Cserti József

ELTE, TTK
Komplex Rendszerek Fizikája Tanszék

A 2010. évi fizikai Nobel-díj a grafénért

Atomcsill, 2010. október 14., ELTE, Budapest

Press release:

The Nobel Prize in Physics 5 October 2010

The Royal Swedish Academy of Sciences
has decided to award the

Nobel Prize in Physics for 2010 to

Andre Geim
University of Manchester, UK

and

Konstantin Novoselov
University of Manchester, UK

"for groundbreaking experiments regarding the two-dimensional material graphene"

Graphene – the perfect atomic lattice

A thin flake of ordinary carbon, just one atom thick, lies behind this year's Nobel Prize in Physics. Andre Geim and Konstantin Novoselov have shown that carbon in such a flat form has exceptional properties that originate from the remarkable world of quantum physics.

Andre Geim

Dutch citizen. Born 1958 in Sochi, Russia. Ph.D. 1987 from Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka, Russia. Director of Manchester Centre for Meso-science & Nanotechnology, Langworthy Professor of Physics and Royal Society 2010 Anniversary Research Professor, University of Manchester, UK.

Konstantin Novoselov

Brittish and Russian citizen. Born 1974 in Nizhny Tagil, Russia. Ph.D. 2004 from Radboud University Nijmegen, The Netherlands. Professor and Royal Society Research Fellow, University of Manchester, UK.

A Nobel-díjas cikk

22 OCTOBER 2004 VOL 306 SCIENCE www.sciencemag.org

Electric Field Effect in Atomically Thin Carbon Films

K. S. Novoselov,[1] A. K. Geim,[1]* S. V. Morozov,[2] D. Jiang,[1]
Y. Zhang,[1] S. V. Dubonos,[2] I. V. Grigorieva,[1] A. A. Firsov[2]

3148 hivatkozás!!!!!!

átlagosan naponta 2 cikk

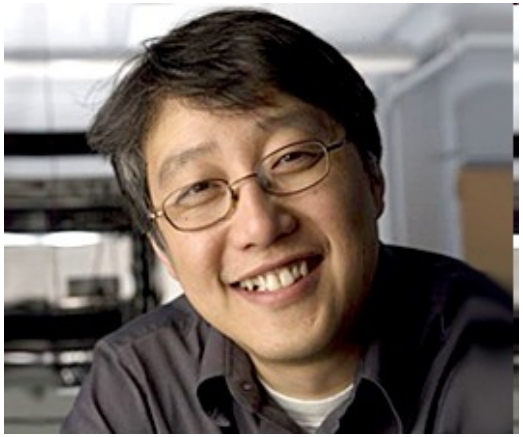
K. S. Novoselov, A. K. Geim, S. V. Morozov, D. Jiang, M. I. Katsnelson, I. V. Grigorieva, S. V. Dubonos, and A. A. Firsov, Nature **438**, 197 (2005).

Vol 438|10 November 2005|doi:10.1038/nature04235 nature

LETTERS

Experimental observation of the quantum Hall effect and Berry's phase in graphene

Yuanbo Zhang[1], Yan-Wen Tan[1], Horst L. Stormer[1,2] & Philip Kim[1]



Philip Kim
Columbia University

További fontos cikkek:

K. Novoselov et al., Nature **438**, 197 (2005)
Y. Zhang et al., Phys. Rev. Lett. **94**, 176803 (2005)
K. Novoselov et al., Nature Physics **2**, 177 (2006)

Az első mérések grafénben

22 OCTOBER 2004 VOL 306 SCIENCE www.sciencemag.org

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Vol 438|10 November 2005|doi:10.1038/nature04233 nature

LETTERS

Two-dimensional gas of massless Dirac fermions in graphene

K. S. Novoselov[1], A. K. Geim[1], S. V. Morozov[2], D. Jiang[1], M. I. Katsnelson[3], I. V. Grigorieva[1], S. V. Dubonos[2] & A. A. Firsov[2]

