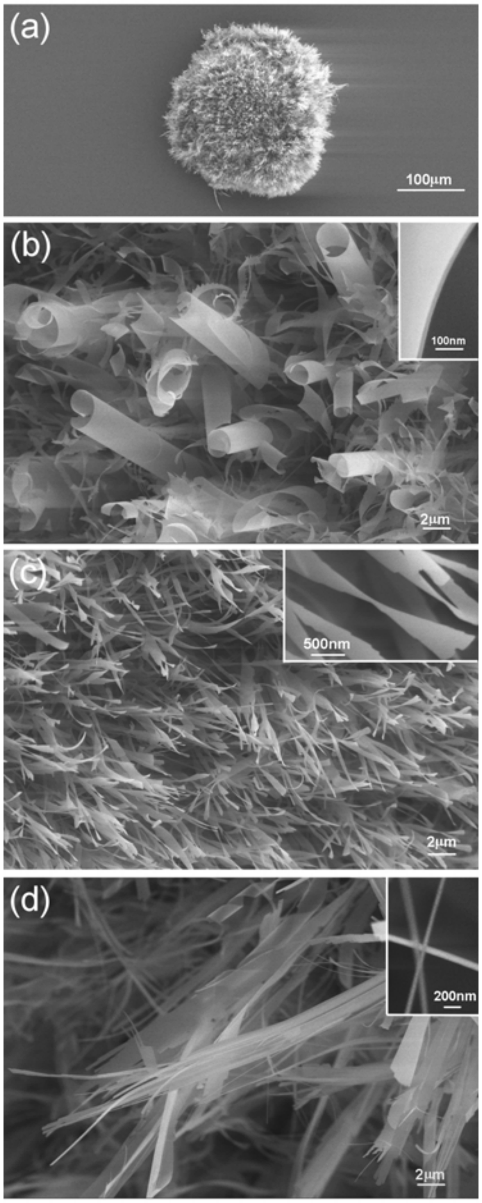

Figure 5. SEM micrographs of (a) Overall view of the B puffy ball, (b) Scrolled B nanostructures. The inset shows the cross-section of one "nano-scroll" of thickness ~17 nm. (c) Grass-like B nanostructures. The inset shows that the nanoribbons are easily twisted and many have "zigzag" edges. (d) B nanoribbons have split ends, forming nanowire-like structures. Terry T. Xu, Jian-Guo Zheng, Nianqiang Wu, Alan W. Nicholls, John R. Roth, Dmitriy A. Dikin, and Rodney S. Ruoff, *Crystalline Boron Nanoribbons:Synthesis and Characterization*, Nano Letters, 2004; 4(5); 963-968.)

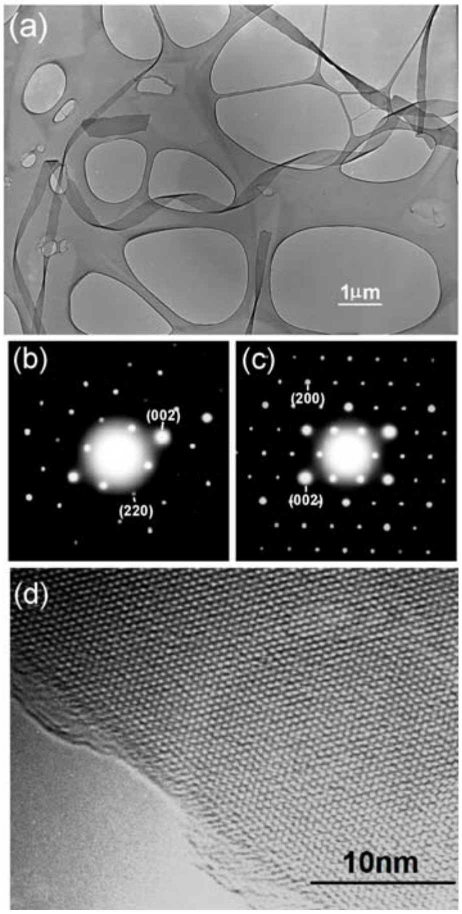

Figure 6. (a) Low magnification TEM image of several twisted B nanoribbons. (b) Diffraction pattern recorded along [1 –1 0] zone axis. (c) Diffraction pattern recorded along [0 1 0] direction. (d) HR-TEM image, showing well-crystallized structure. Terry T. Xu, Jian-Guo Zheng, Nianqiang Wu, Alan W. Nicholls, John R. Roth, Dmitriy A. Dikin, and Rodney S. Ruoff, *Crystalline Boron Nanoribbons:Synthesis and Characterization*, Nano Letters, 2004; 4(5); 963-968.