Fracture Toughness Enhancements in Carbon Nanotube Reinforced Ceramic Matrix Composites

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Purpose

- Determine whether benefits may be derived from the addition of nanotubes to ceramic matrix composites for the high temperature / structural applications that are of interest to NASA. These include – coatings, fuel cells, "smart" engine components, sensors, piezoelectrics, etc.

Possible Benefits

- Weight reduction from CNT additions
- conductivity enhancements
- structural property improvements

Concerns

- Carbon has poor oxidation resistance
- High processing temperatures are required for ceramic matrix composites – may damage fragile nanotubes.

Approach

Use commercially available carbon nanotubes (CNT) to reinforce common ceramic matrices of interest to NASA such as Al_2O_3, ZrO_2, SiC, glass, etc.

Develop alternate nanotubes for improved oxidation resistance for use in ceramic matrix composites - synthesize significant quantities of BN and SiC nanotubes

Processing Steps-

Suspend CNTs in solution – sonicated for several hours

Addition of ceramic matrix material and plasticizers

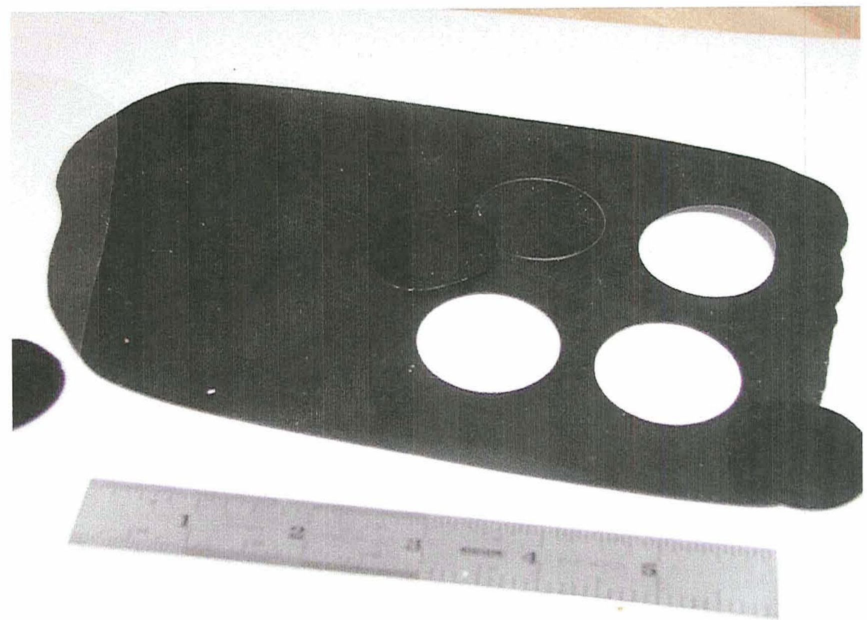
Tape casting of thin films

Hand lay up tapes

Binder burn-out

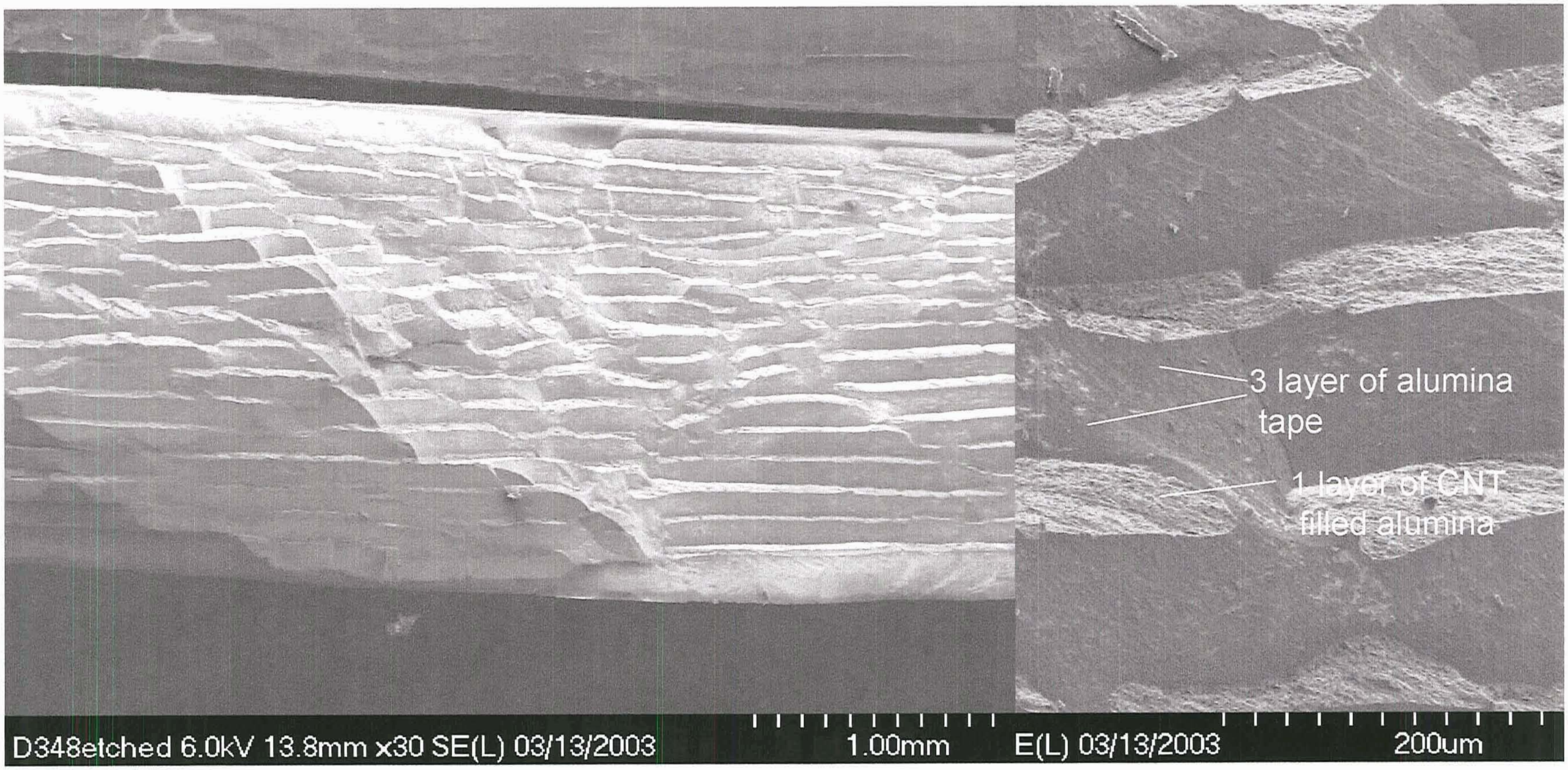
Hot pressing

Tape Casting



Carbon Nanotube filled Alumina Composite

5 wt % CNT in alternating layers



Fractured surface shows composite behavior with crack deflection between layers

Carbon Nanotube filled Alumina Composite

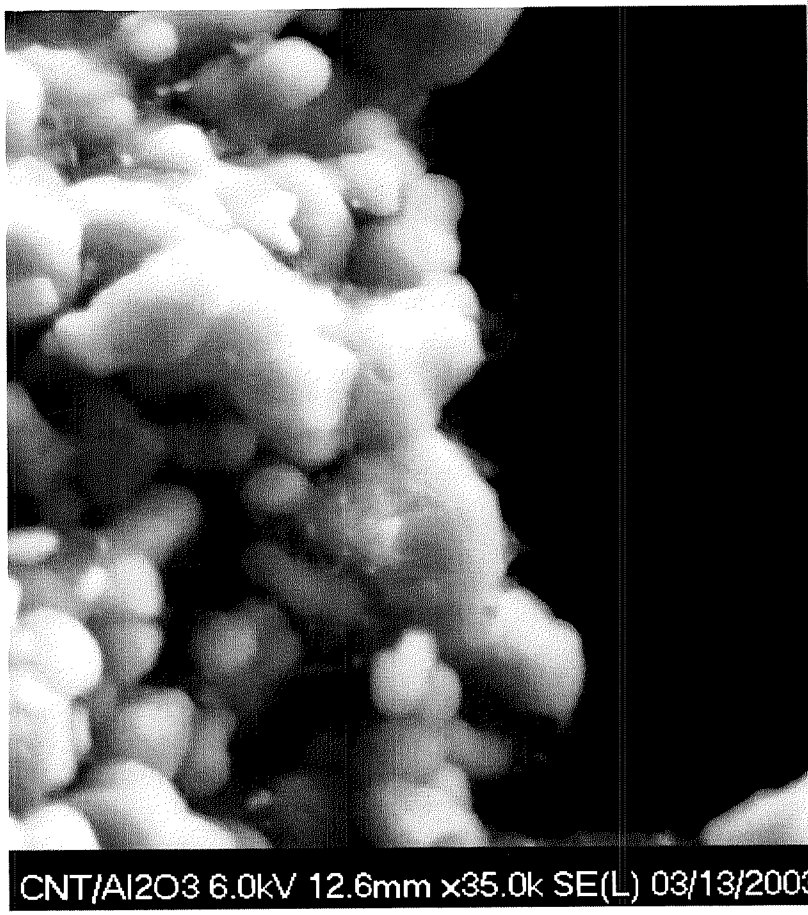
5 wt % CNT in alternating layers

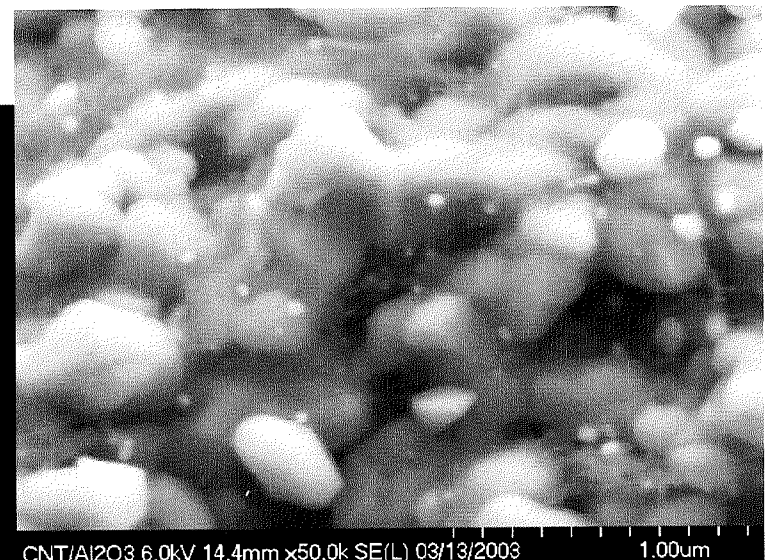
CNT additions resulted in an order of magnitude sintered grain size reduction

