A 9-a editie a Seminarului National de nanostiinta si nanotehnologie

RF field effect transistors based on graphene

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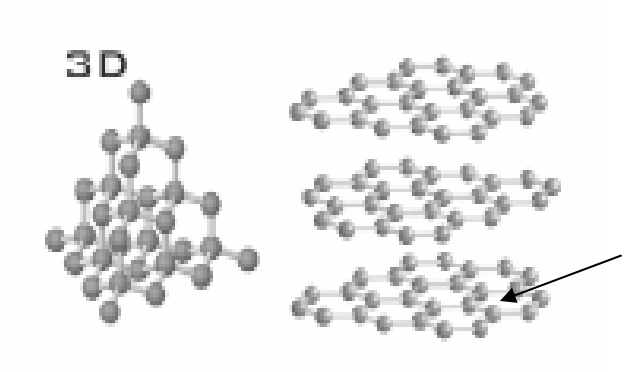
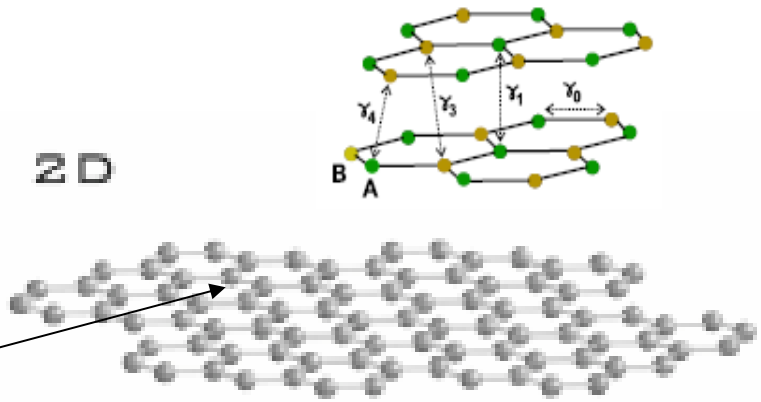
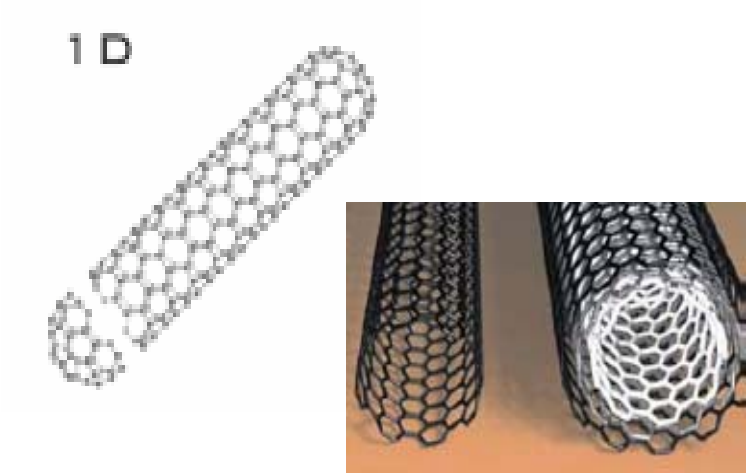
Carbon-based materials



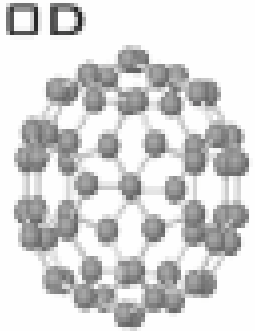
GRAPHENE =one atom thick material



K.S. Novoselov et al., Science 306 (2004) 666
Theory: P.R. Wallace, Phys. Rev. 71 (1947) 622

