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Scanning transmission electron microscopy: The major beneficiary of aberration correction?

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To contribute to a celebration marking the centennial of Otto Scherzer's birth is a pleasant but daunting honor. For the majority of the twentieth century, his insights dominated transmission electron microscopy. Not only did he provide the effective engineering constraints of all electron microscopes that attempted the highest spatial resolution but also sowed the seeds that lead to the lifting of those constraints. Practicable aberration correction was initiated by him and this paper will describe some recent applications.

As has been frequently pointed out, knowing which atoms are where is, in a sense, a complete characterization of a material. Aberration corrected STEM, which allows the electron energy loss spectrum (EELS) to be also collected at atomic resolution now allows atom column by atom column characterization to be performed [1,2,3]. Having demonstrated this level of performance then begs the question as to future directions in analytical electron microscopy. Recent examples from the SuperSTEM Laboratory that indicate the direction in which we intend to progress are studies of carbon structures one to a few atoms thick and biological samples. This has motivated a drive to lower accelerating voltages and data will be shown from 80kV and 60kV. It has also motivated a drive to optimize the information acquired from those counts that are available in materials that damage.

Graphene and exotically functionalized single wall carbon nano-tubes are ideal systems to study at lower accelerating voltages because carbon has a knock-on threshold in these materials around 80keVdepending on the detailed bonding of the carbon. Aberration correction allows atomic resolution information to be acquired at these lower accelerating voltages as shown in Figure 1. This also illustrates the threshold of damage for multiwall carbon anaotubes.

Where a sample is too beam sensitive for routine approaches to high spatial resolution EELS spectroscopy, we propose a technique that retains some spatial information but averages over a large number of equivalent positions in the sample. This is not universally applicable but would allow, for example, an averaged EELS spectrum to be acquired from the surface of a beam sensitive nano-particle by scanning around the surface of many particles while collecting one spectrum. As a short hand, we have termed this 'smart acquisition'.

These two approaches (lowering the accelerating voltage and smart acquisition) are two indicative examples of new areas to explore in the landscape of electron microscopy that have become fruitful as a direct result of aberration correction.[5]

References
[1] M. Bosman,et al., *Phys. Rev. Lett.* 99, (2007) 086102
[2] D. A. Muller et al., *Science* 319, (2008), 1073–1076.
[3] K. Kimoto et al., *Nature* 450**,** (2007), 702–704
[4] A. L. Bleloch, *Advances in Imaging and Electron Physics*, 153 (2008) 195-223
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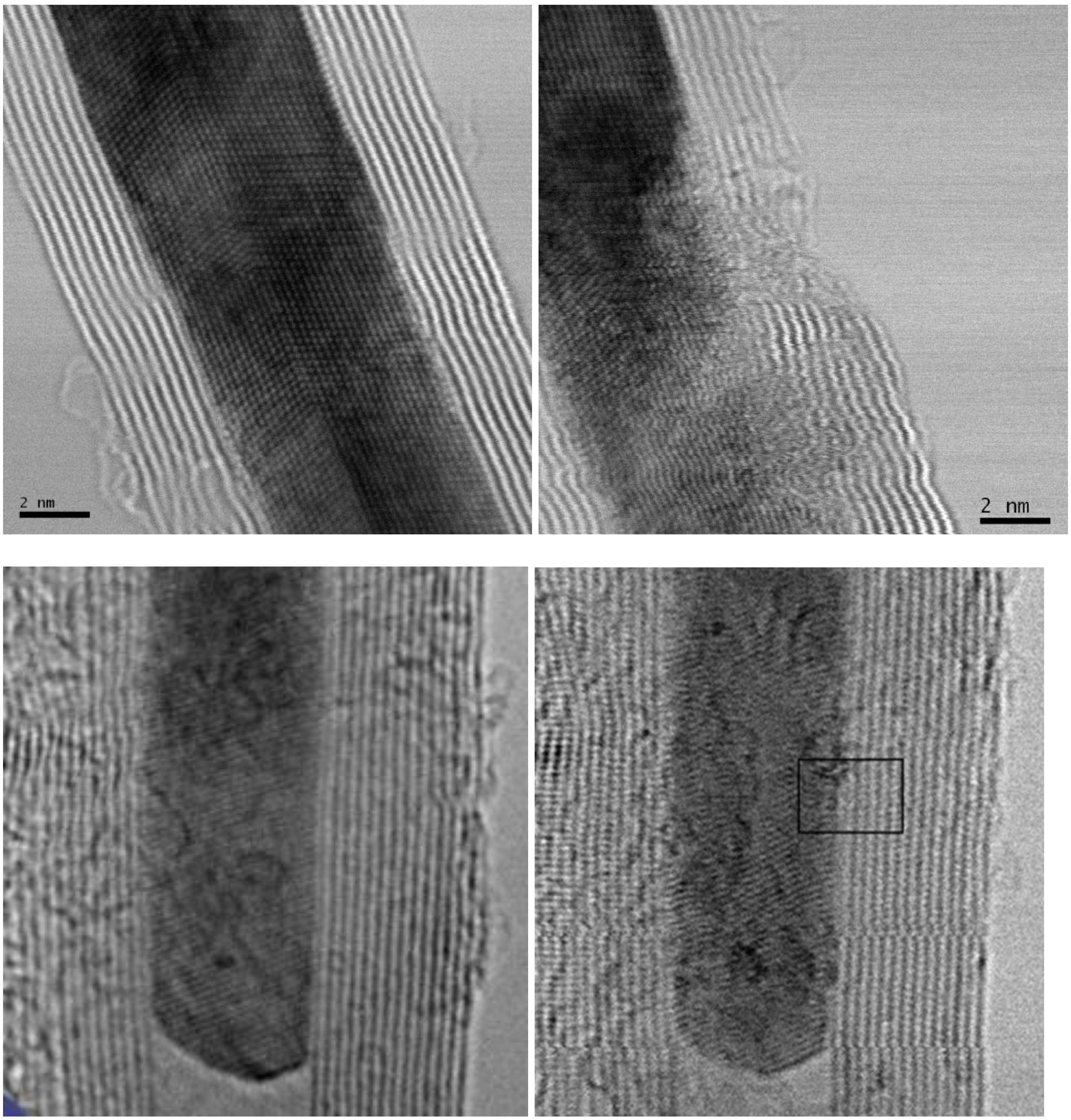

FIG. 1. STEM bright field images of a filled multiwall carbon nanotube at 100kV (top) and 80kV (bottom). Images on the left were acquired before an EELS spectrum image was acquired from the right hand edge of the tube. The damage is obvious at 100kV and undetectable at 80kV. (Adapted from [4])

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