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Electronic structure of carbon nanotubes studied by photoemission microscopy

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The local electronic structure of multi-walled carbon nanotubes (MWNTs) was studied using photoemission microscopy technique. The valence band and the C 1s photoemission spectra from spatially selected regions were systematically obtained along tube axes to extract position dependence of the electronic structure of MWNTs.

The MWNTs aligned perpendicularly on a Si substrate were grown using the microwave plasma enhanced-CVD method. The diameter and the length of the nanotubes were about 30 nm and 10 _ m, respectively. The photoemission microscopy measurements were performed at ESCA microscopy beamline. The spatial resolution was 90 nm, and the photon energy was set to 500 eV. A typical cross-sectional C 1s image of the cleaved sample is shown in Fig. 1. An apparent contrast can be seen, owing to topographic effects. A larger density of states was observed at the tips than at the sidewalls in an energy range from the Fermi level to a binding energy of _1 eV, as shown in Fig. 2. However, an indication of band bending along the tube axes, which would explain such a spectral difference between the tips and sidewalls, was not observed in the C 1s spectra (not shown). Thus, we conclude that the tips have a characteristic density of states near the Fermi level. Furthermore, we showed that the effects of the five-member rings and the curvature at tips do not explain the characteristic electronic structure near the Fermi level. Detailed discussion and a possible reason for the observed result will be presented.

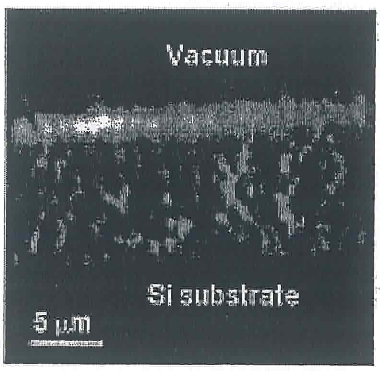

Fig. 1. C 1s image of the aligned MWNTs.

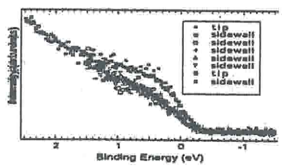

Fig. 2. Valence band spectra near the Fermi level from spatially selected regions.