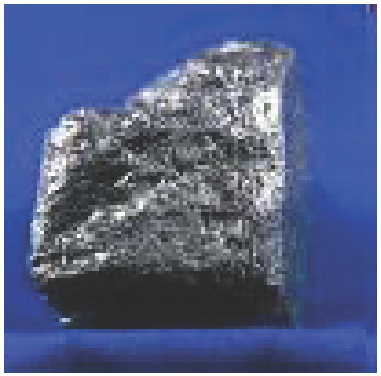


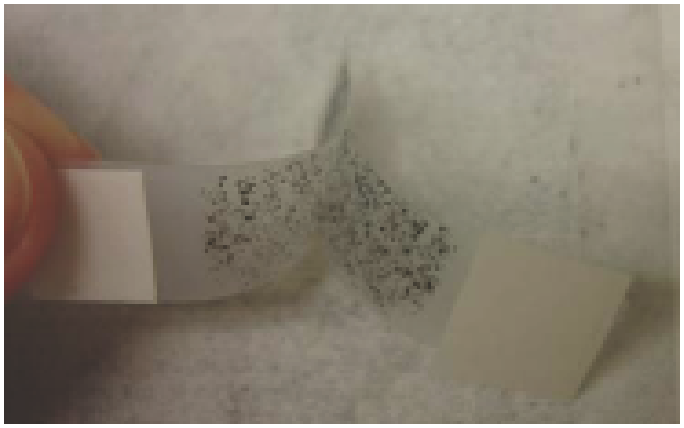
S. Iijima, Nature 354 (1991) 56



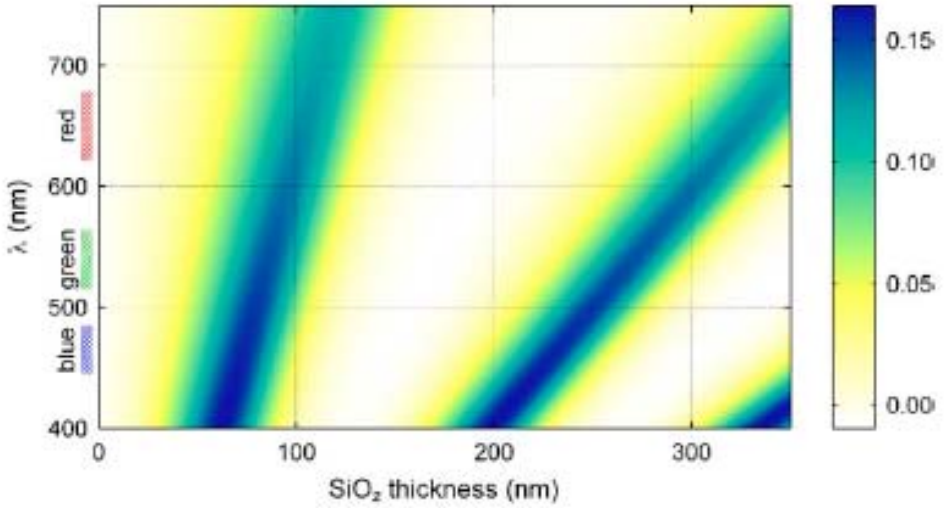
H.W. Kroto et al., Nature 318 (1985) 162

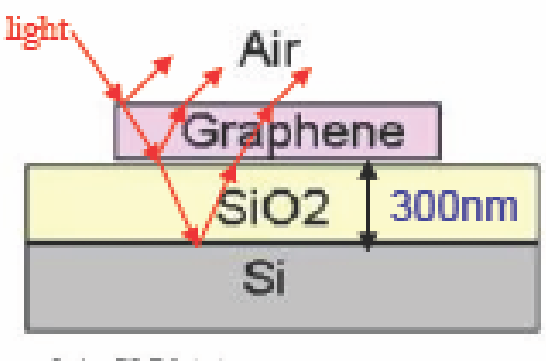
"exfoliation" (scotch tape)