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LETTERS

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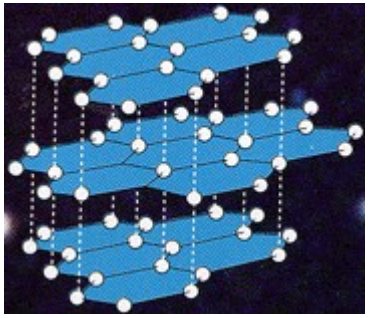
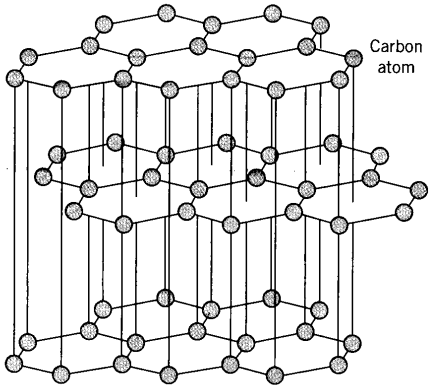
K. Novoselov et al., Science **306**, 666 (2004)
K. Novoselov et al., Nature **438**, 197 (2005)
Y. Zhang et al., Phys. Rev. Lett. **94**, 176803 (2005)
Y. Zhang et al., Nature **438**, 201 (2005)
K. Novoselov et al., Nature Physics **2**, 177 (2006)

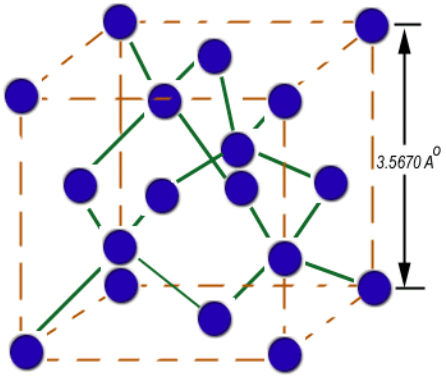
A szén két módosulata

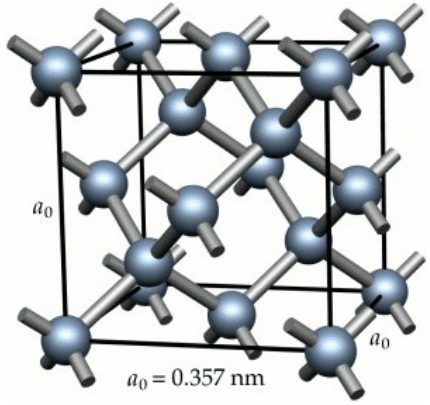
Grafit





Gyémánt





Grafit

Nagyon puha

Átlátszatlan

Elektromosan jó vezető

Nagyon olcsó

Gyémánt

Nagyon kemény

Átlátszó

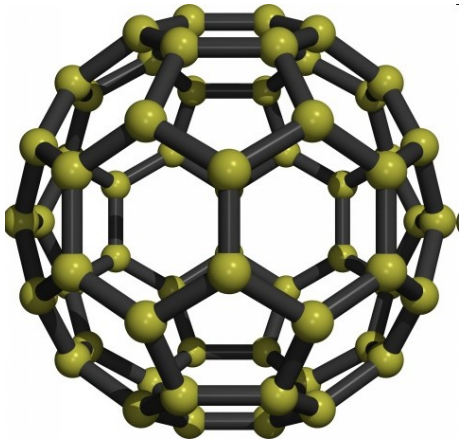
Szigetelő

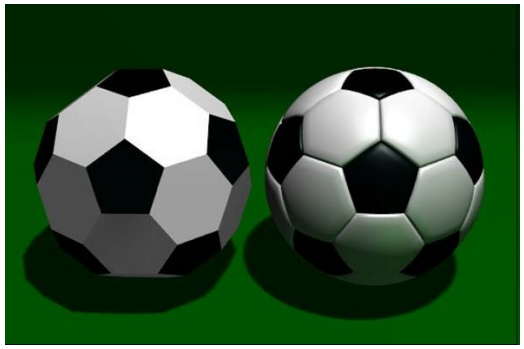
Nagyon drága

A szén további módosulatai

Fullerén, C60

(1985)

