



## Dr. Renu Sharma

### Area of Research:

Understanding nanoscale catalytic processes, including nucleation and growth of carbon nanotubes and semiconducting nanowires.

Pioneer in the development of environmental cell scanning transmission electron microscopy combining atomic-scale resolution with dynamic chemical analysis of gas-solid reactions.

### Honors and Degrees:

B.S., B.Ed. in Physics and Chemistry, Panjab University, Chandigarh, India

M.S. in Solid State Chemistry, University of Stockholm, Sweden

Ph.D. in Solid State Chemistry, University of Stockholm, Sweden

Swedish Institute Fellowship

Faculty Research Fellowship, Deutscher Akademischer Austauschdienst (DAAD), Past

President, Arizona Imaging and Microanalysis Society

Senior Research Scientist, LeRoy Eyring Center for Solid State Science, Arizona State University (ASU), Tempe, Arizona



Dr. Renu Sharma

Project Leader, Nanofabrication Research Group  
Center for Nanoscale Science and Technology,  
National Institute of Standards and Technology

Renu Sharma has seen dreams come true. She's seen science fiction turn into science reality. In her lifetime, what were once just theories about catalytic reactions for carbon nanotube growth are now verified using atomic-level imaging and analysis. Her work as a research scientist has been transformed by the development of powerful scanning transmission electron microscopes. After years of study and research, Dr. Sharma is still imbued with a sense of wonder.

"For me, this is fun...to be able to sit down and see things as they're happening. Some of the things you can't even explain—why things are happening and how they are happening—it's amazing," said Sharma regarding how the use and development of advanced transmission electron microscopy has transformed her field.

"I remember when I was first showing videos of carbon nanotube growth at a conference years ago. I was answering some technical questions from the audience about chemical reactions. Then, suddenly, one man stood up and said, 'I don't care! I'm just amazed to see these things!' He had prepared so many hypotheses about how the reaction would occur, but now for the first time, you could actually see it. As a scientist, you have fantasies about what would happen. And now you can see that it is not the case—the whole process is different from what you thought," she said.

**“[There were]...many hypotheses about how the reaction would occur, but now for the first time, you could actually see it.”**

Today, Dr. Sharma is a Project Leader in the Center for Nanoscale Science and Technology at the National Institute of Standards and Technology (NIST), part of the U.S. Department of Commerce.

## FEI CUSTOMER PROFILE

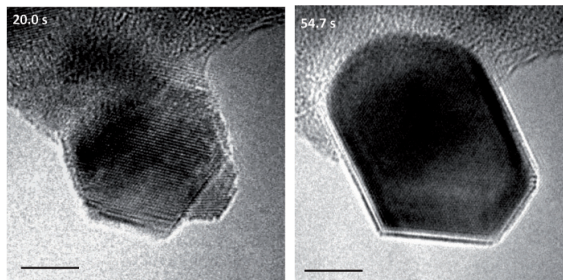
Dr. Sharma joined NIST's Center for Nanoscale Science and Technology (CNST) in 2009, coming from Arizona State University (ASU), where she began as a Faculty Research Associate in the Department of Chemistry and Biochemistry and the Center for Solid State Science. Dr. Sharma has been one of the pioneers in the development of environmental cell scanning transmission electron microscopy (ESTEM), combining atomic-scale resolution with dynamic chemical analysis of gas-solid reactions. She has applied this powerful implementation of TEM to characterize the atomic-scale mechanisms underlying the synthesis and reactivity of nanoparticles (including catalysts), nanotubes, nanowires, inorganic solids, ceramics, and semiconductors.

At the CNST, Dr. Sharma is establishing advanced TEM measurement capabilities for nanoscience research and overseeing the operation of a new TEM, available in the NanoFab, the CNST's national, shared-use nanofabrication facility.

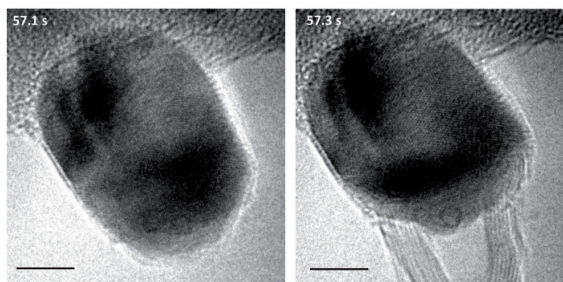
"I'm interested in understanding the growth processes for carbon nanotubes and nanowires and how to control their growth," said Dr. Sharma. "For example, in the semiconductor industry, you want total control of your process. You need to grow carbon nanotubes at a specific place, with controlled diameter, length, and so on, otherwise they will have different properties. Controlled synthesis for carbon nanotubes is even more important because there are so many types of structures. We need to know which catalyst particle is reactive and how the reaction is proceeding. Can it be deactivated? Can it be activated again? I've worked with four or five other research groups on this, including at ASU, using the FEI Tecnai F20 to find the answers," she said.

How does Dr. Sharma view the future of research in her area? "Back in 1995, a group of us were working simultaneously, trying to incorporate the possibility to follow gas-solid reactions using transmission electron microscopes. Honestly, I never thought the whole technology would come to this point! Now, we have the ability to control the gas [vapor] pressure in the environmental chamber to 2000 Pa and sample temperature to 800° C, for imaging with atomic-level resolution. Of course, we still have some steps missing for following all of the steps in a reaction because we can't collect data with high spatial resolution, but it is still a big leap forward."

With nanoscale boundary-breaking tools at hand, Dr. Sharma will continue to make her own breakthroughs in carbon nanotubes and beyond.



Sequence of high resolution images extracted from a digital video, recorded at 650 °C in 1300 Pa of  $C_2H_2$  gas flow, showing sequence of structural transformation occurring in a Fe containing particle, deposited *in situ*, by electron beam induced decomposition (EBID) using iron nona carbonyl. Time of image extraction is given in upper left-hand corner and the bar is 5 nm. After 20 s of exposure to  $C_2H_2$ , particle consisted of small crystallites with  $Fe_3O_4$  structure. After 34.7 s crystallites reduced and coalesced to form a single crystal of Fe.



The particle changed the shape as well as the crystal structure from Fe to  $Fe_3C$  prior to the nucleation and growth of Multiwalled CNTs. Note that the particle retained  $Fe_3C$  structure after CNT nucleation. The structural changes were determined using diffractograms (not shown). Ref: *Nano Letters* 9, 689-694 (2009).

**Selected Publications:** Dr. Sharma has over 140 publications. Here are a few.

**Site-specific Fabrication of Fe Particles for Carbon Nanotube Growth**, R. Sharma, E. Moore, P. Rez, and M. M. J. Treacy, *Nano Letters* 9, 689-694 (2009).

**Ledge Flow Controlled Catalyst Interface Dynamics During Si Nanowire Growth**, S. Hofmann, R. Sharma, C. T. Wirth, F. Cervantes-Sodi, C. Ducati, T. Kasama, R. Dunin-Borkowski, J. Drucker, P. Bennett, and J. Robertson, *Nature Materials* 7, 372-375 (2008).

**Controlling the Catalyst During Carbon Nanotube Growth**, J. Robertson, S. Hofmann, M. Cantoro, A. Parvez, C. Ducati, G. Zhong, R. Sharma, and C. Mattevi, *Journal of Nanoscience and Nanotechnology* 8, 6105-6011 (2008).

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**World Headquarters**  
Phone: +1.503.726.7500

**FEI Europe**  
Phone: +31.40.23.56000

**FEI Japan**  
Phone: +81.3.3740.0970

**FEI Asia**  
Phone: +65.6272.0050