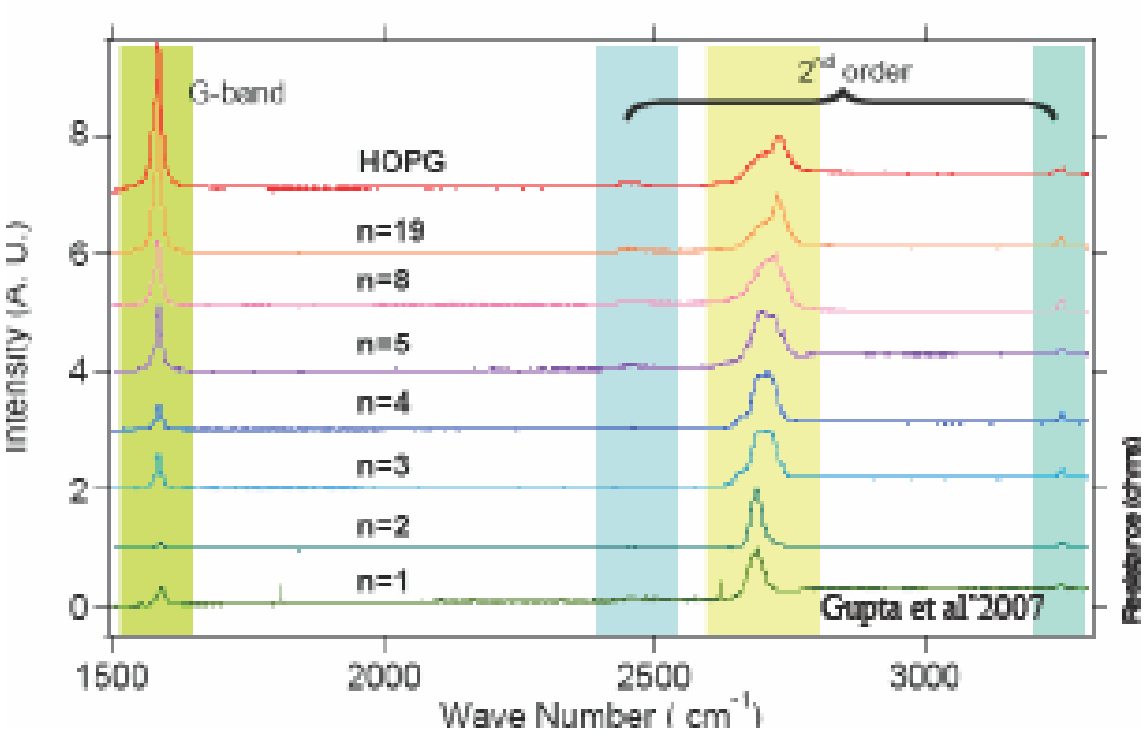
λ





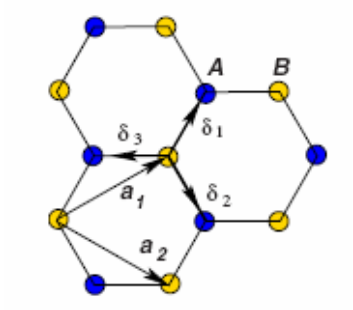
$Si0_2$ thickness

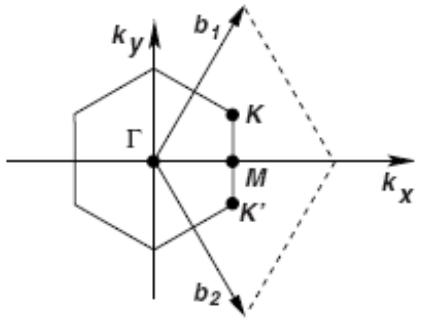
Optical view

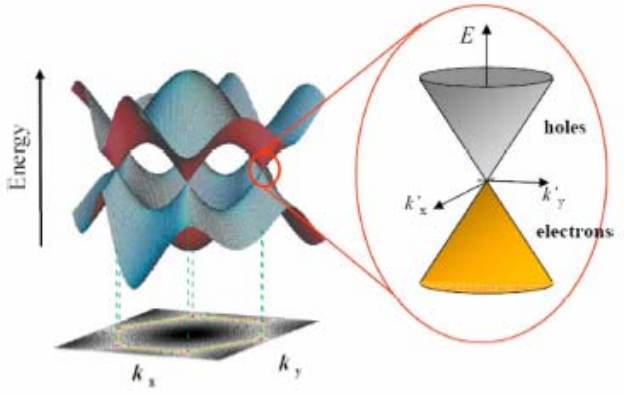


Raman signature

Electronic band structure
Determined by the π bonds formed by hybridization of the p_z orbitals of different C atoms

