In situ photoelectron spectra of an electron-beam irradiated C_{60} film

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We have 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 50 K 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 illustrated 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 shown in Table 1, this nanocarbon can be classified into a new π-electron conjugated carbon allotrope that is 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.

We have recently examined the valence photoelectron spectra of the polymer, using *in situ* high-resolution ultraviolet photoelectron spectroscopy [3, 4], 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 [5], which is somewhat larger than that of ca. 0.5 for 1D metallic single-walled carbon nanotubes [6]. Using the Schrodinger equation dealing with the motion of free particles on a curved surface modulated by positive and negative Gaussian curvatures periodically and alternatively, we have first demonstrated that the increase in the exponent value is caused by a curvature-induced effective potential that works for electrons conducting along the curved surface [7].

To our best knowledge, the peanut-shaped C_{60} polymer is only an existed material with a negative Gaussian curvature, whose electronic and optical properties are revealed. Thus we believe that the present system will open a new field of "quantum science of condensed matters in Liemannian space".

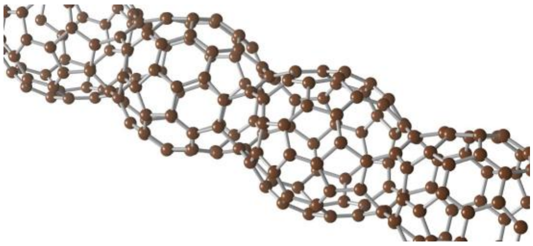

Fig. 1. Schematic illustration of one-dimensional peanut-shaped C_{60} polymer.

Table 1. Classification of π-electron conjugated carbon materials using Gaussian curvature.

Material	Gaussian curvature (K)
Graphite	0
Fullerenes	> 0
Nanotubes	0 (body), > 0 (capped edge)
Mackay crystal	< 0
Peanut-shaped polymer	> 0, < 0

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[1] J. Onoe, T. Nakayama, M Aono, and T. Hara, Appl. Phys. Letters **82** (2003) 595.
[2] Y. Toda, S. Ryuzaki, and J. Onoe, Appl. Phys. Letters **92** (2008) 094102.
[3] J. Onoe *et al*., Phys. Rev. B **75** (2007) 233410.
[4] J. Onoe, T. Ito, and S. Kimura, J. Appl. Phys. **104** (2008) 103706.
[5] T. Ito, J. Onoe, H. Shima, H. Yoshioka, and S. Kimura, in preparation for submission.
[6] H. Ishii *et al*., Nature **426** (2003) 540.
[7] H. Shima, H. Yoshioka, and J. Onoe, Phys. Rev. B **79** (2009) 201401 (R).