Determination of Bonding Structures of Vertically Aligned Carbon Nanotubes on Metal Electrodes

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Carbon nanotubes (CNTs) have been attracting a great deal of attention since their discovery due to their unique electrical and thermal properties [1]. It is thus suggested that CNTs be used for wiring materials for LSI interconnects. In order to apply CNTs for the LSI interconnects, it is important to achieve low-resistance ohmic contacts between CNTs and metal electrodes [2]. Photoelectron spectroscopy (PES) is suitable for probing such contacts, since the bonding states at the interface can be elucidated with this technique. In this study, we have investigated the bonding structure at the interface between the CNTs and the metal electrodes using the core-level PES.

The PES measurements were performed at Beamline BL47XU of Spring-8. The photon energy we used was 6 keV. CNTs were grown on a nickel/titanium double layer deposited on a silicon substrate using chemical vapor deposition. The nickel layer was used as catalyst for CNT growth, while the titanium layer was employed as a metal electrode. The titanium and nickel layers were 50 nm and 30 nm thick, respectively.

Figure 1 shows Ti 2p core-level spectra after the CNT growth. Emission angles of 10 and 75 degrees relative to the surface normal direction correspond to the spectra (a) and (b), respectively. Analyzing the spectra, it has been found that two features in the spectrum (a) are assigned to titanium oxide and titanium carbide. The observation of titanium carbide means that good ohmic contacts were formed at the interface. However, no feature corresponding to titanium carbide has been found in the spectrum (b), while the feature for titanium oxide still exists. Since the spectrum (b) provides bonding information in the region 1 nm from the surface (considering the electron mean free path of about 4 nm), the results suggest that the oxidation of the titanium layer proceeded during the growth process and prevented from forming titanium carbide near the surface. Our results also indicate that a titanium layer of 4 nm is thick enough to have ohmic contacts between CNTs and titanium electrodes.

References

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Acknowledgements

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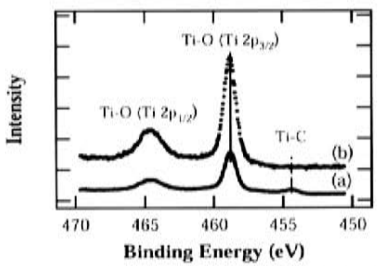

Figure 1 Ti 2p core-level spectra after the CNT growth.

Visualization of microstructure in advanced porous materials by X-ray CT

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Introduction: The porous aluminum as advanced structural materials has complicated shapes and the 3D analysis is one of the major roles in order to progress the mechanical qualities. In this study, the in-situ compressive tests with reflective contrast imaging apply to investigate the microstructure and fracture behavior in Al foams.

Experiments: The experiments were performed at BL47XU beam line using X-ray CT with the energy 20keV. The combination of the CCD detector (1000×1018 pixels, 12×12 μm^2) and the optical lens has a voxel size 1μm^3. The CT scan of a sample with 750 transmitted images was done during a 180° rotation and the total scanning time was 90min. The radiographs were reconstructed by the method of convolution back projection. The samples for in-situ compression testing were the Al-Zn-Mg alloy foams. The material test rig was specially designed for CT experiments using a poly-carbonate tube as a load frame. The actuator consists of an air pressure cylinder and an air servo valve. The max compression is 2kN and the max tension is 1kN. Due to the extremely precise sample stage, the weight of the rig is about 6kg.

Results: The microstructural features, such as micropores and particles in the cell walls were visualized. Due to the measurable region 1mm^3, the compression test was done using the method of local tomography. The foam samples for compression tests with three loads are cylinders with the height 7mm and the diameter 7mm. The six measurable regions in the sample were CT scanned. Figure 1 shows the 3D reconstructed volumes captured in the compression test at the displacements under three loads, 0μm, 400μm, and 500μm, respectively. The macro crack was generated at the right upper part. The center of gravity of the cell walls has been fallen down as increasing loads. In comparison with the fracture behaviors in the six cell walls, the relations between microstructural features and fracture behaviors in one cell were not only investigated, but also the fracture mechanism may be totally evaluated in the sample. The 3D quantitative analysis of the microstructures in the cell walls has been performed using the method of local tomography.

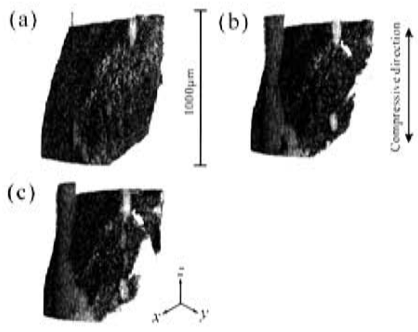

Fig.1. 3D reconstructed volumes captured in the compression test at the displacements with three loads, (a) 0μm, (b) 400μm, and (c) 500μm, respectively.