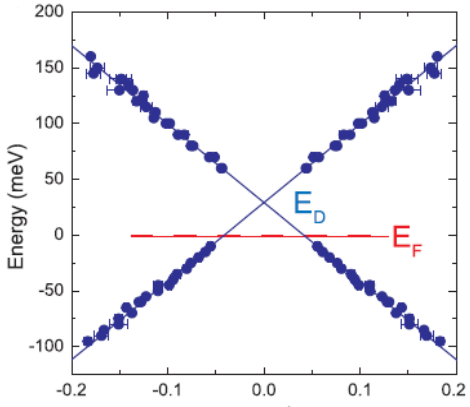




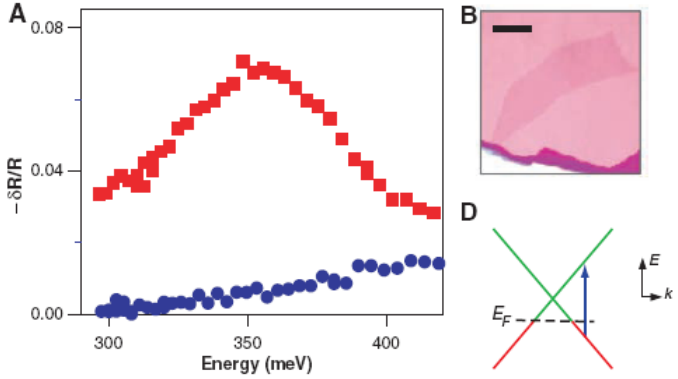


$$E_{\pm}(k) = \pm \hbar v_F \, |k|$$

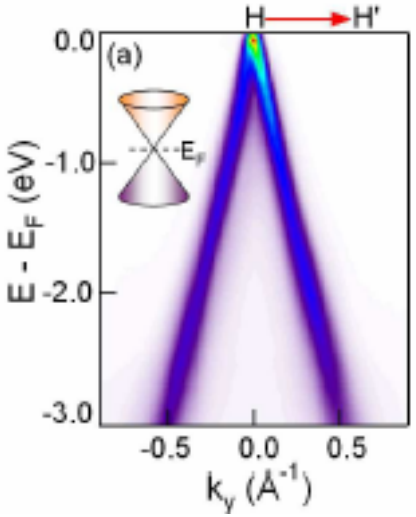
$$v_F \cong c/300$$



D.L. Miller et al., Science 324 (2009) 924



F. Wang et al., Science 320 (2008) 206



S.Y.Zhou et al., Nature Physics 2 (2006) 595

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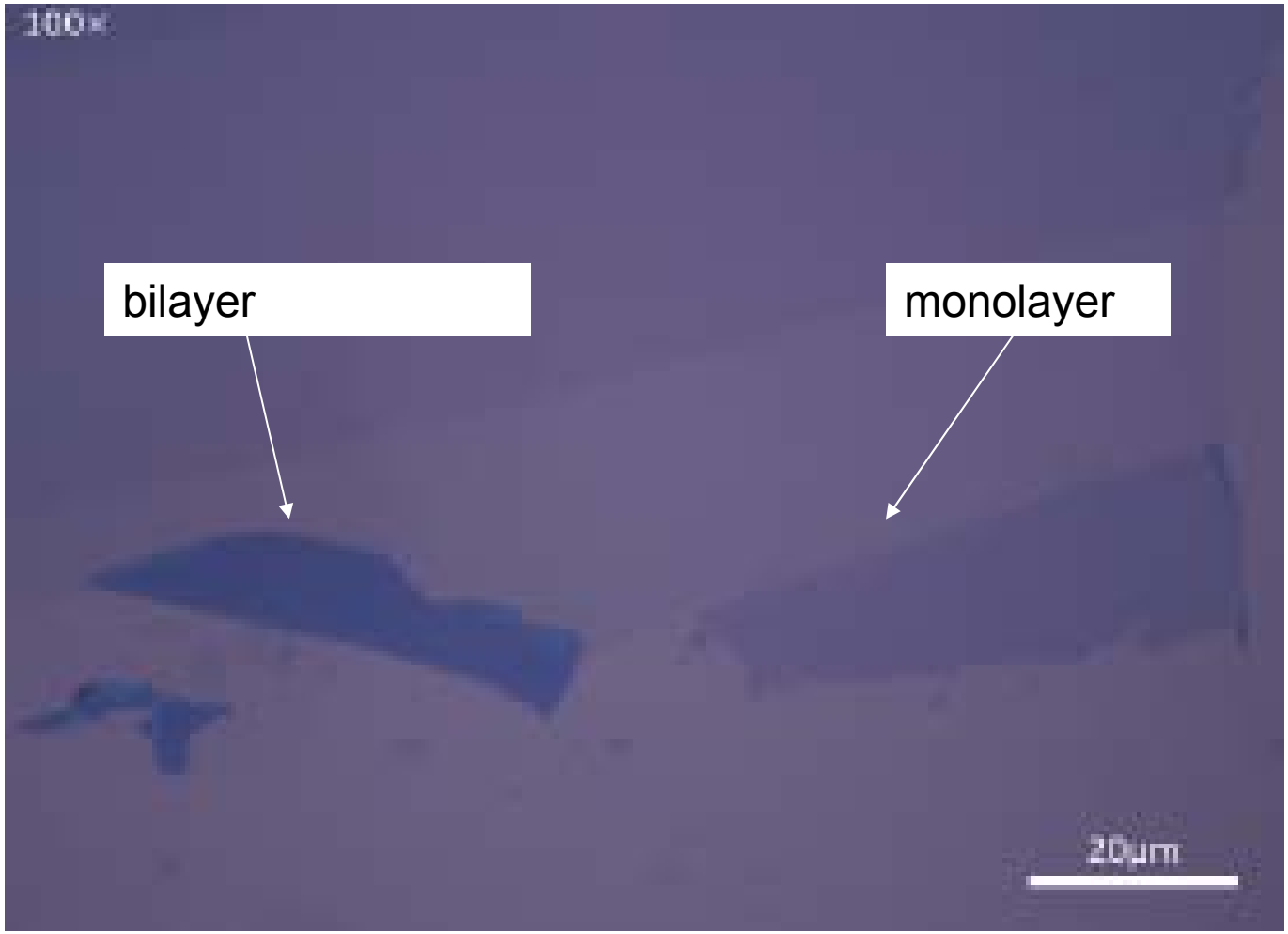