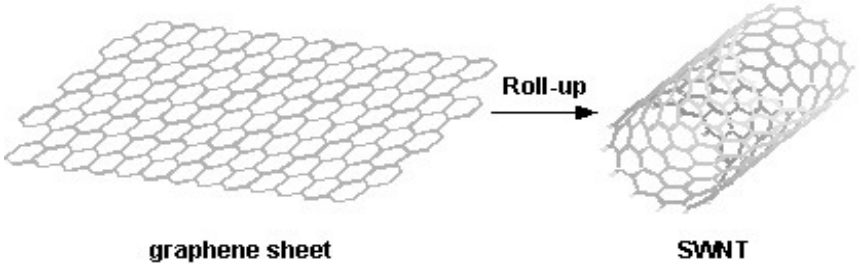




1996. Kémiai Nobel-díj,
Robert F. Curl Jr., Sir Harold W. Kroto and Richard E. Smalley
"for their discovery of fullerenes".

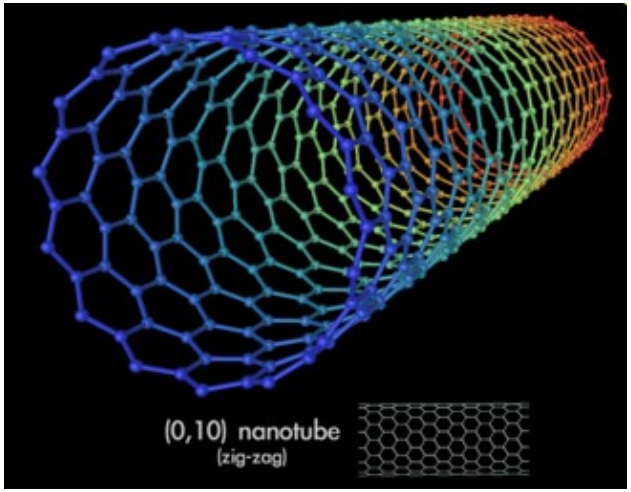
Grafén

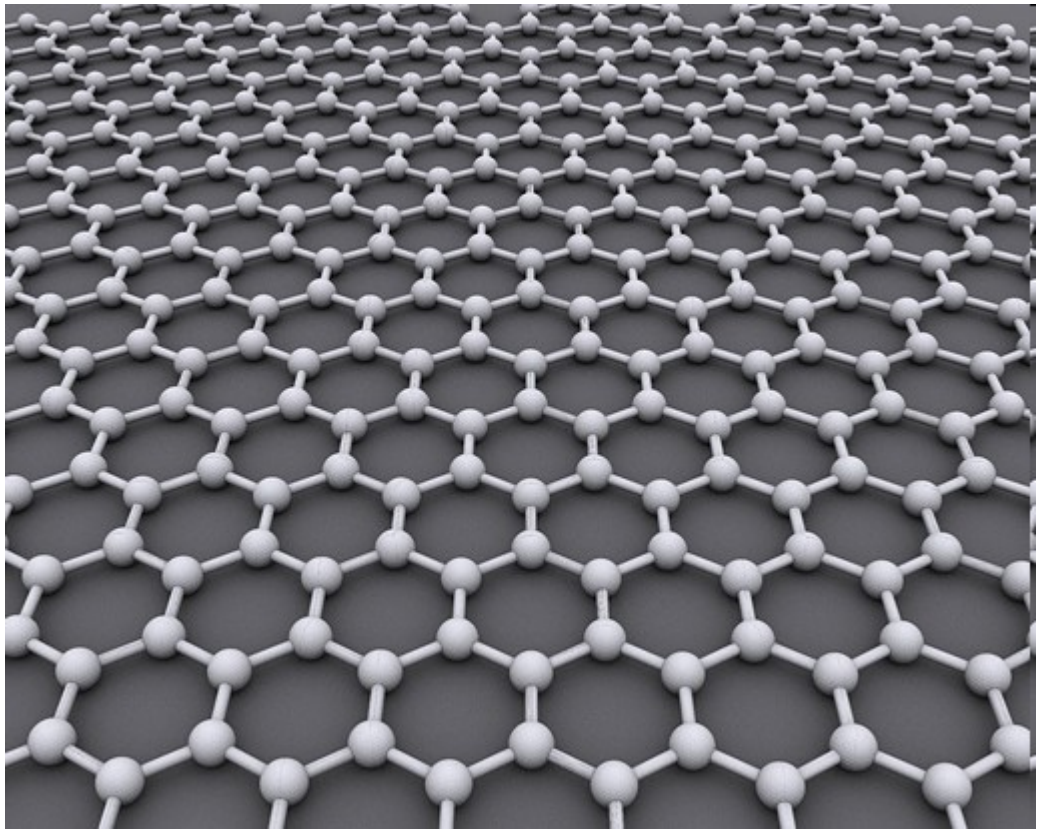
(2004)



