Graphene Transparent Electrodes

11 January 2012
Phosphor-Free White LED for Solid State Lighting Network

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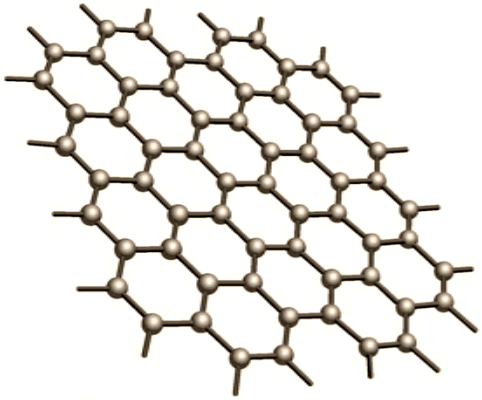
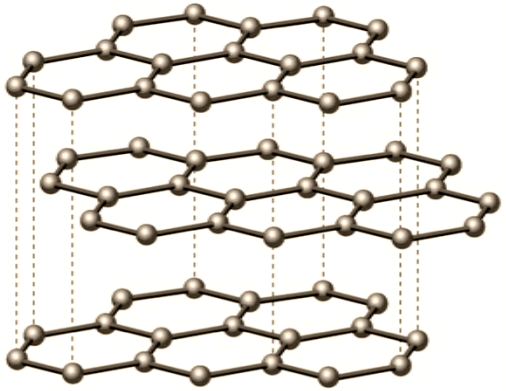
McGill