Graphene –the wonder material!!!

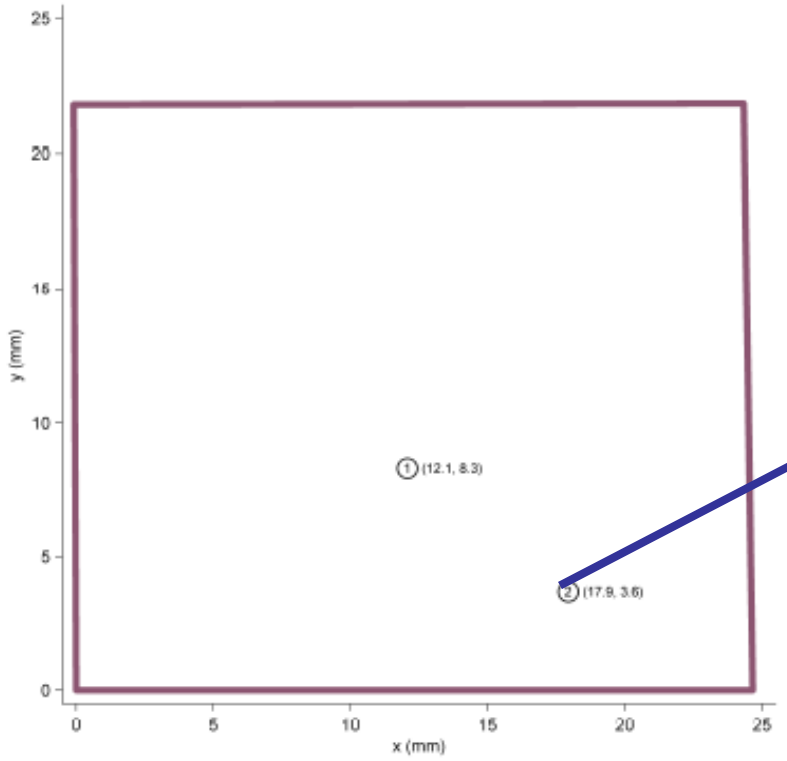
Parameter	*Value and units*	*Observations*
Thermal conductivity	5000 W/mK	Better thermal conductivity than in most crystals
Young modulus	1.5 TPa	Ten times greater than in steel
Mobility	40 000 $cm^2V^{-1}s^{-1}$	At room temperature (intrinsic mobility) maximum mobility : 200 000 $cm^2V^{-1}s^{-1}$) on suspended graphenes
Mean free path (ballistic transport)	≈ 400 nm	At room temperature
Electron effective mass	0.06 m_0	At room temperature
Hole effective mass	0.03 m_0	At room temperature
Fermi velocity	c/300=1000000 m/s	At room temperature