Abrupt transitions are found between CNT rich zones and alumina

Carbon Nanotube filled Alumina Composite

5 wt % CNT in alternating layers





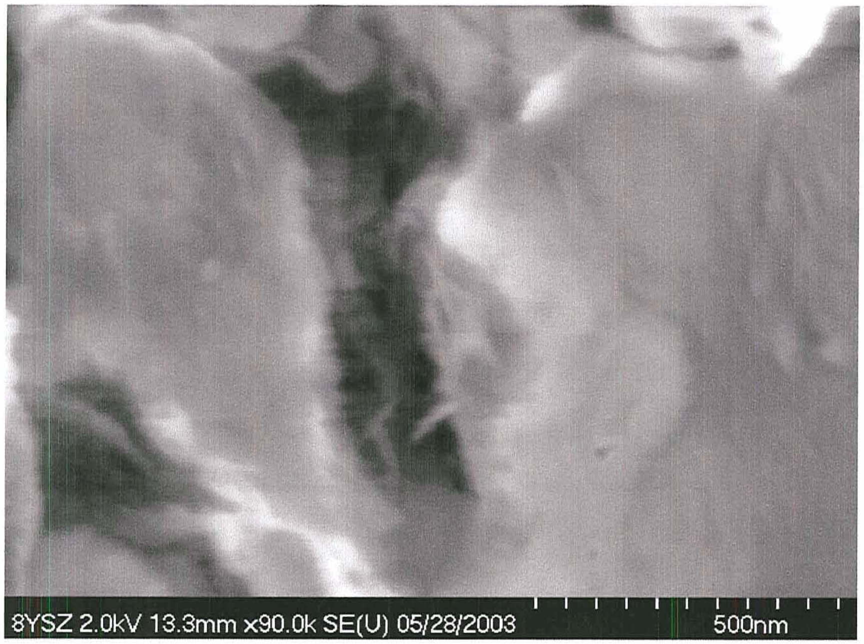
Carbon Nanotube filled ZrO_2 Composite
5 wt % CNT in alternating layers

3 layers of ZrO2
1 layer of CNT filled ZrO2

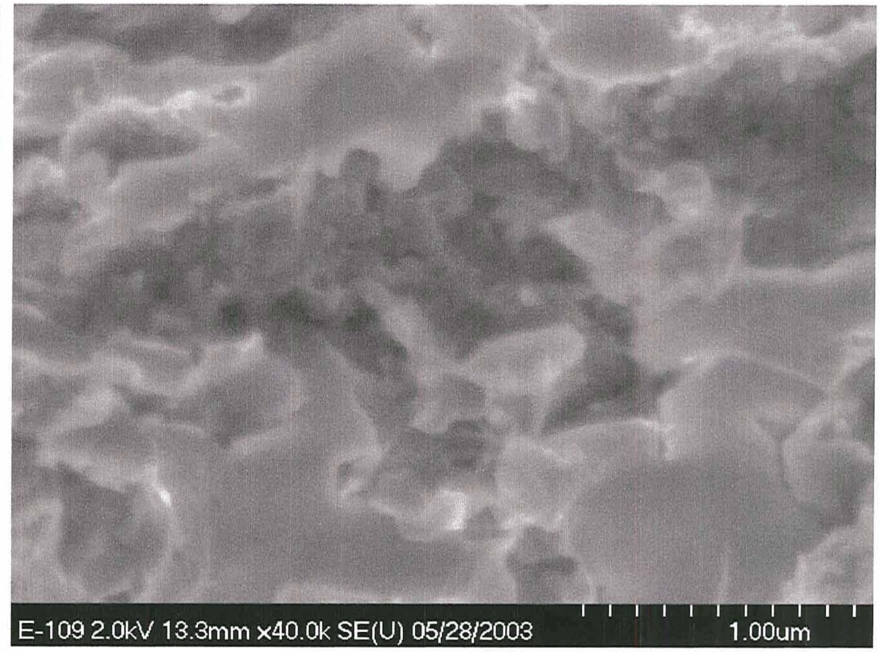
Fractured surface shows composite behavior
with crack deflection between layers