graphitic material family

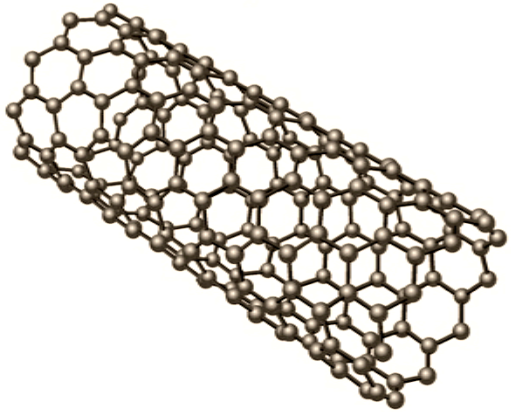
graphene

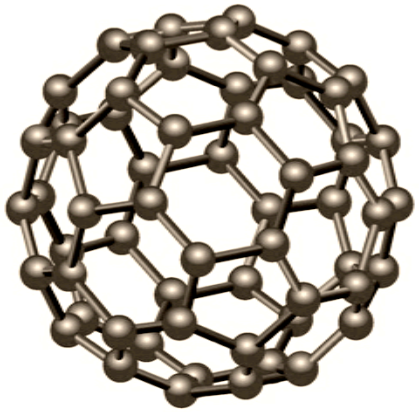




graphite

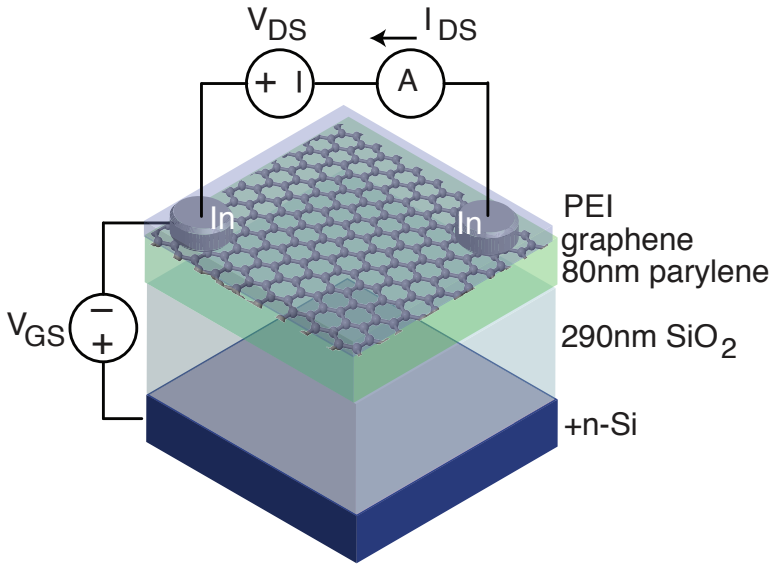
nanotube

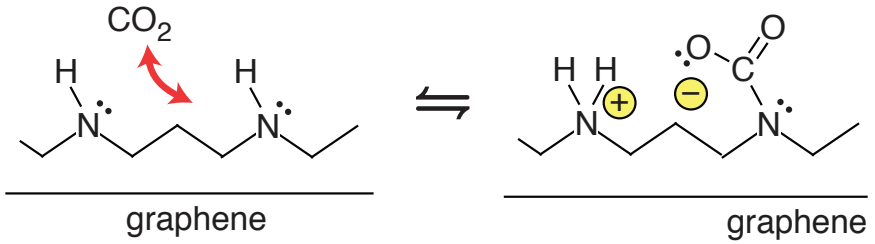


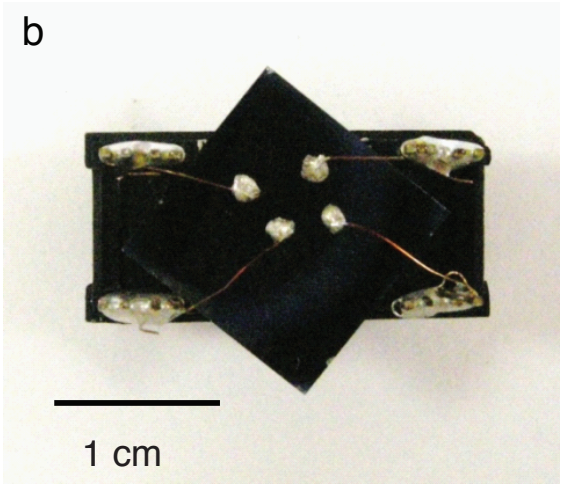


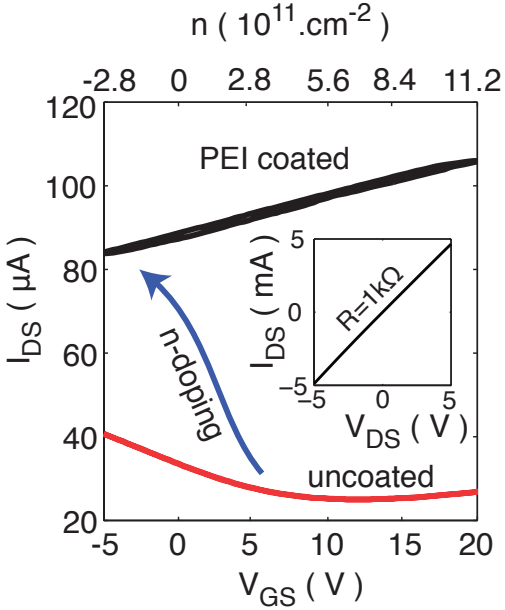
fullerene

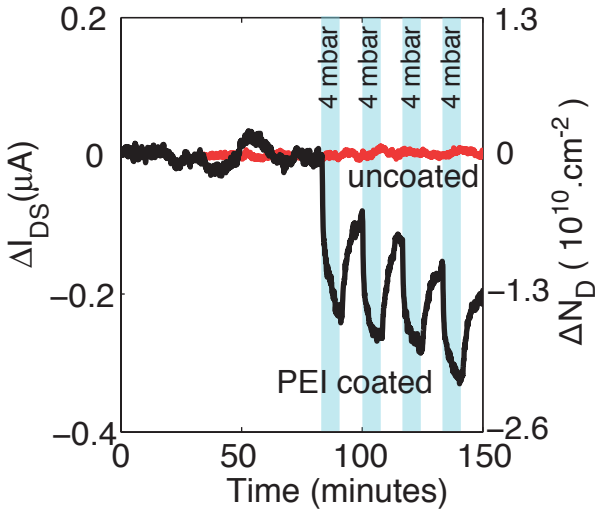
non-covalent functionalization







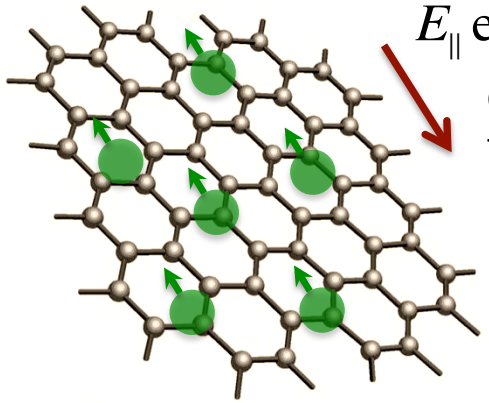




S. Sabri et al., Appl. Phys. Lett. **100**, 113106 (2012).

optical response

optical response is described by ***optical frequency conductance***



$E_{\parallel}\exp(-i\omega t)$

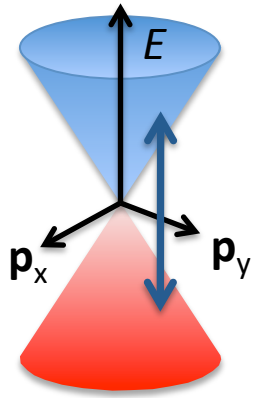
optical electric field

$J_{\parallel}\exp(-i\omega t)$

optical current

$$G = \frac{J_{\parallel}}{E_{\parallel}}$$

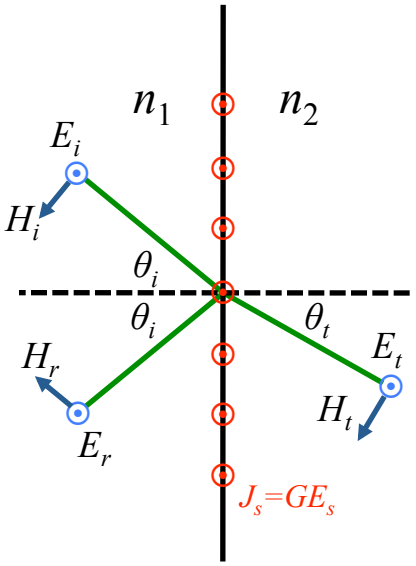
interband absorption dominates over the visible spectrum



$$G = \frac{J_{\parallel}}{E_{\parallel}} = \frac{e^2}{4\hbar}$$

absorption: $$A = \frac{Z_0 G}{n} = \frac{\pi\alpha}{n} \sim \frac{0.023}{n}$$

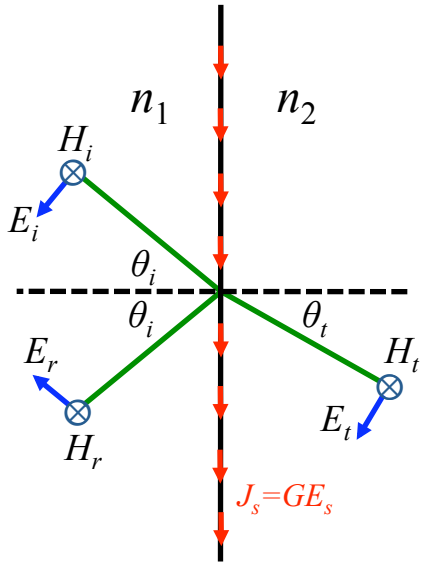
Fresnel Coefficients



(TE) *s*-polarization

$$r_s = \frac{E_r}{E_i} = \frac{n_1\cos\theta_i - \left(n_2\cos\theta_t + m\pi\alpha\right)}{n_1\cos\theta_i + \left(n_2\cos\theta_t + m\pi\alpha\right)}$$