Sample MD04 Datasheet

Parent Wafer

Supplier	Mircea Dragoman
Resistivity	High
Oxide	≈300 nm dry thermal oxide

Substrate Map



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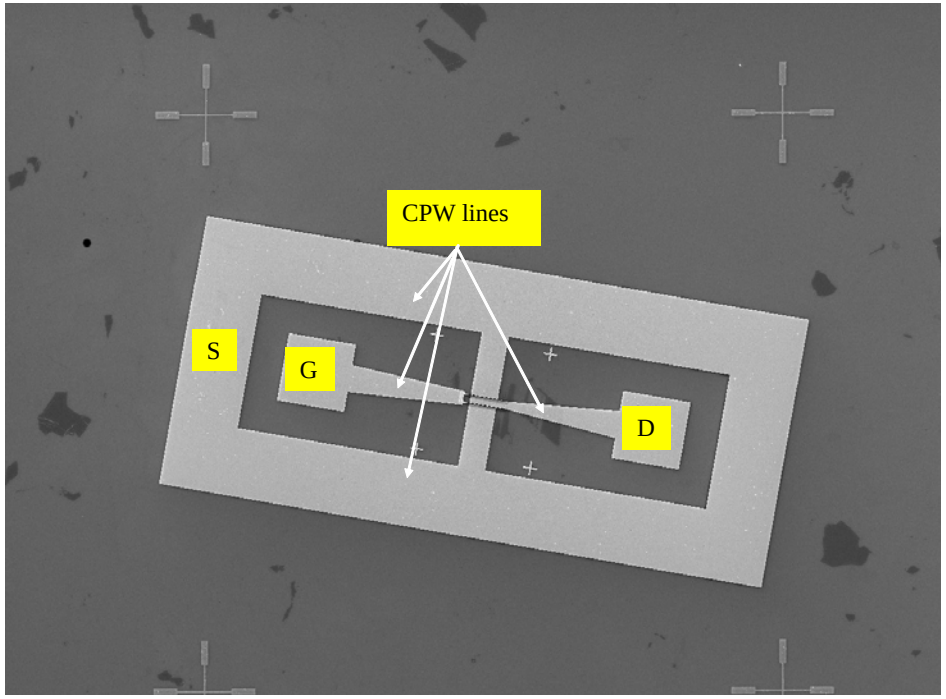

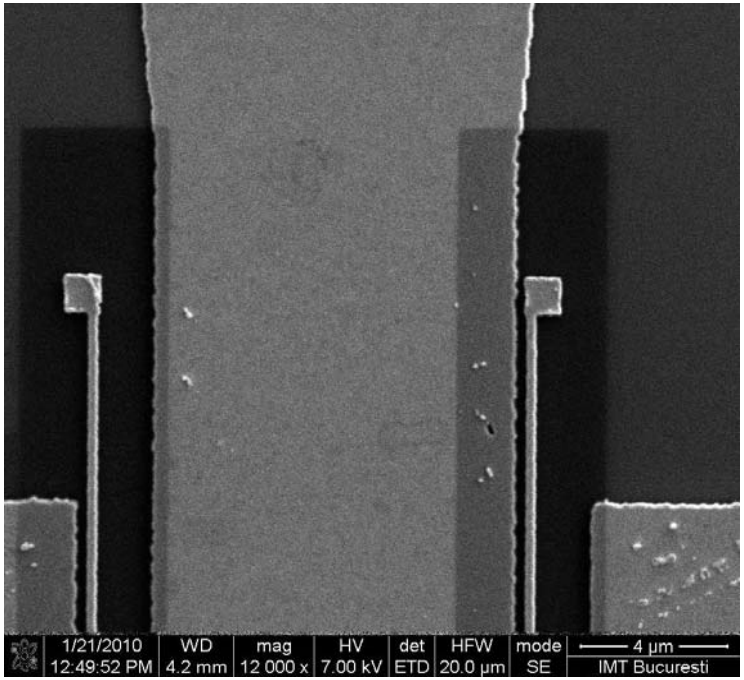

The relevant dimensions of the graphene FET are: gate length 200 nm, source-drain distance 2 µm and source-drain width 40 µm . The gate dielectric is a 100 nm thick PMMA layer