Nanocső

(1991)

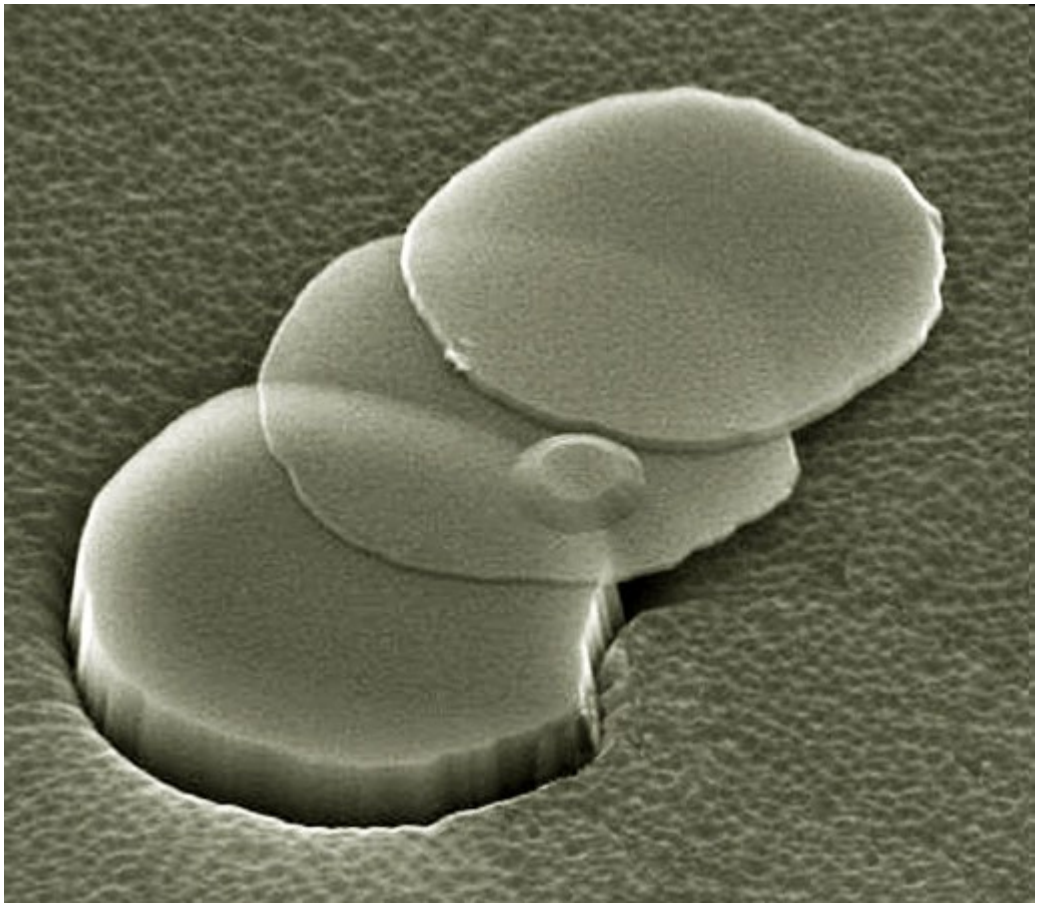




Graphene is an atomic-scale honeycomb lattice made of carbon atoms.

Olyan, mint a selyem ruha.
Szilicium lapon összegyűrődött grafén lapok.
Felvétel: pásztázó elektron mikroszkóppal 5000-szeres nagyítás.
20 mikronos méret.

University of Manchester. Science vol 324, 15 May 2009



Scanning electron micrograph (SEM) of a fallen mesa of graphite.
This is the way graphene molecules were "extracted" from bulk graphite.
To be reasonably visible in SEM, we show a 10 nm carbon flake (30 layer thick).

