Electronic Supplementary Material (ESI) for Nanoscale

Formation of a carbon nanoribbon by spontaneous collapse of a carbon nanotube grown from a γ-Fe nanoparticle via an origami mechanism

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Supporting Information

SEM observation of the sample

SEM images in Fig. S1 show an overview of our sample. Due to the limited resolution of our SEM, it is very difficult to affirm which is nanoribbon or nanotube. Some nanowires {in (a)-(e)} show bright contrast at their tip, while those in (f)-(h) do not, indicating the root growth. It is very likely that these bright parts are Fe catalyst nanoparticles. The SEM images show that both the tip growth and root growth are active in our growth process.

If the expelled nanotube does not touch the substrate at the beginning of its growth, the Fe catalyst nanoparticle stays on the substrate. This is the root growth mode. If the nanotube is expelled at the boundary of the catalyst nanoparticle and substrate, it results in the tip growth. Our origami mechanism is compatible with both growth mode, therefore we speculate that the origami mechanism is not affected which it is accompanied by the tip mode or the root mode.

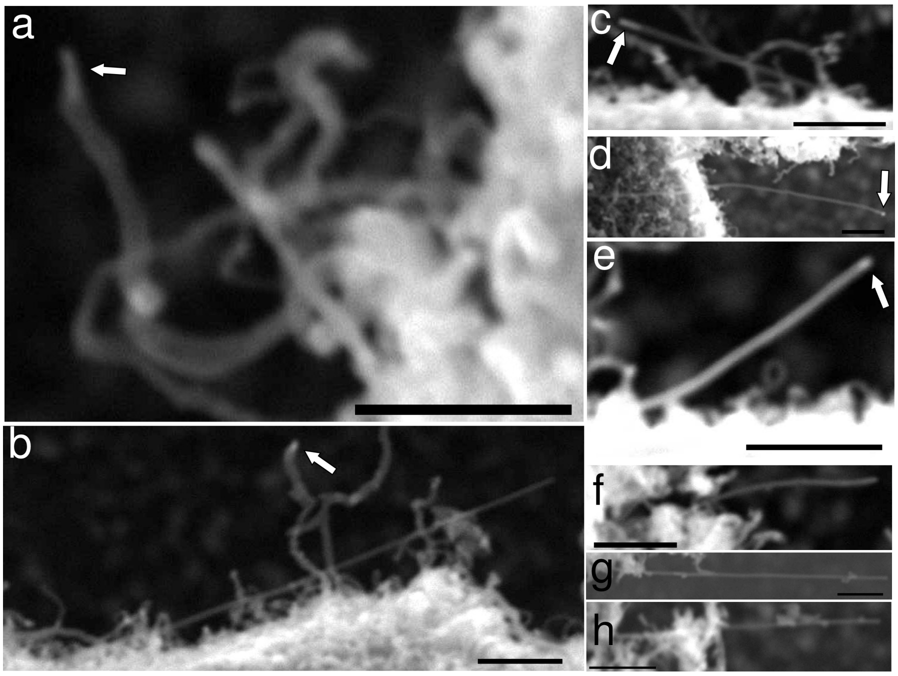

Fig S1: SEM images of the formed nanowires. The bright parts indicated by arrows are considered to be Fe catalyst nanoparticles located at the tip of each nanowires. Scale bars: 1 μm.

Supplementary TEM images

In Fig. S2, some TEM images of nanoribbons and nanotubes are shown. We found both the tip and root growth for both nanoribbon and nanotube. This result suggests again that the difference between the tip and root growth modes is simply attributable to initial position of expelling carbon and does not have a strong effect on formed structure. In (c), we show an example of the tube/ribbon transition with the tip growth mode: the nanotube was formed first, and then the part of nanoribbon was formed successively. The origin of the transition has not been revealed yet; however, we speculate that it might have been caused by a change in local temperature or fluctuation of structure of the catalyst nanoparticle.