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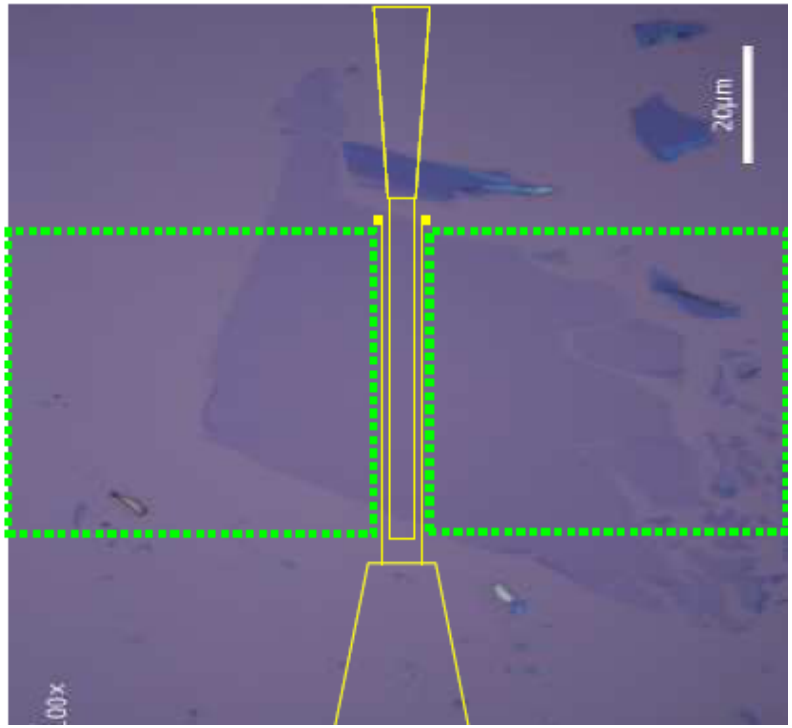
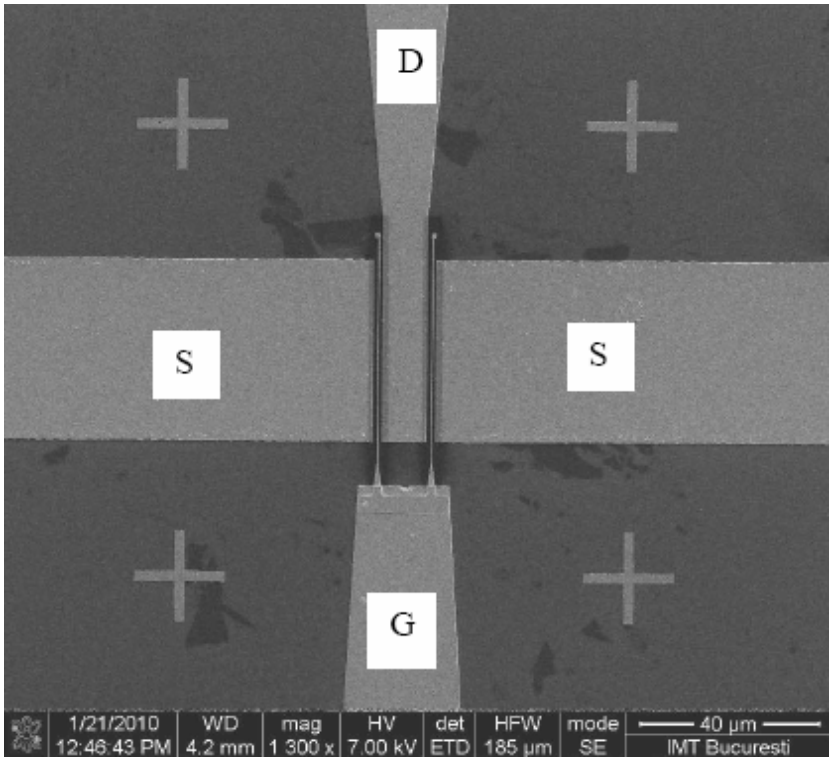
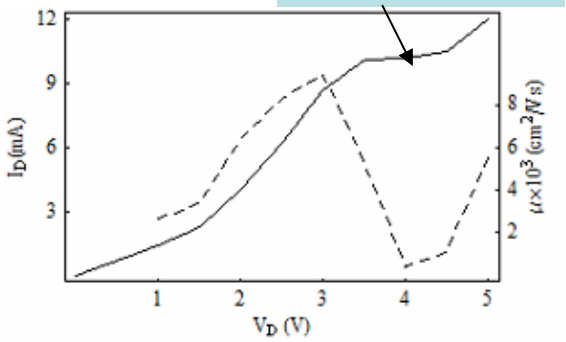
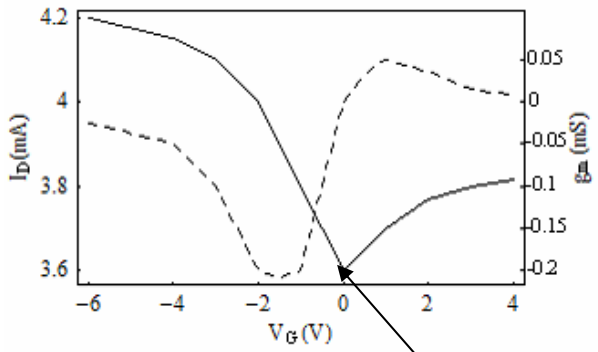