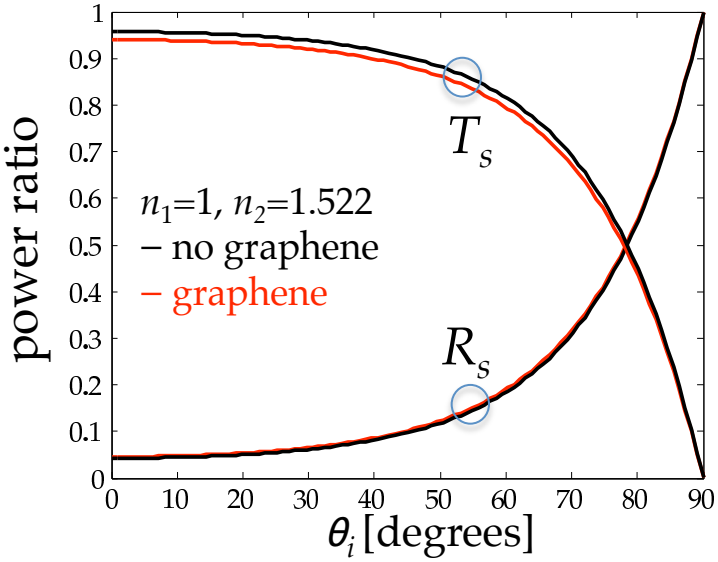
$$t_s = \frac{E_t}{E_i} = \frac{2n_1\cos\theta_i}{n_1\cos\theta_i + \left(n_2\cos\theta_t + m\pi\alpha\right)}$$

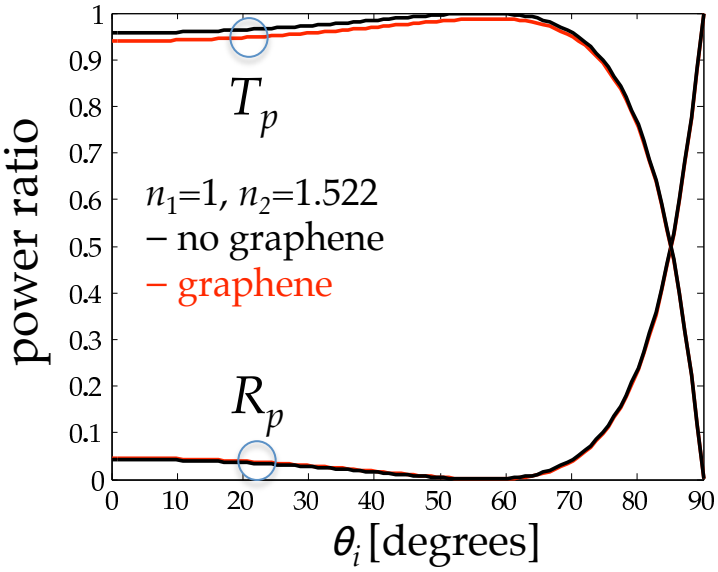


(TM) *p*-polarization

$$r_p = \frac{E_r}{E_i} = \frac{\left(\frac{n_2}{\cos\theta_t} + m\pi\alpha\right) - \frac{n_1}{\cos\theta_i}}{\left(\frac{n_2}{\cos\theta_t} + m\pi\alpha\right) + \frac{n_1}{\cos\theta_i}}$$

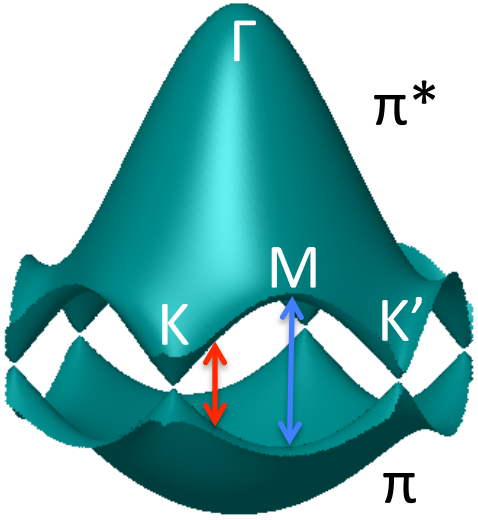
$$t_p = \frac{E_t}{E_i} = \frac{2\frac{n_1}{\cos\theta_t}}{\left(\frac{n_2}{\cos\theta_t} + m\pi\alpha\right) + \frac{n_1}{\cos\theta_i}}$$