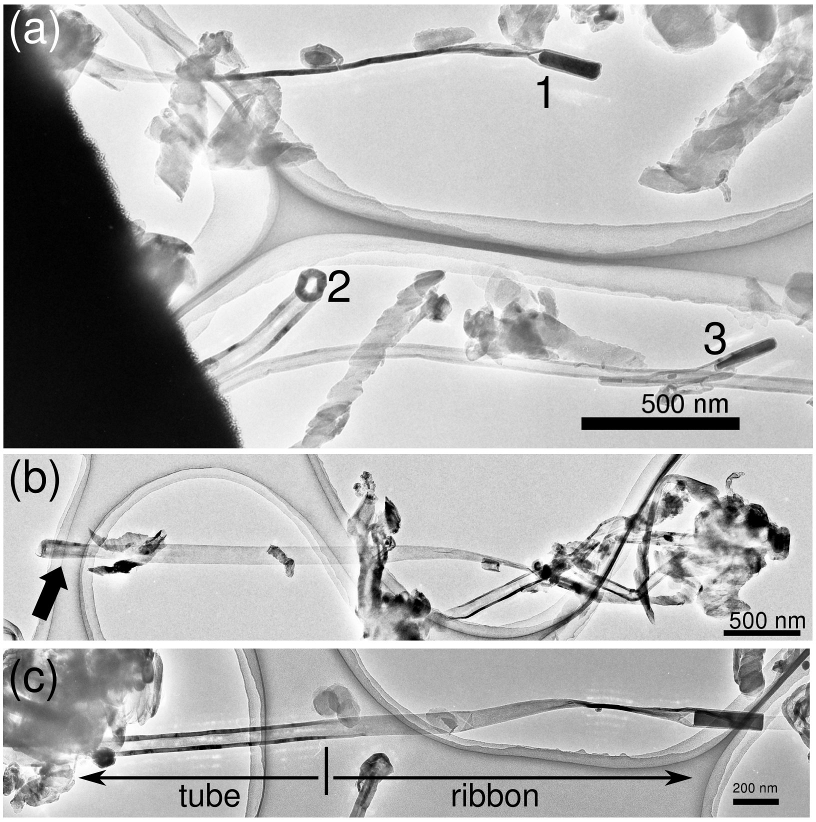

Fig. S2: TEM images of nanoribbons and nanotubes. The nanoribbon #1 in (a) is of tip growth, while that in (b) indicated by an arrow is of root growth. The nanotube #2 is of root growth and #3 is of tip growth. (c) Tube/ribbon structure with tip growth .

EDX analysis of an Fe catalyst nanoparticle

Fig. S3 shows EDX spectra taken from an Fe nanoparticle at the tip of a naonribbon. It is very likely that the C peak is due to the graphite layer around the Fe nanoparticle. The EDX spectrum confirms that the particle mainly consists of Fe. Due to the surrounding graphite layers, further analysis of C content in the Fe nanoparticle could not be performed.

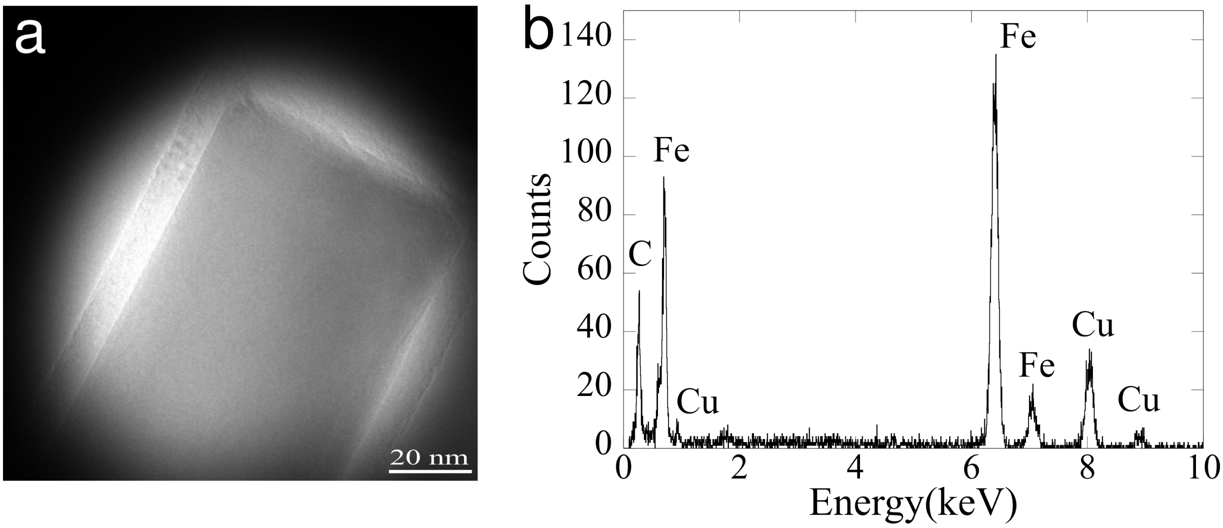

Figure S3: EDX analysis of the tip of a nanoribbon including an Fe catalyst nanoparticle: (a) TEM image and (b) EDX spectrum. The Cu peaks are due to a TEM microgrod.

Raman spectrum

Fig. S4 is a Raman spectrum from our sample (carbon nanostructures on a Si substrate). The Raman spectrum was obtained at room temperature under the following conditions: wave length 532 nm, power 6.5 mW, probe size about 1 micron. The spectrum shows G, D, and 2D bands, confirming the formation of nanotubes and nanoribbons.

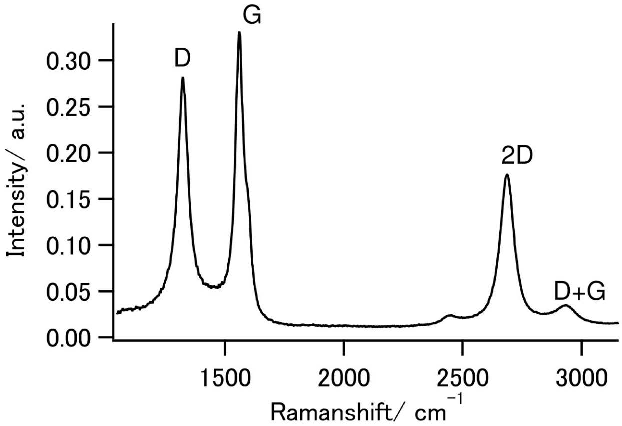

Fig. S4: Raman spectrum from carbon nanostructures grown on a Si substrate.