University of Manchester, United Kingdom

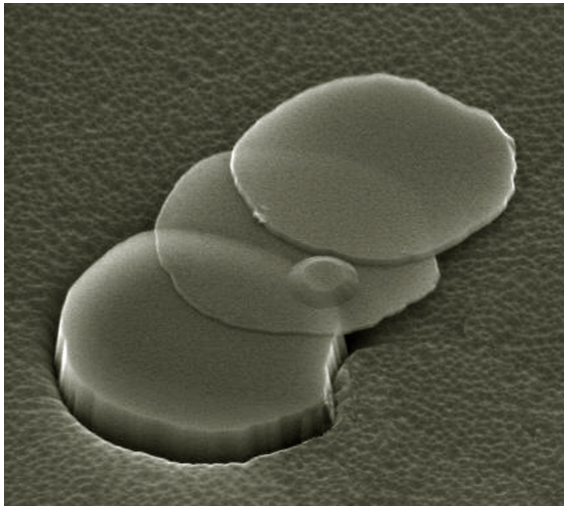
A grafén előállításának módjai

- „Hántolás” grafitból (cellux, Manchester group, 300 nm vastag SiO)

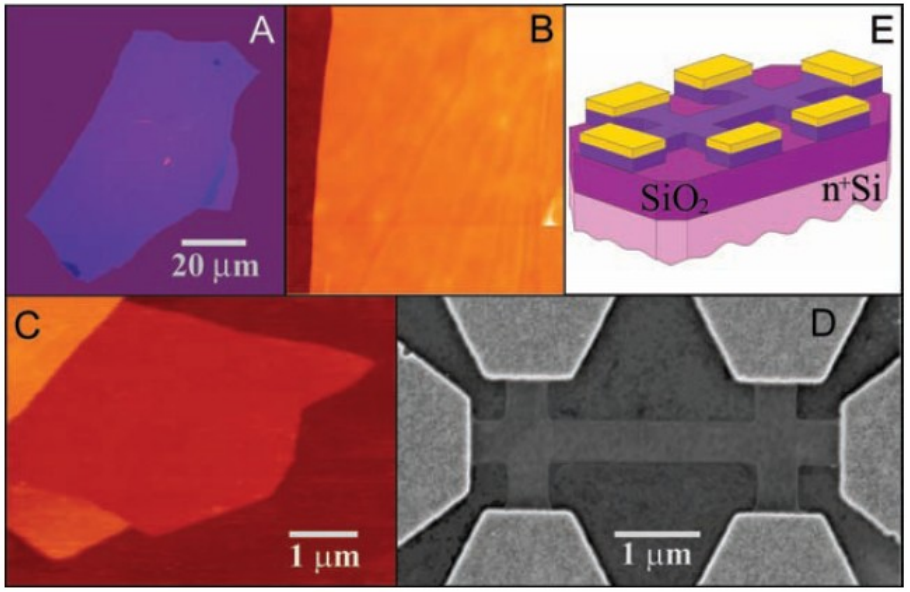
$$\text{Méret} \sim 1 \ \text{mm}^2$$

- Kémiai reakcióval
- Szén nanocső felvágása
- Pásztázó elektronmikroszkóp litográfia (MFA, Biró László csoportja)

Andre Geim és csoportja, Manchester University



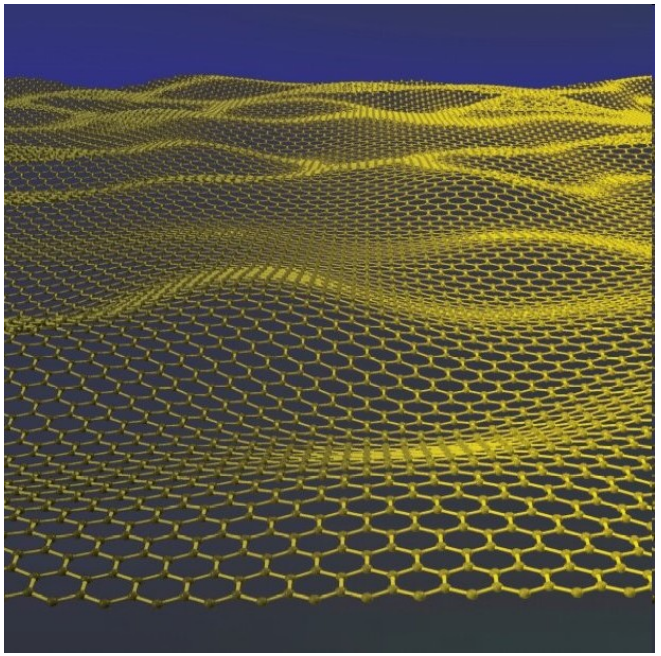
10 nm méretű grafén pikkely (30 réteg)



Grafén szilicium-oxid lapkán.
Elektródákat kapcsoltak hozzá.