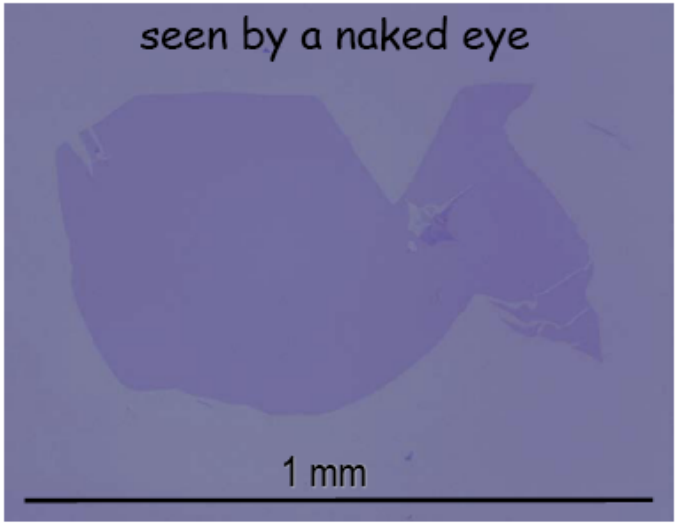




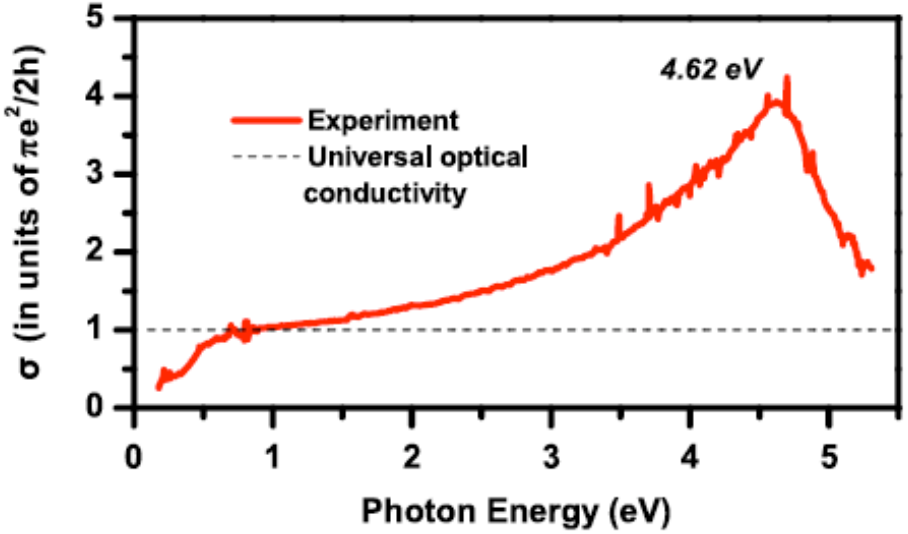
T. Szkopek, IEEE JQE. **47**, 500 (2011).

graphene optical transparency

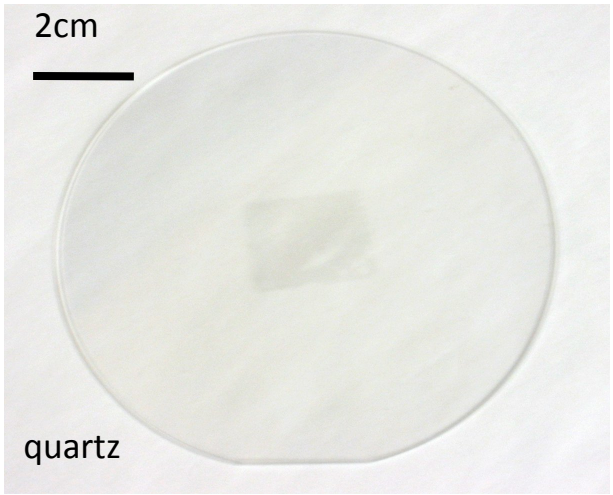




A. Geim, Nobel Lecture, 2010

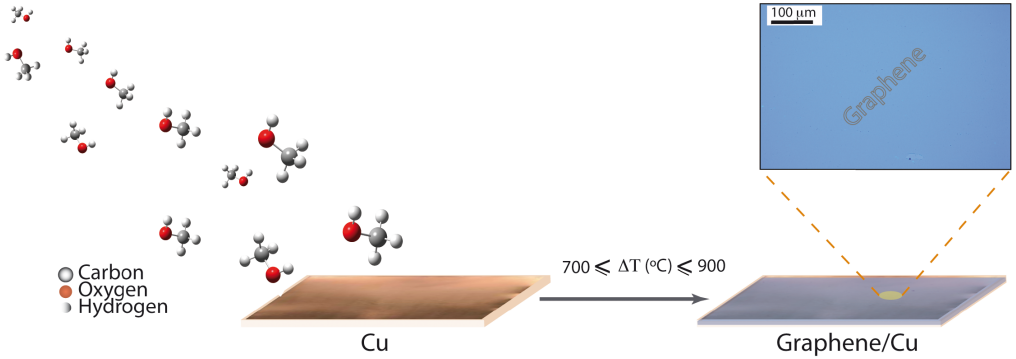


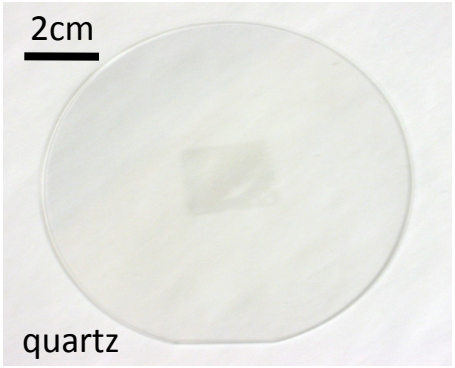
K.F. Mak, J. Shan and T. Heinz, PRL **106**, 046401 (2011).