Observations from Carbon Nanotube filled ZrO_2 Composite

5 wt % CNT in alternating layers



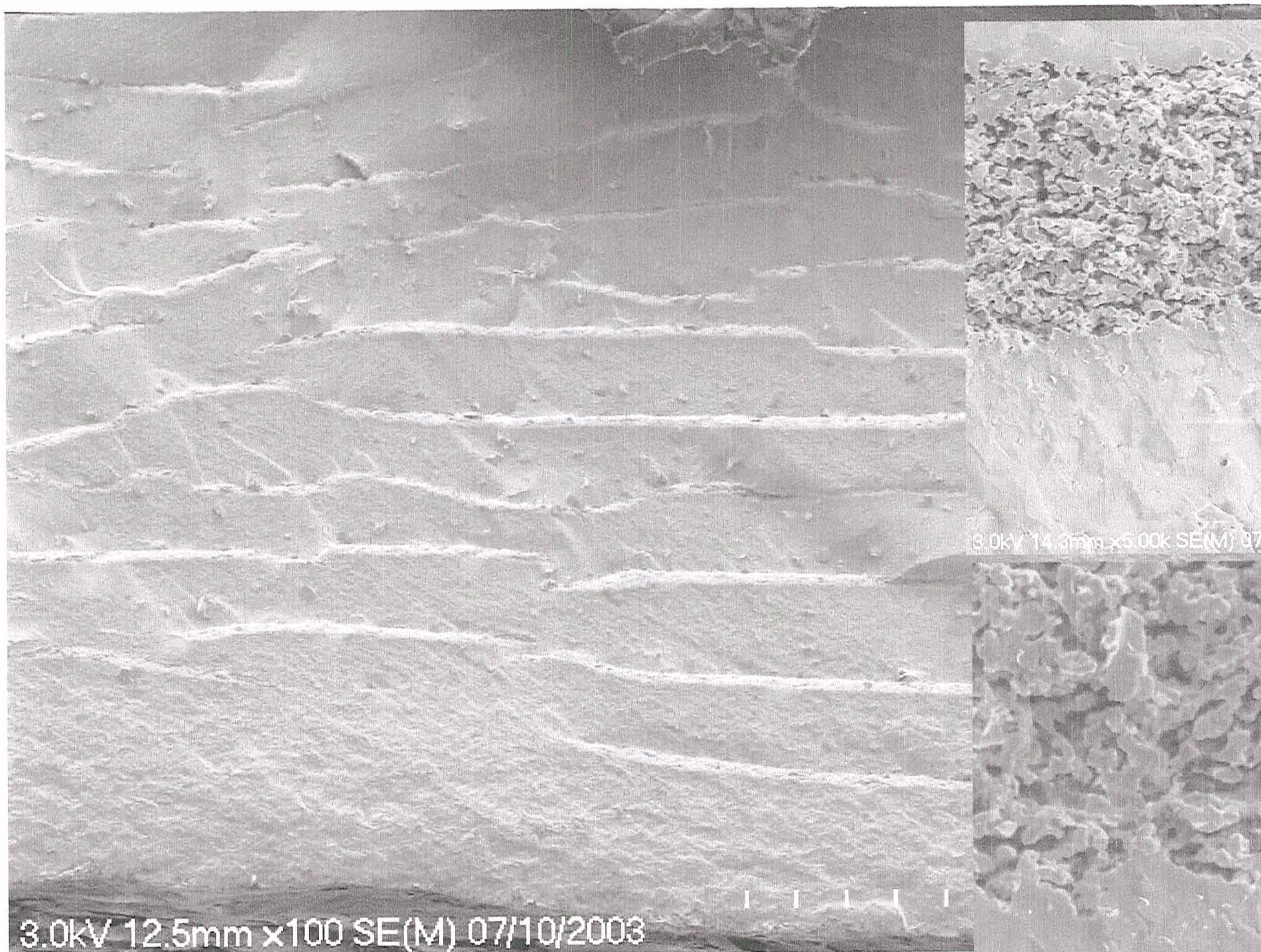
CNT survived hot pressing conditions in 8YZrO2 matrices