Researchers use electron-beam lithography to microfabricate graphene devices.
Kindly provided by University of Manchester, United Kingdom

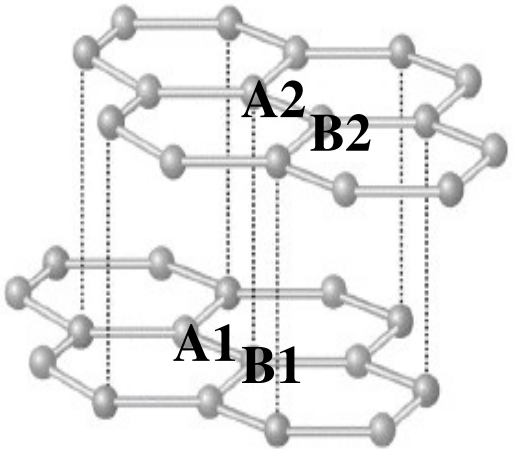
A réteg nem tökéletesen sík



Kétrétegű grafén

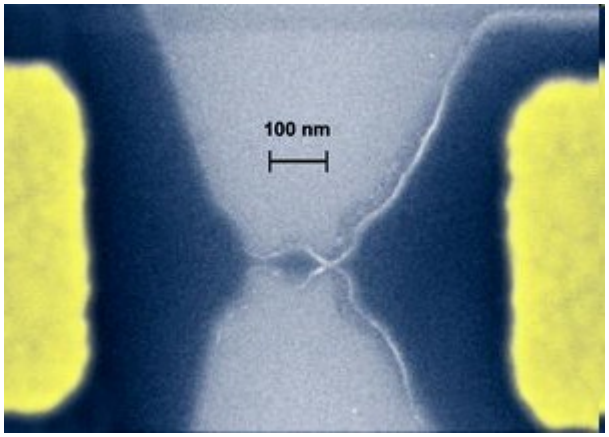
(Bilayer graphene)

Bernal stacking (A2 – B1)



Alkalmazások

graphene transistor:



IBM, 2010 február

on and off rate of **100 gigahertz**

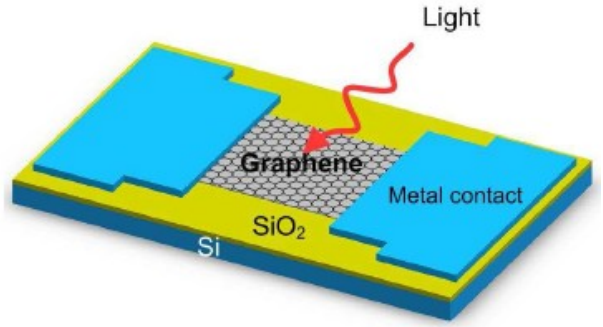
Jobb, mint a szilícium alapú tranzszitor

Bourzac, Katherine (2010-02-05). "*Graphene Transistors that Can Work at Blistering Speeds*". MIT Technology Review.