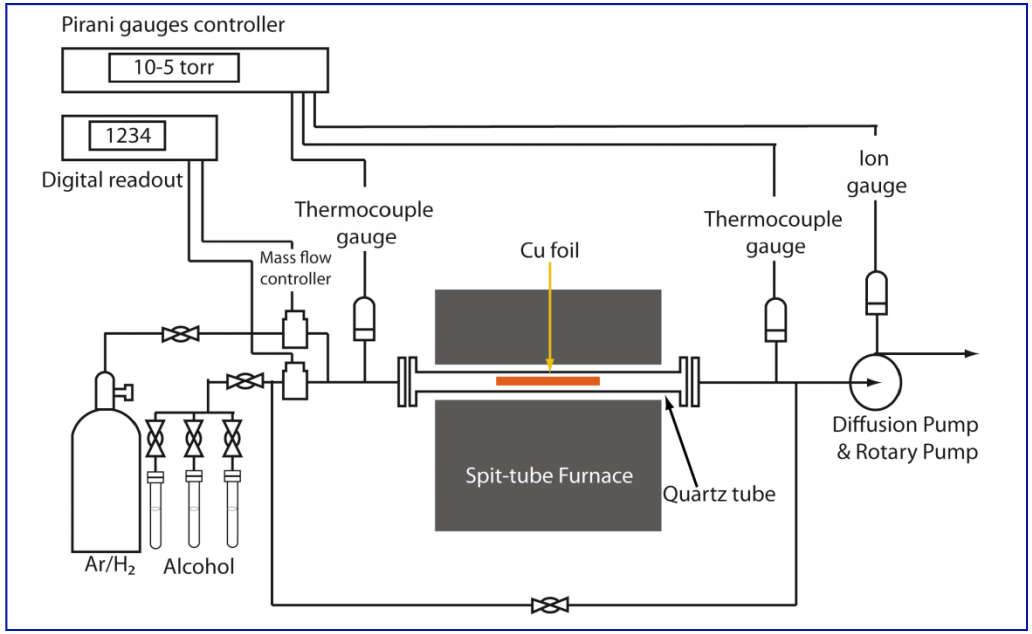
H. Skulason, M. Siaj, T. Szkopek

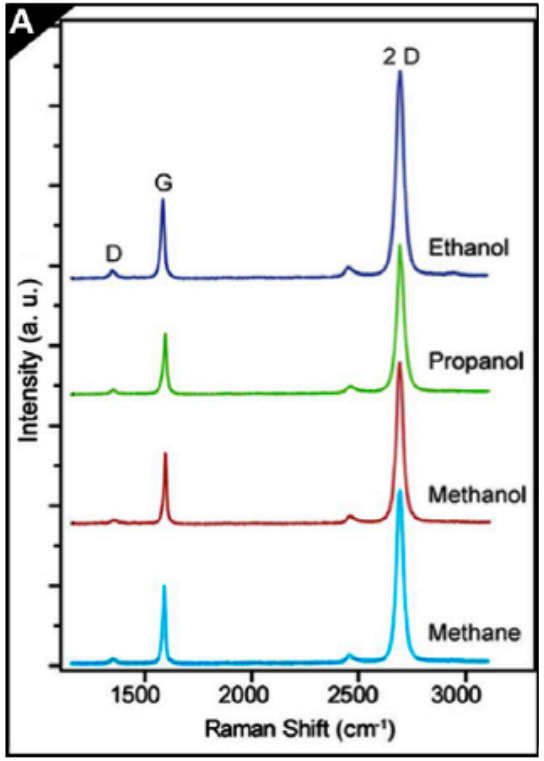
large area graphene growth





CVD growth with M. Siaj @ UQAM

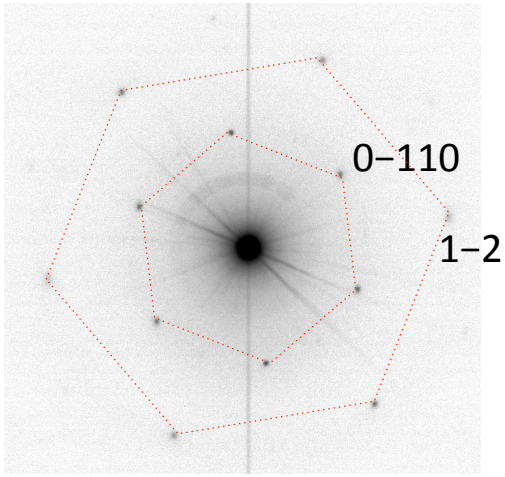




A. Guermoune et al. Carbon **49**, 4204 (2011).

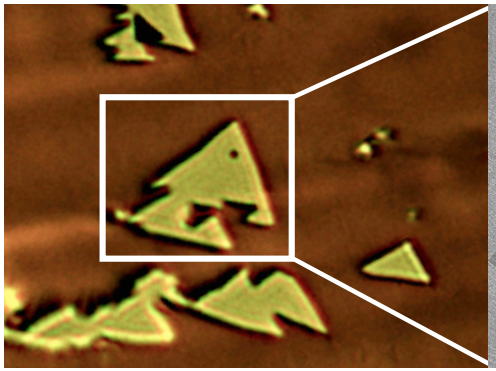
high mechanical strength

TEM diffraction

