We have studied on deformation process of a bridged carbon nanotube (CNT) during Joule heating by in-situ transmission electron microscopy (TEM). Many papers reported that a CNT got thin or cut at the central portion due to or cutting and reconnecting of bonds or sublimation of carbon atoms during the Joule heating [1~4]. In this study, another type of deformation was observed, namely shrinking deformation along the axial direction of the CNT. We found that such a shrinking was observed when the CNT was bridged between rather flexible electrodes, namely the CNT could change its length during the heating. This result suggested that these deformation process strongly depended on how release the tensile stress applied to the CNTs caused by sublimation of carbon atoms during the Joule heating. Therefore we measured the stress loaded to the CNT during the Joule heating. For the measurement, a cantilevered probe for scanning probe microscopy was used as the flexible electrode, which spring constant was 0.02~0.41 N/m. A single or double wall CNT is bridged between the cantilevered probe and a Pt/Si substrate by operating a nanomanipulation holder (TEM-STM system, nanofactory) in TEM (JEM-2500SE, 90kV). Current is then applied to the CNT, and its deformation process was recorded. When the CNT began shrinking, cantilevered probe underwent deflection and made balance to the tensile force, so that the tensile force applied to the CNT were able to be measured by monitoring the deflection of cantilevered probe. In this system, tensile stress applied to the CNT gets increase as the degree of shrinking increased, and the CNT finally cut or detached from the electrode. Experimental results revealed that the shrinking deformation of CNTs occurred with loading tensile stress under 1.9 N/m². It is also suggested that such a shrinking deformation was promoted when topological defects formed; carbon atoms may selectively evaporate from such defective site.

Fig. 1: A series of TEM images showing shrinking deformation of a carbon nanotube. We can see that the cantilevered probe underwent deflection by pulling. Initial length of this nanotube was 239 nm, and shrank about 100 nm at the bottom image.