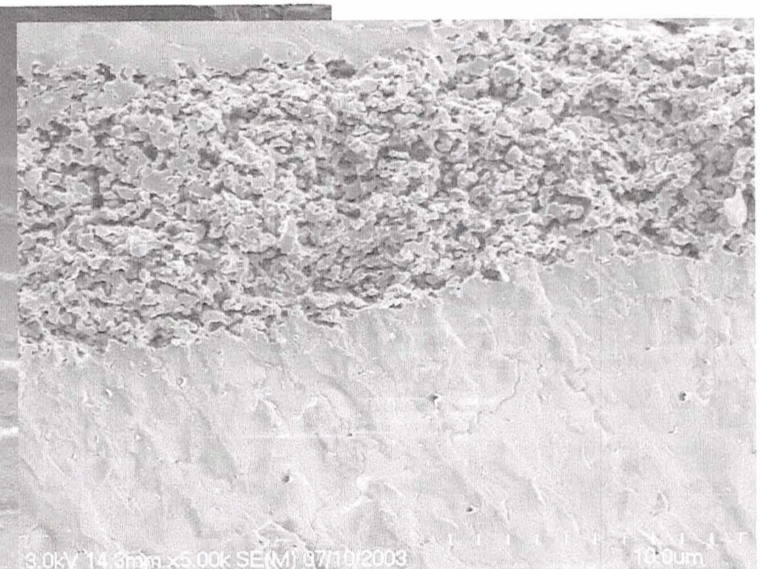


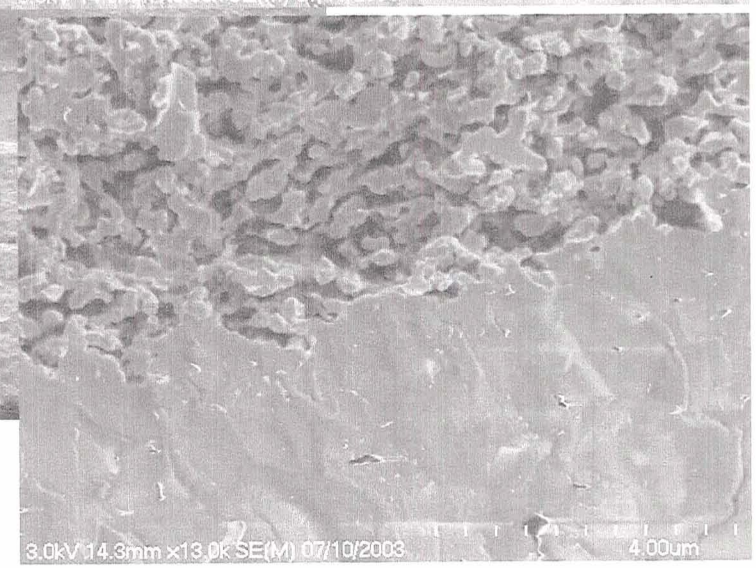
CNT were not well dispersed, resulting in adjacent areas with widely different grain sizes