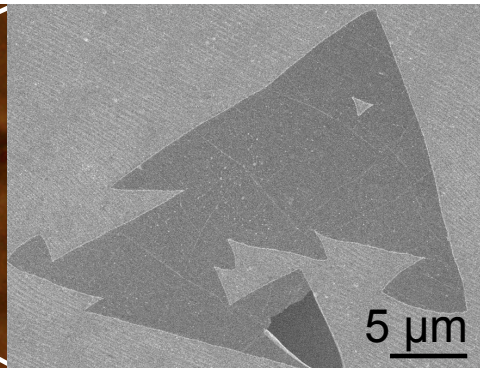


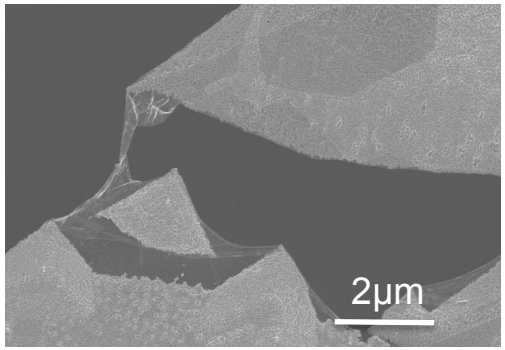
single crystal
graphene monolayer

optical image

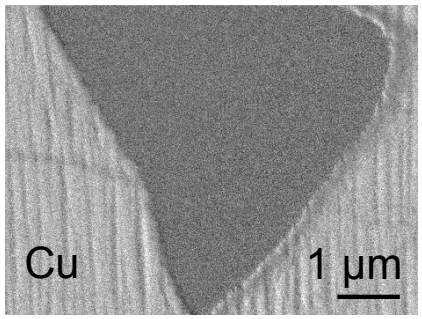


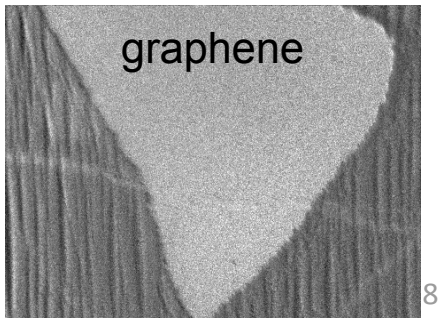
SEM image





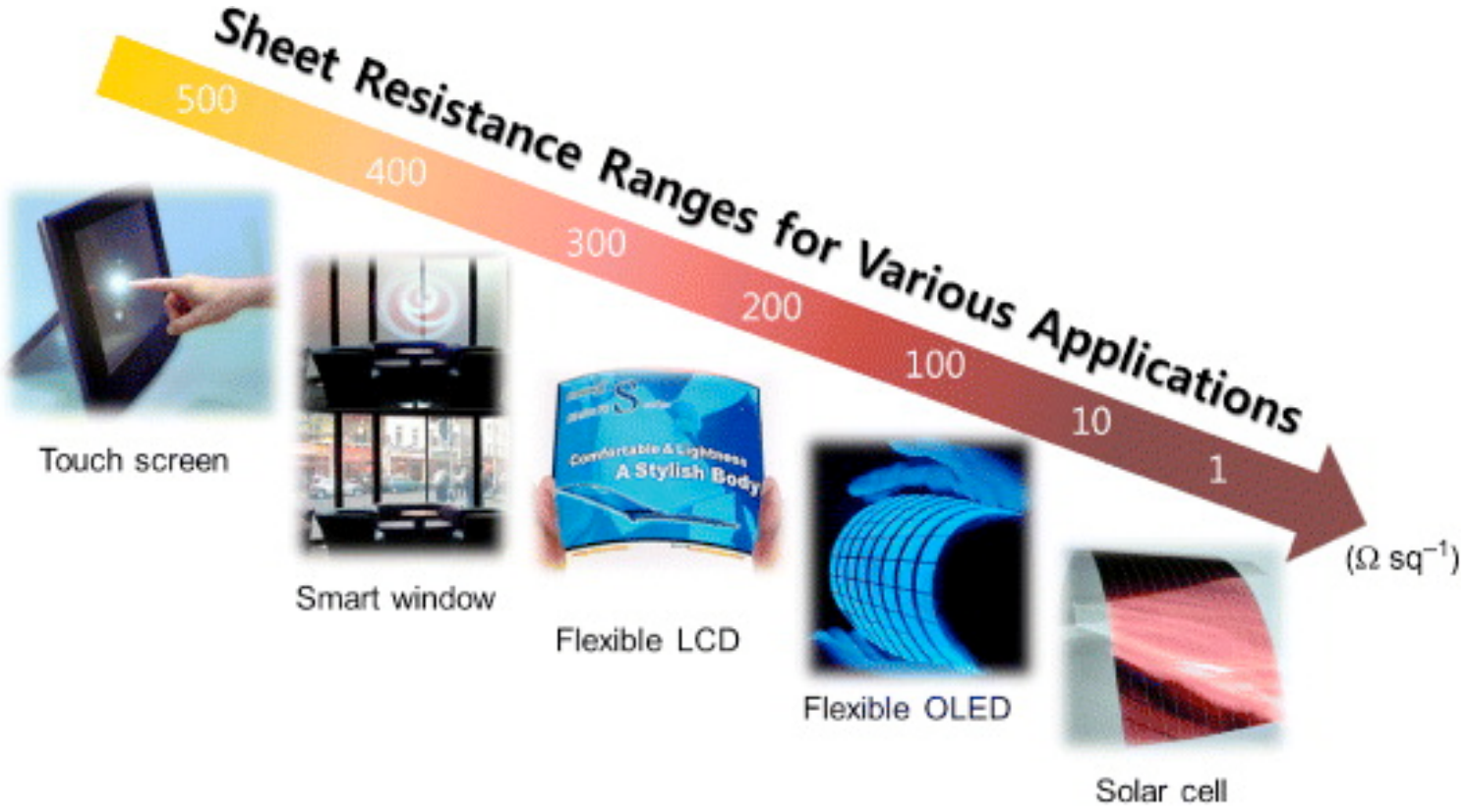
Auger map





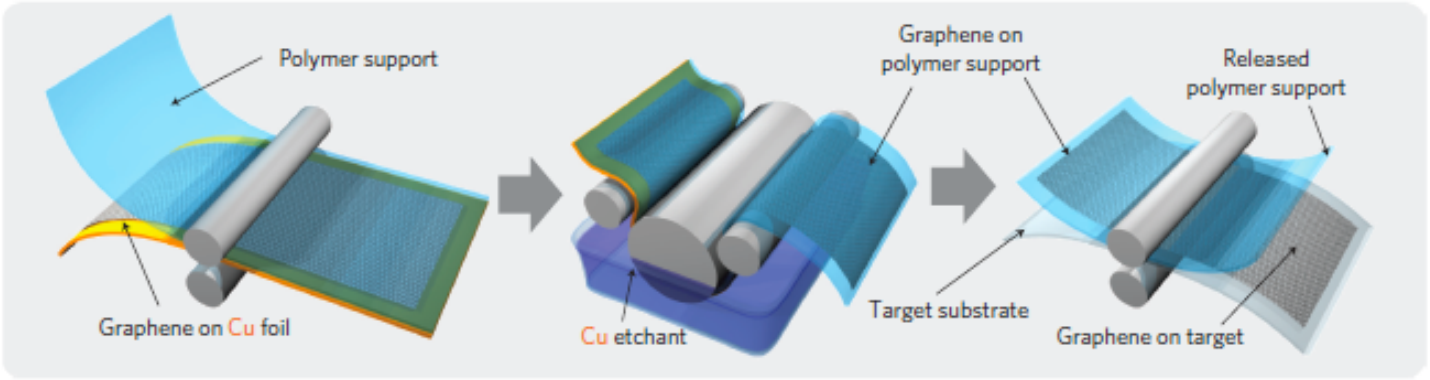
E. Ledwosinska et al. Appl. Phys. Lett. **101**, 033104 (2012)

