

## Single-Walled Carbon Nanotubes and Graphene as Highly Efficient Hole Extraction and Transport Layer for Solar Cells

Shigeo Maruyama, Kehang Cui, Takaaki Chiba, Xiao Chen, Rong Xiang, Shohei Chiashi  
Department of Mechanical Engineering, The University of Tokyo

Structured single-walled carbon nanotubes (SWNTs) and millimeter-scale monocrystalline graphene are investigated as an advanced hole extraction and transport layer in various kinds of solar cells [1-4]. We found out that three-dimensional honeycomb structured SWNTs fabricated by breath figure directed self-assembly demonstrated higher fill factor and low serial resistance compared with random network. We also obtained a ten-fold increase in the power conversion efficiency (PCE) by using millimeter-scale monocrystalline graphene compared with polycrystalline graphene, with the PCE over 11% before any intentional doping process. The hole collecting and transport function of SWNTs was also demonstrated in perovskite solar cells [3] and organic solar cells [4] with high PCE. More importantly, all these solar cells have high stability in the ambient.

References:

- [1] K. Cui et al., *J. Phys. Chem. Lett.*, **4** (2013), 2571.
- [2] K. Cui et al., *J. Mater. Chem. A*, **2** (2014) 11311.
- [3] T. Chiba, T. Sakaguchi, A.G. Nasibulin, E.I. Kauppinen, R. Xiang, S. Chiashi, S. Maruyama, (2015).
- [4] I. Jeon, K. Cui, T. Chiba, A. Anisimov, A.G. Nasibulin, E.I. Kauppinen, S. Maruyama, Y. Matsuo, submitted (2014).