One-dimensional metallic peanut–shaped nanocarbons with positive and negative Gaussian curvatures: Toward a new science of quantum electronic systems on curved surfaces

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We found that electron-beam (EB) irradiation of a C_{60} film gives rise to formation of a peanut-shaped C_{60} polymer with metallic electron-transport properties in air at room temperature [1]. The temperature dependence of the photo-excited carriers lifetime for the peanut-shaped polymer indicated the energy gap formation at below 50K in a similar manner to the Peierls instability for quasi-one-dimensional (1D) metallic materials such as $K_{0.3}MO_3$ [2], thus suggesting that the polymer is a 1D metal.

As shown in FIG. 1, the 1D peanut-shaped polymer is fascinating from a viewpoint of topology, because it has both positive and negative Gaussian curvatures (κ) lined alternatively and periodically. As far as we know, this nanocarbon can be classified into a new π-electron conjugated carbon allotrope different from graphite ($\kappa = 0$), fullerenes ($\kappa > 0$), nanotubes ($\kappa = 0$ at body, $\kappa > 0$ at cap edge), and hypothetical Mackay crystal ($\kappa < 0$). Accordingly, the 1D peanut-shaped polymer is expected to exhibit physical and chemical properties different from those of the conventional π-electron conjugated carbon materials. Indeed, we have recently examined the valence photoelectron spectra of the polymer, using *in situ* high-resolution ultraviolet photoelectron spectroscopy [3], and observed the Tomonaga-Luttinger liquids (TLL) behavior as the direct evidence for 1D metal and obtained the TLL exponent (α) to be ca. 0.6 [4], which is larger than that of ca. 0.5 for 1D metallic single-walled carbon nanotubes [5]. Using the Schrodinger equation dealing with quantum electronic systems on curved surfaces modulated by Gaussian curvature, we have revealed that the increase in the exponent value is caused by a curvature-induced effective potential that works for electrons conducting along the curved surface [6]. We believe that the present system will open a new field of "Quantum Science on Curved Surfaces".

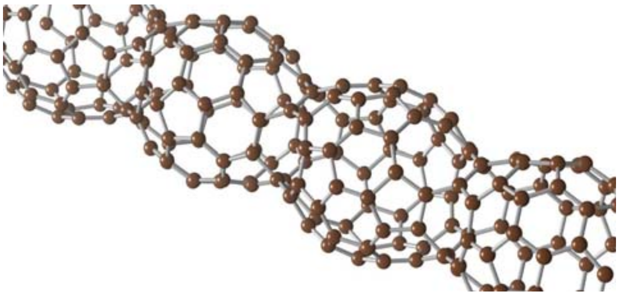

Figure 1. Schematic representation of 1D peanut-shaped nanocarbon

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[1] J. Onoe, T. Nakayama, M Aono, and T. Hara, *Appl. Phys. Lett.* **82**, 595 (2003).
[2] Y. Toda, S. Ryuzaki, and J. Onoe, *Appl. Phys. Lett.* **92**, 094102 (2008).
[3] J. Onoe et al., *Phys. Rev. B* **75**, 233410 (2007).
[4] T. Ito, J. Onoe, H. Shima, H. Yoshioka, and S. Kimura, to be submitted.
[5] H. Ishii et al., *Nature* **426**, 540 (2003).
[6] H. Shima, H. Yoshioka, and J. Onoe, *Phys. Rev. Lett.*, submitted.