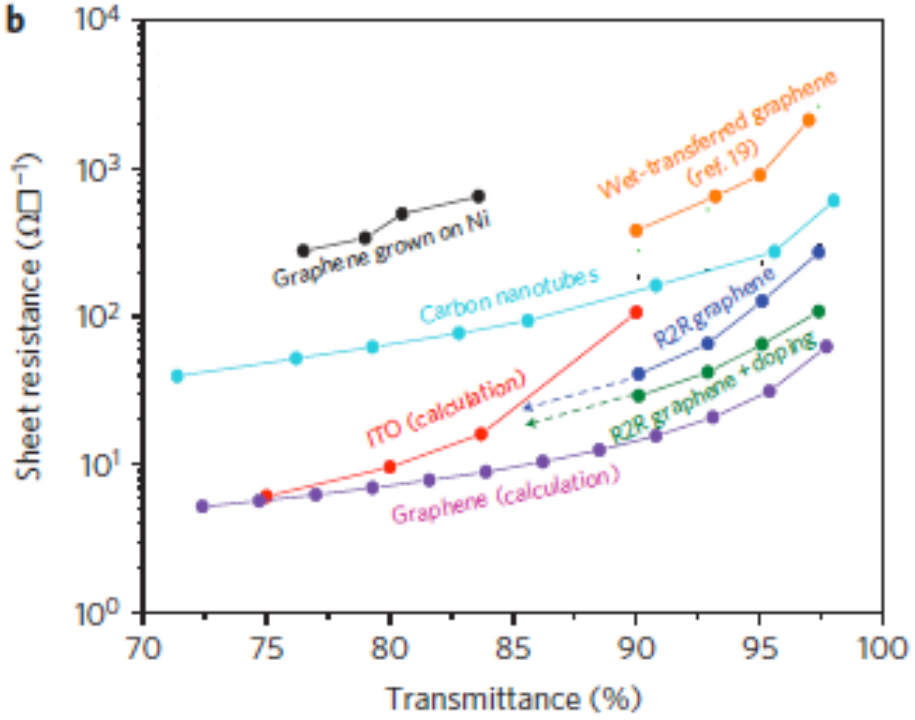
electrical sheet resistance

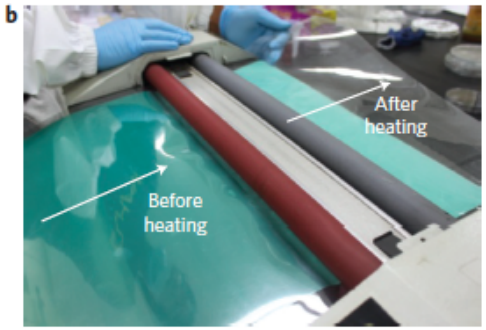


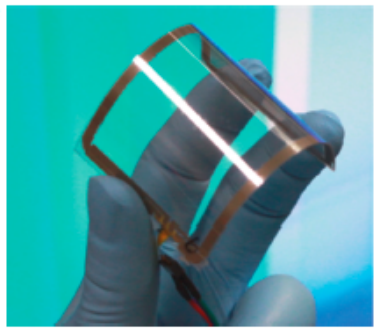
S. Bae et al Phys. Scr. **2012** 014024 (2012).

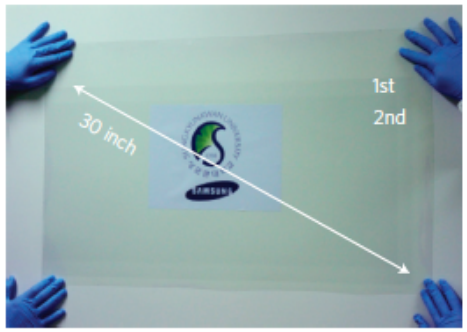
flexible transparent electrodes for touch screens @ SKKU

