High sensitive visualization of localized electric field using low energy electron beam deflection

S. Jeong, and J. Fujita

Institute of Applied Physics, and Tsukuba Research Center for Interdisciplinary Materials Science (TIMS), University of Tsukuba, Tsukuba 305-8571, Japan

fujita@bk.tsukuba.ac.jp

G. Edwards, *Deben UK Ltd.*

Charge localization on a defective graphene could arise the short range but the very intense local field at the specific reaction site, thus the visualization of the localized field will bring essential development to the physical elucidation of the catalytic reaction mechanism. Electron beam holography is one of a powerful tool to visualize the electromagnetic field, having the detection sensitivity of about 10^2V/μm at the tip of the CNT [1]. However, the interfered fringes became shorter with the shorter wavelength at the higher accelerating voltage, which brings down the detection limit with the blurring of the interference. While the maximum resolution would be traded off with the primary e-beam energy, the use of low energy e-beam in a SEM system gives the large deflection nearby the local charge [2,3]. Thus the high sensitivity could be expected for the detection the local electric and magnetic field [4]. Here we report the massive improvement of the detection sensitivity showing about 1 V/μm order at the use of 1 to 3 keV of the primary e-beam, which is about two order of the magnitude smaller than that of our previous report [3]. We also demonstrated the visualization of the localized electric field that was induced at the tip of the CNT using our improved method.

Figure 1 shows the schematics of the visualization principle [2,3], where a low-acceleration electron beam (typically about 3 to 10keV) is deflected by the local electric field of a specimen. According to the Rutherford scattering model, the deflection angle θ is defined by $\tan\frac{\theta}{2} = \frac{1}{4\pi}\frac{Qe}{m_e b^2 v_0^2}$, where m_e is the mass of the electron, e is the elementary charge, v_0 is the velocity of the electron, Q is the image charge assumed at the center of curvature of the probe tip, b is Impact diameter. Based on the above principle, the localized electric field was visualized, and the electric field intensity was calculated as shown in Fig.2. The low energy e-beam sensitively created the image of the localized field at the top of the CNT fiber, as shown in Fig.3. (a) Shows the bright field image of the CNT fibers and (b) is the corresponding dark field image. (c) Showed the deflection image when the -80V of the biasing was applied to the CNT voltage, and the localized field can be reconstructed by the contour bands for the outer green area for 30V/um, yellow area for 13V/μm, and inner red area for 6V/μm. Figure 4 shows the smallest electric field of 4V/μm was visualized and about $1.7\text{x}10^4$ of the electron could be localized at the top of the CNT fibers.

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References

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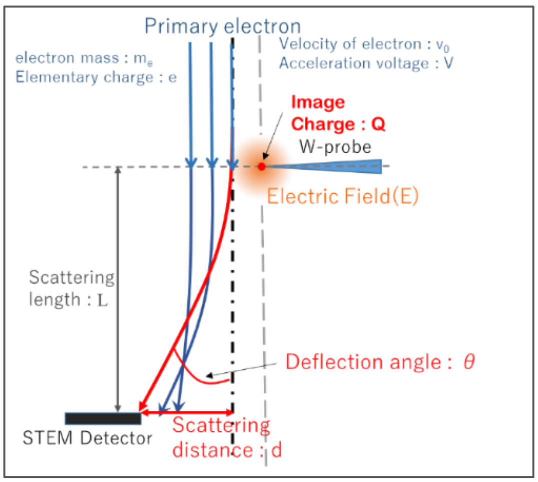

Figure 1: Schematic of the electric field visualization: When the electron beam passes through a locally strong electric field region near the tip of the probe, the trajectory is greatly bent and reaches the STEM detector at the bottom (the red line).

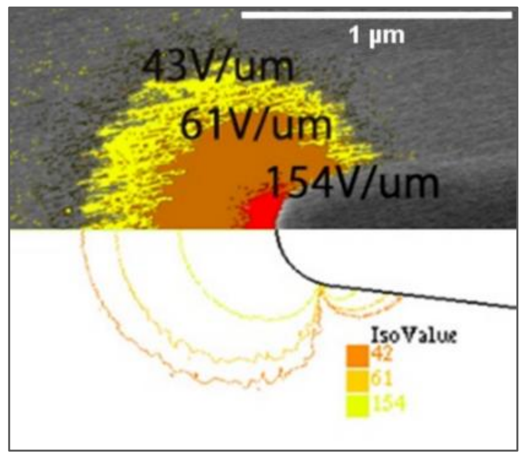

Figure 2: Visualization of localized electric field and FEM simulation mapping: The tip biasing voltage was -50V, and the distribution of the local electric field agree well with the FEM simulation.

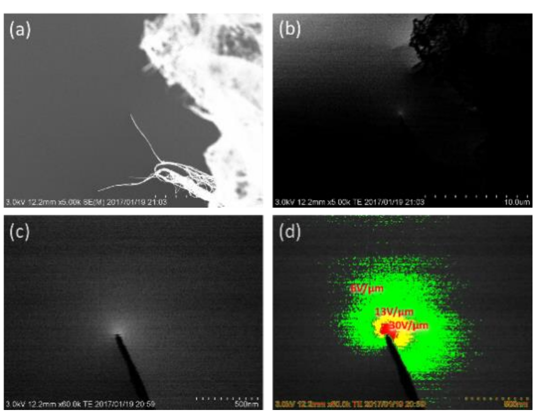

Figure3: The low energy e-beam sensitively created the image of the localized field at the top of the CNT fiber

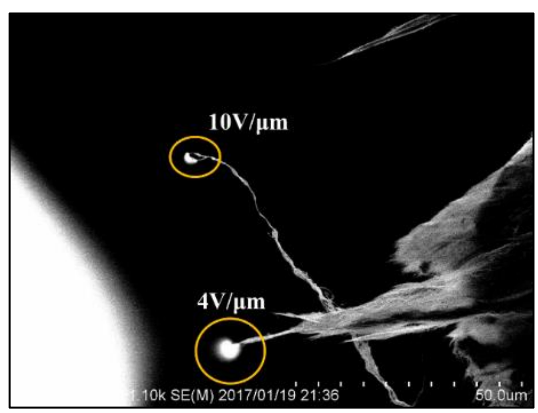

Figure 4: Visualization of local electric field of CNT tips