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My Joy of Research in SEM

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While I was an undergraduate student, I was fascinated by the grain boundary segregation in metallic alloys in relation with the formation of unwanted precipitated that reduce their mechanical properties. This quickly led me to perform graduate studies in electron microscopy, especially TEM, to perform such measurements. Then, I found a paper by David Joy *et al.* [1] that describe the effect of Fast Secondary Electrons [FSE] on x-ray generation. Their simulations showed that they are emitted almost perpendicularly to the incident beam and also that they can generate a significant fraction of the x-rays for energy lines below 1 keV. I already saw the possible degradation of the spatial resolution to measure Oxygen or Carbon segregation at grain boundaries. As a result, I became heavily interested about Monte Carlo simulations of electron trajectories in solids around 1985. Them, I developed my first Monte Carlo programs, from scratch while I was a graduate student at École Polytechnique de Montéal, for the simulation of the effect of FSE on Cliff-Lorimer K factors in the TEM [2] and also of the quantification of spherical inclusions in bulk specimens using x-ray microanalysis in the SEM [3]. I met David Joy the first time at the 1988 EMSA conference of Milwaukee where I asked him questions about the modelling of ionization cross-sections that fails at low overvoltage giving negative values and therefore subtracting the x-ray intensities generated by the FSE. As a result, we started to collaborate and I visited him many times in Knoxville. He gave me his computed values of the Mott elastic cross sections around 1992.This was great because they are difficult to compute but are more accurate than the Rutherford cross sections below 10 keV. With my graduate students at that time, Dominique Drouin and Pierre Hovington, they were used to develop the CASINO program that is well known since its release in 1996 [4]. David Joy help has to be credited in the development of CASINO. Figure [1] shows a classical plot of electron trajectories in Si at 30 keV computed with CASINO.

While I visited David Joy the first time in Knoxville, in March 1991, I remember that we were in an highway when he told me that STEM in the SEM will be fantastic because with the new cold field emitters and no lens below the sample, the chromatic aberration will be minimal and the spatial resolution of this imaging mode will be amazing. David Joy made many instrumental contributions in this regards, especially with the Hitachi S-5500. I followed David Joy idea with the Hitachi SU-8000 and SU-8230 for STEM at 30 keV, especially with Nicolas Brodusch and Hendrix Demers [5]. Recently, I acquired the SU-9000EA from Hitachi that has a resolution of 2,2 Å in Bright Field STEM at 30 keV. Multi-walls carbon nanotubes imaged in these conditions are shown in Figure [2] with a resolution of 3.4 Å. Clearly, each time I work with the SU-9000EA, the vision that David Joy had in 1991 is shown to me.

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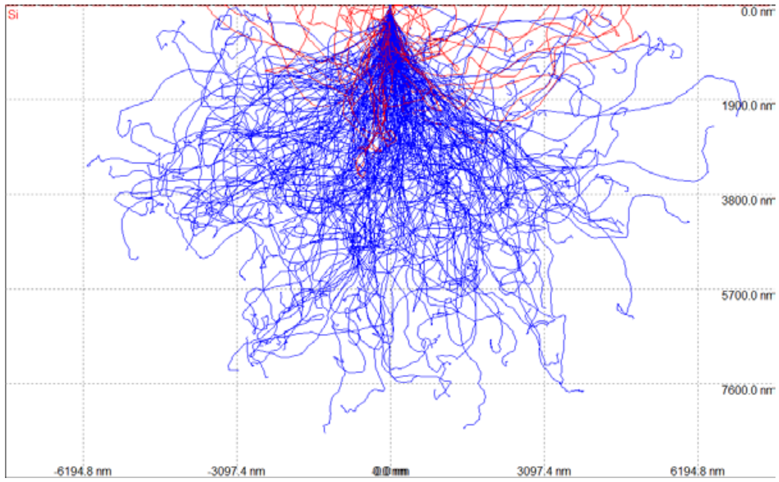

Figure 1. Monte Carlo simulations of electron trajectories in bulk Silicon at 30 keV simulated with CASINO. CASINO is available for free at www.mermg.com.

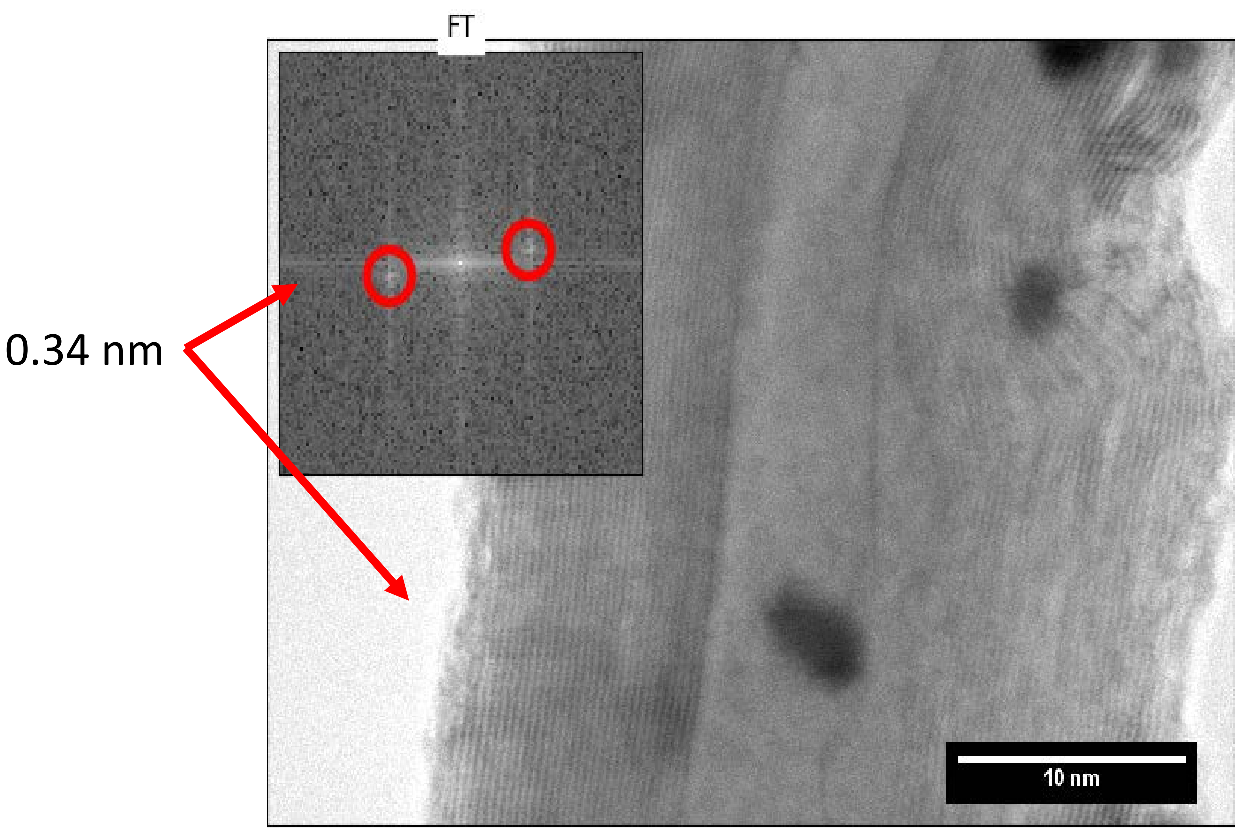

Figure 2. Multi-walls carbon nanotubes imaged in STEM mode, Bright Field, with the SU-9000EA at 30 keV.

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