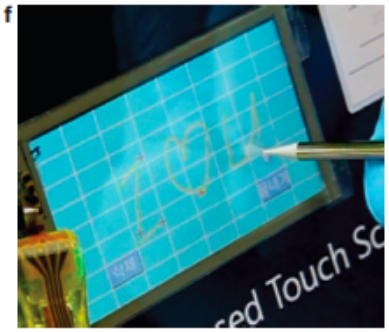






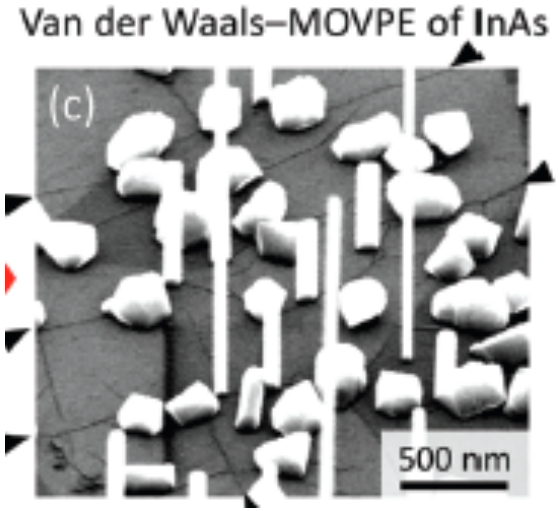


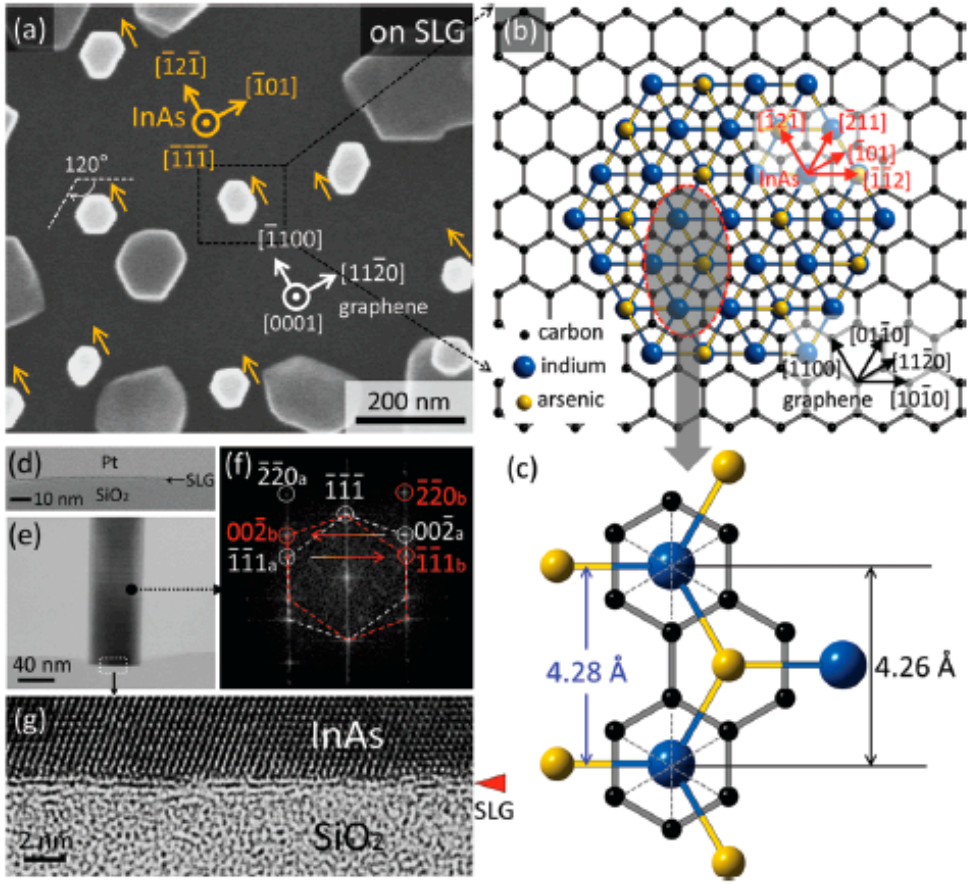




S. Bae et al Nature Nanotechnol. **5** 574 (2010).

possibilities: epitaxial nanowire growth on graphene

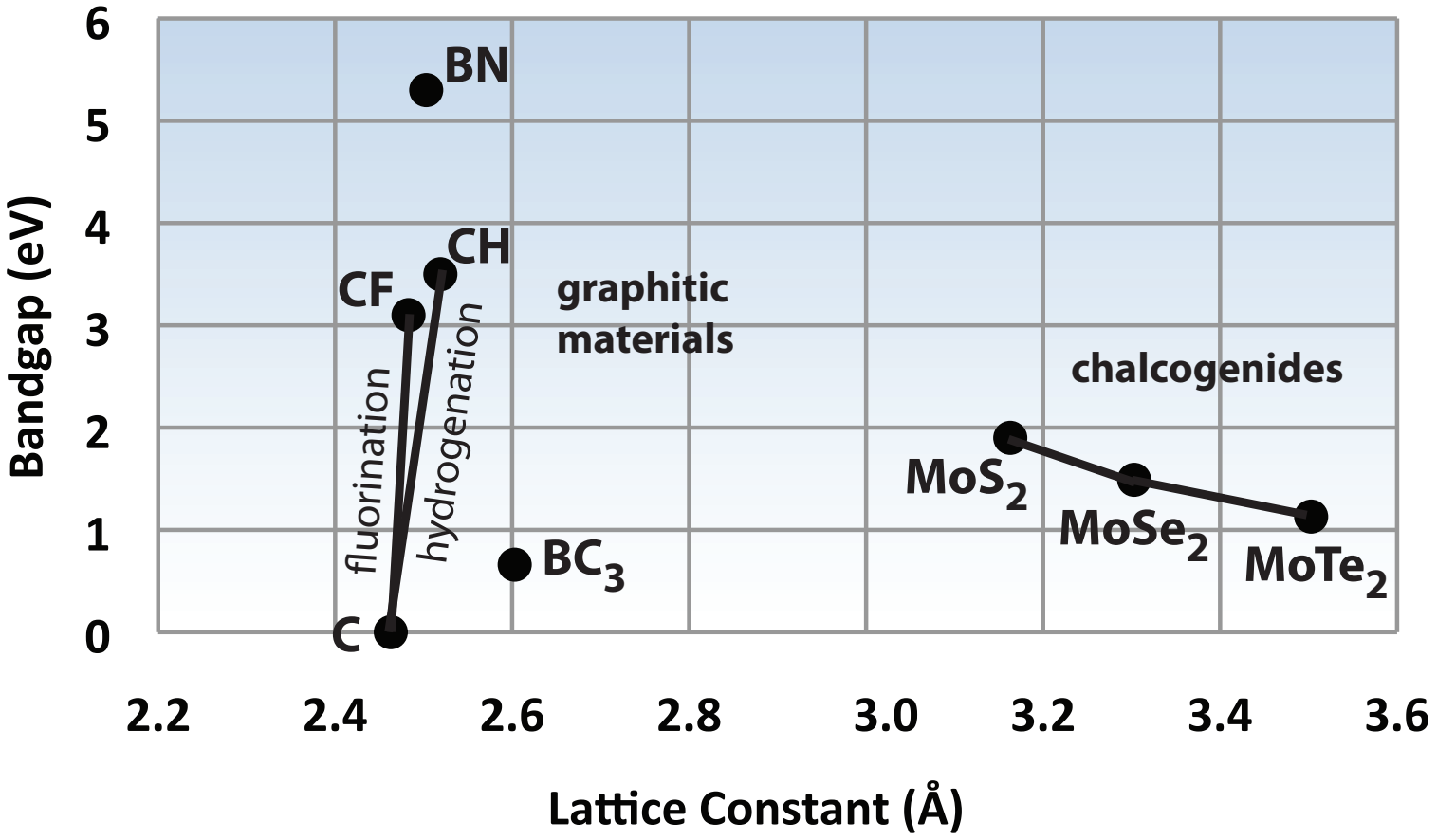




Y.J. Hong et al Nano Lett. **12** 1431 (2012).

2D crystals

various degrees of experimental observation…



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Collaborators

McGill: Z. Mi, P. Kambhampati,

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U Vienna: A. Grüneis

ITME Warsaw: W. Strupiński

U Warsaw: J. Baranowski

CNRS Toulouse: C. Proust

thank you for your attention