Dirac point

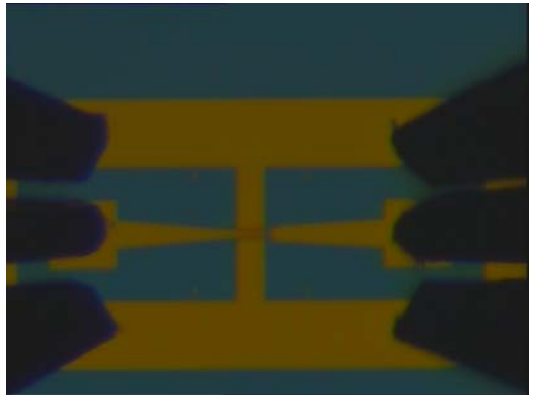


(a)



(b)

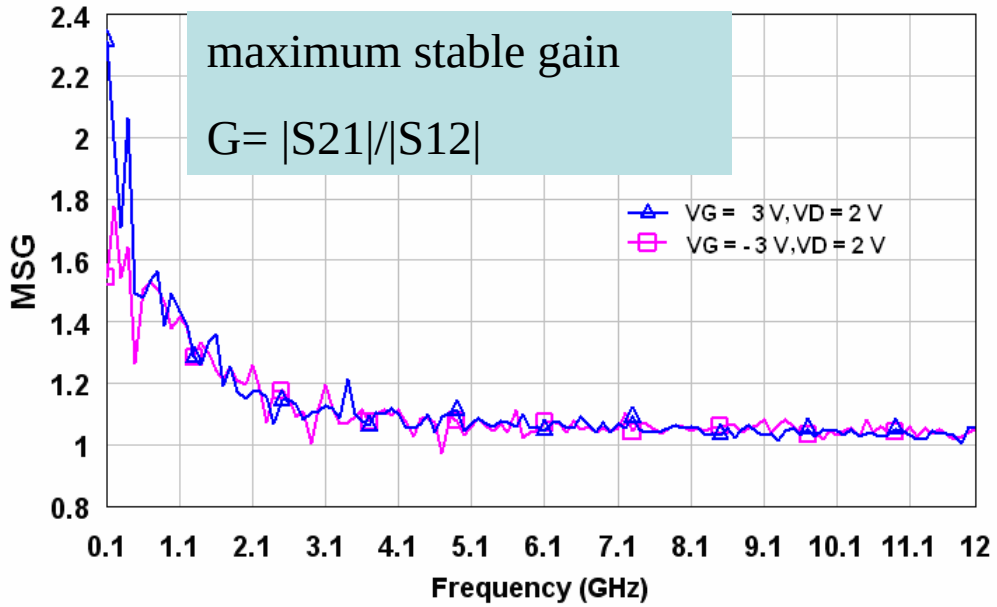
Dirac point



cutoff frequency =80 GHz

maximum stable gain

G= |S21|/|S12|



Conclusions:

Mobility ≈9000 cm^2/Vs in the FET channel (9 times grater than in CMOS transitors)

Gain > 10 GHz

Cutoff frequency >80 GHz

We will reduce the gate dielectric to 80 nm

Gate length<100 nm

Expected cutoff frequency 0.4-1 THz