Grafén fotonika és optoelektronika

F. Bonaccorso, Z. Sun, T. Hasan, A. C. Ferrari: *Graphene Photonics and Optoelectronics*, arXiv:1006.4854v1

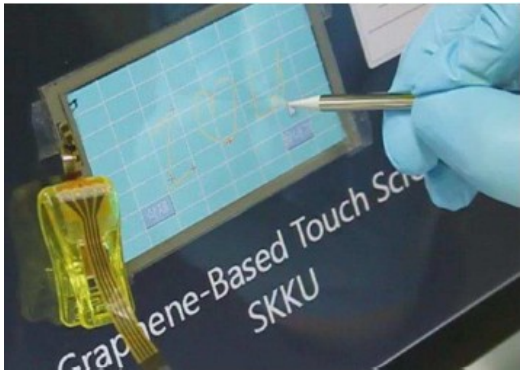
fotodetektor



X. Wang, L. Zhi, N. Tsao, Z. Tomovic, J. Li, K. Mullen, Angew. Chem. 47, 2990 (2008).

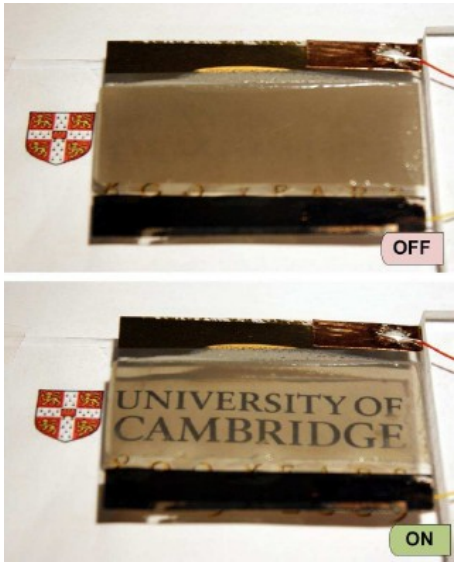
napelem X. Wang, L. Zhi, K. Mullen, Nano Lett. 8, 323 (2007).
Z. Liu, Q. Liu, Y. Huang, Y. Ma, S. Yin, X. Zhang, W. Sun, Y. Chen, Adv. Mater. 20, 3924 (2008).

érintőképernyő



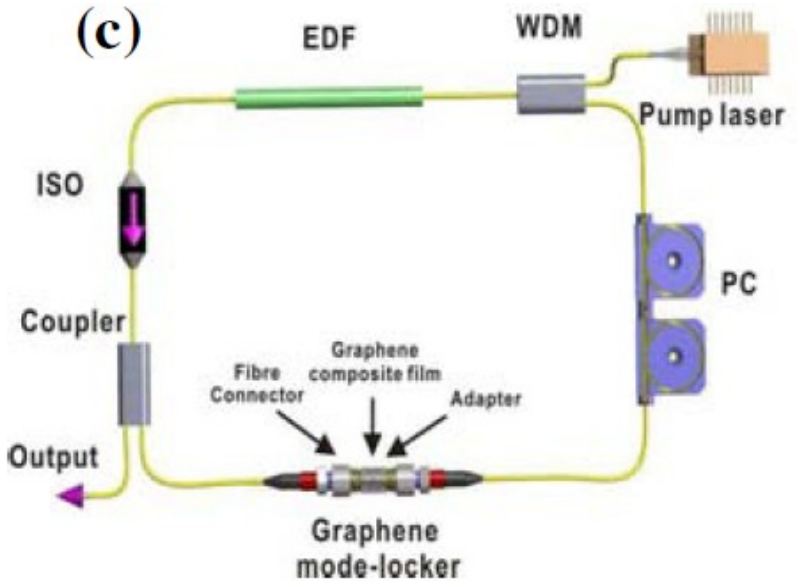
S. Bae, H. K. Kim, X. Xu, J. Balakrishnan, T. Lei, Y. I. Song, Y. J. Kim, B. Ozyilmaz, J.-H. Ahn, B. H. Hong, S. Iijima, arXiv , 0912.5485v1 (2009); Nat. Nano. (2010)

Andrea Ferrari csoportja
University of Cambridge
Nanomaterials and Spectroscopy Group



smart window

ultrafast lasers



Sun, Z. Hasan, T. Popa, D. Torrisi, F. Wang, F. Bonaccorso, F. Ferrari, A. C. : *Ultrafast fiber laser mode-locked by graphene based saturable absorber*,

További lehetséges kutatási irányok

- Grafén alapú elektronika:
  p-n átmenet, nagy mozgékonyság,
  nagy áram, mechanikailag stabil
  $\approx$ 0.3 μm szabadúthossz 300 K-en!!!!
  kapcsolási idő < 10^{-13}s

- Hidrogén tárolás, kémiai szenzor (gáz molekulák érzékelése)

- A kvantumelektrodinamika tesztelése részecskegyorsító nélkül

- …..

Csak 6 éve kutatják a grafént!