

University of Groningen

## High Performance Ambipolar Field-Effect Transistor of Random Network Carbon Nanotubes

Bisri, Satria Zulkarnaen; Gao, Jia; Derenskyi, Vladimir; Gomulya, Widianta; Iezhokin, Igor; Gordiichuk, Pavlo; Herrmann, Andreas; Loi, Maria Antonietta

*Published in:*  
Advanced materials

*DOI:*  
[10.1002/adma.201202699](https://doi.org/10.1002/adma.201202699)

**IMPORTANT NOTE:** You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

*Document Version*  
Publisher's PDF, also known as Version of record

*Publication date:*  
2012

[Link to publication in University of Groningen/UMCG research database](#)

*Citation for published version (APA):*

Bisri, S. Z., Gao, J., Derenskyi, V., Gomulya, W., Iezhokin, I., Gordiichuk, P., Herrmann, A., & Loi, M. A. (2012). High Performance Ambipolar Field-Effect Transistor of Random Network Carbon Nanotubes. *Advanced materials*, 24(46), 6147-6152. <https://doi.org/10.1002/adma.201202699>

### Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

### Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

*Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.*

# ADVANCED MATERIALS

## Supporting Information

for *Adv. Mater.*, DOI 10.1002/adma.201202699

High Performance Ambipolar Field-Effect Transistor of  
Random Network Carbon Nanotubes

*Satria Zulkarnaen Bisri,\* Jia Gao, Vladimir Derenskyi,  
Widianta Gomulya, Igor Iezhokin, Pavlo Gordiichuk, Andreas  
Herrmann, and Maria Antonietta Loi\**

Supporting Information for

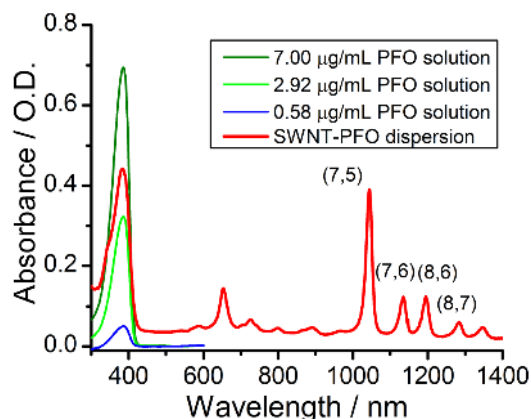
# **High Performance Ambipolar Random Network Field-Effect Transistor Carbon Nanotubes**

Satria Zulkarnaen Bisri\*, Jia Gao, Vladimir Derenskyi, Widianta Gomulya, Igor  
Iezhokin, Pavlo Gordiichuk, Andreas Herrmann, Maria Antonietta Loi\*

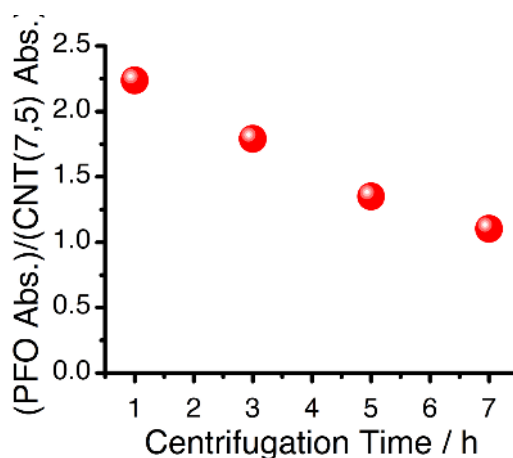
To whom correspondence should be addressed:

E-mail: [s.z.bisri@rug.nl](mailto:s.z.bisri@rug.nl), [m.a.loi@rug.nl](mailto:m.a.loi@rug.nl)

