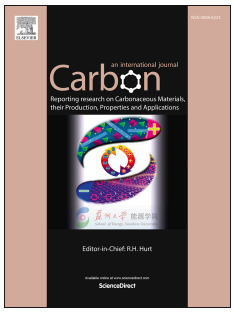
Accepted Manuscript



Broadband optical properties of graphene by spectroscopic ellipsometry

Wei Li, Guangjun Cheng, Yiran Liang, Boyuan Tian, Xuelei Liang, Lianmao Peng, A.R. Hight Walker, David J. Gundlach, Nhan V. Nguyen

PII: S0008-6223(15)30499-1

DOI: 10.1016/j.carbon.2015.12.007

Reference: CARBON 10552

To appear in: *Carbon*

Received Date: 21 August 2015

Revised Date: 12 November 2015

Accepted Date: 5 December 2015

Please cite this article as: W. Li, G. Cheng, Y. Liang, B. Tian, X. Liang, L. Peng, A.R. Hight Walker, D.J. Gundlach, N.V. Nguyen, Broadband optical properties of graphene by spectroscopic ellipsometry, *Carbon* (2016), doi: 10.1016/j.carbon.2015.12.007.

Broadband optical properties of graphene by spectroscopic ellipsometry

Wei Li[1,2], Guangjun Cheng[2], Yiran Liang[1], Boyuan Tian[1], Xuelei Liang[1,*], Lianmao Peng[1], A.R. Hight Walker[2], David J. Gundlach[2], Nhan V. Nguyen[2,*]

1. Key Laboratory for the Physics and Chemistry of Nanodevices and Department of Electronics, Peking University, Beijing, 100871, China.
2. Physical Measurement Laboratory, National Institute of Standards and Technology, Gaithersburg, MD 20899, USA.

Abstract

The optical properties of chemical vapor deposition grown graphene were measured with high accuracy by spectroscopy ellipsometry in the energy range of 0.7 eV to 9.0 eV, which is spectrally broader compared with those reported in literature. The refractive index (n) and extinction coefficient (k) of graphene were accurately obtained and compared with directly measured transmittance data. The absorption of graphene follows the well-known fine structure constant in the visible range, becomes lower below 1 eV, and shows a strong absorption peak around 4.8 eV. The latter was *attributed to the* resonant excitons near the van Hove singularity at the M point of the Brillouin zone. A higher energy absorption peak *was observed* at 6.4 eV *resulting from the* excitonic effect of the σ-to-σ* transition at the Γ point of the Brillouin zone. The multi-layer graphene, fabricated by repeated transfer, exhibit similar optical properties to mono-layer graphene and the 4.8 eV *absorption* peak exhibits a layer-number dependent peak shift, similar to the exfoliated *AB-stacked* multi-layer graphene. The broadband optical properties reported in this letter are believed to enhance the understanding of the optical properties of graphene and will benefit the development of graphene-based optoelectronic devices.

*Corresponding authors. E-mail: liangxl@pku.edu.cn (Xuelei Liang); Nhan.Nguyen@nist.gov (Nhan V. Nguyen)