Observations from Carbon Nanotube filled ZrO_2 Composite

5 wt % CNT in alternating layers

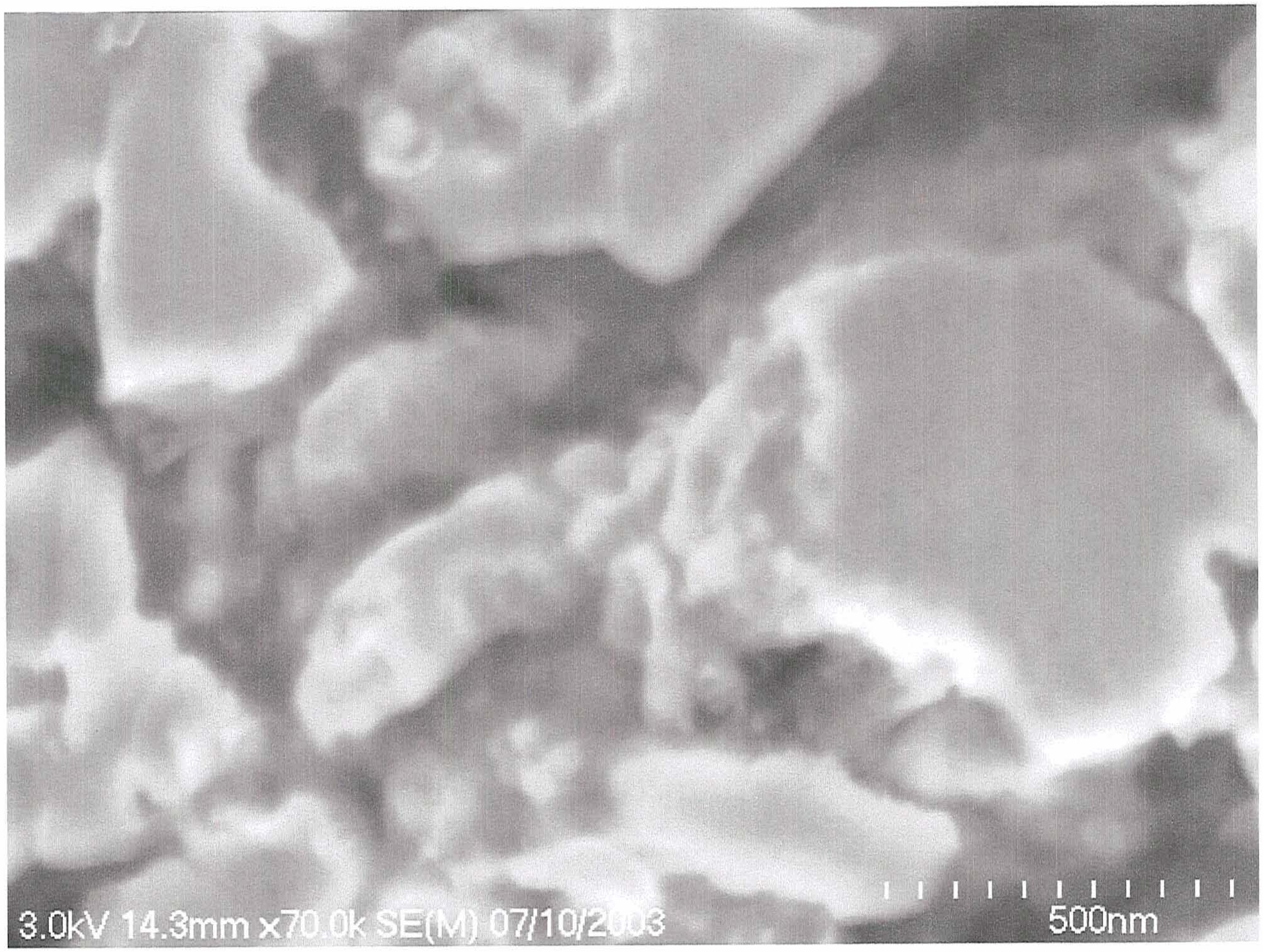






Improved dispersion of nanotubes resulted in more uniform grain size in the CNT- ZrO_2 layers

Observations from Carbon Nanotube filled ZrO2 Composite
5 wt % CNT in alternating layers



Carbon nanotubes between ZrO2 grains

Conclusion s

- Carbon nanotubes can be well dispersed and incorporated into ceramic matrices of alumina and zirconia.

- Carbon nanotubes were found to survive hot pressing process conditions (up to 1500C).

- Carbon nanotubes provided enhanced work of fracture for both alumina and zirconia matrices.

- Carbon nanotubes resulted in decreased grain growth of at least an order of magnitude.

Future Work

- Examine the effect of CNT on additional matrices including SiC and BAS glass
- BN nanotube additions to ceramic matrix composites
- Samples of both CNT and BNNT composites for high temperature mechanical behavior
- Perform conductivity measurements