Supplementary Information I. The Concentration of the Residual Polymers

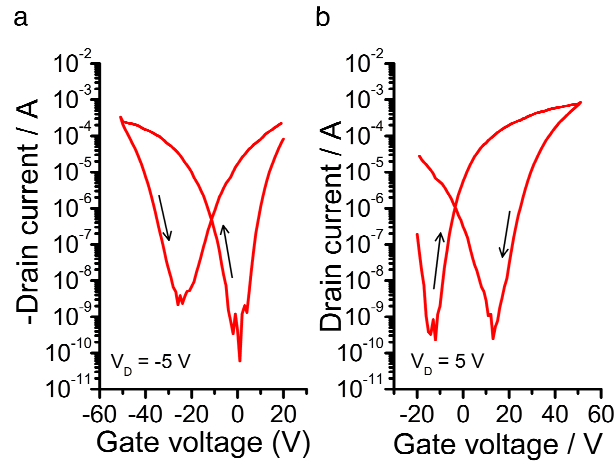


**Figure S1.** Comparison between the absorption spectra of the SWNT-PFO enriched dispersion used to fabricate the FETs and several PFO solutions with different concentrations. The remaining PFO concentration in the SWNT-PFO dispersion is less than 7.00  $\mu\text{g/mL}$ , but slightly higher than 2.92  $\mu\text{g/mL}$ .



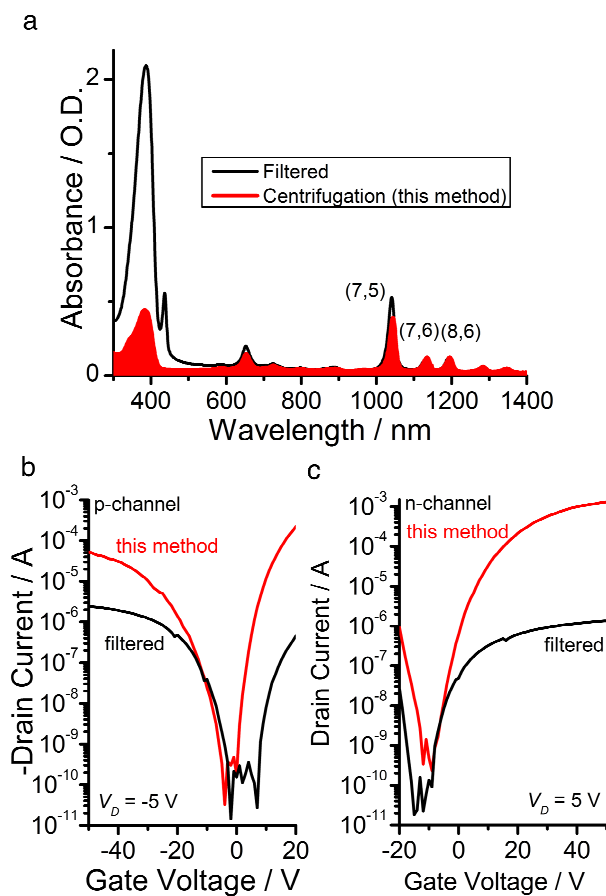
**Figure S2.** Ratio between the absorbance peak of the PFO and the peak of CNT(7,5) species versus the centrifugation time (second step). This plot quantifies the residual polymer amount as the function of the centrifugation time.

Supplementary Information II. Hysteresis in The Transport Characteristics



**Figure S3.** Plot of the forward and backward sweep  $I_D$ - $V_G$  transfer characteristics of **(a)** p-channel operation and **(b)** n-channel operation of the ambipolar FET that show hysteresis behavior. This kind of hysteresis is normally observed in bottom gated CNT network FETs. These two plots correspond to the transfer characteristics in Fig. 2b.

Supplementary Information III. The Influence of Residual Polymer towards  
The Electronic Transport



**Figure S4.** (a) Comparison between the absorption spectra of the enriched SWNT dispersion through ultracentrifugation (this method) and through multiple filtrations<sup>[11d]</sup>. It is obvious that the present method provides much lower residual polymer concentration, despite the similar concentration of the nanotubes. (b) The comparison of p-channel operation and (c) n-channel operation between the devices ( $L = 20 \mu\text{m}$ :  $W = 10 \text{mm}$ ), fabricated from filtered SWNT dispersion (black line) and ultracentrifuged SWNT dispersion (present method, red line). Both holes and electron transports, both in terms of mobility values and on/off ratio, are much higher in the devices fabricated from ultracentrifuged SWNT dispersion. The values of hole and electron mobility of the filtered SWNT are  $2.28 \times 10^{-3} \text{ cm}^2/\text{V}\cdot\text{s}$  and  $1.10 \times 10^{-3} \text{ cm}^2/\text{V}\cdot\text{s}$ , respectively. The on/off ratios are in the order of  $10^4$  for both charge carriers.