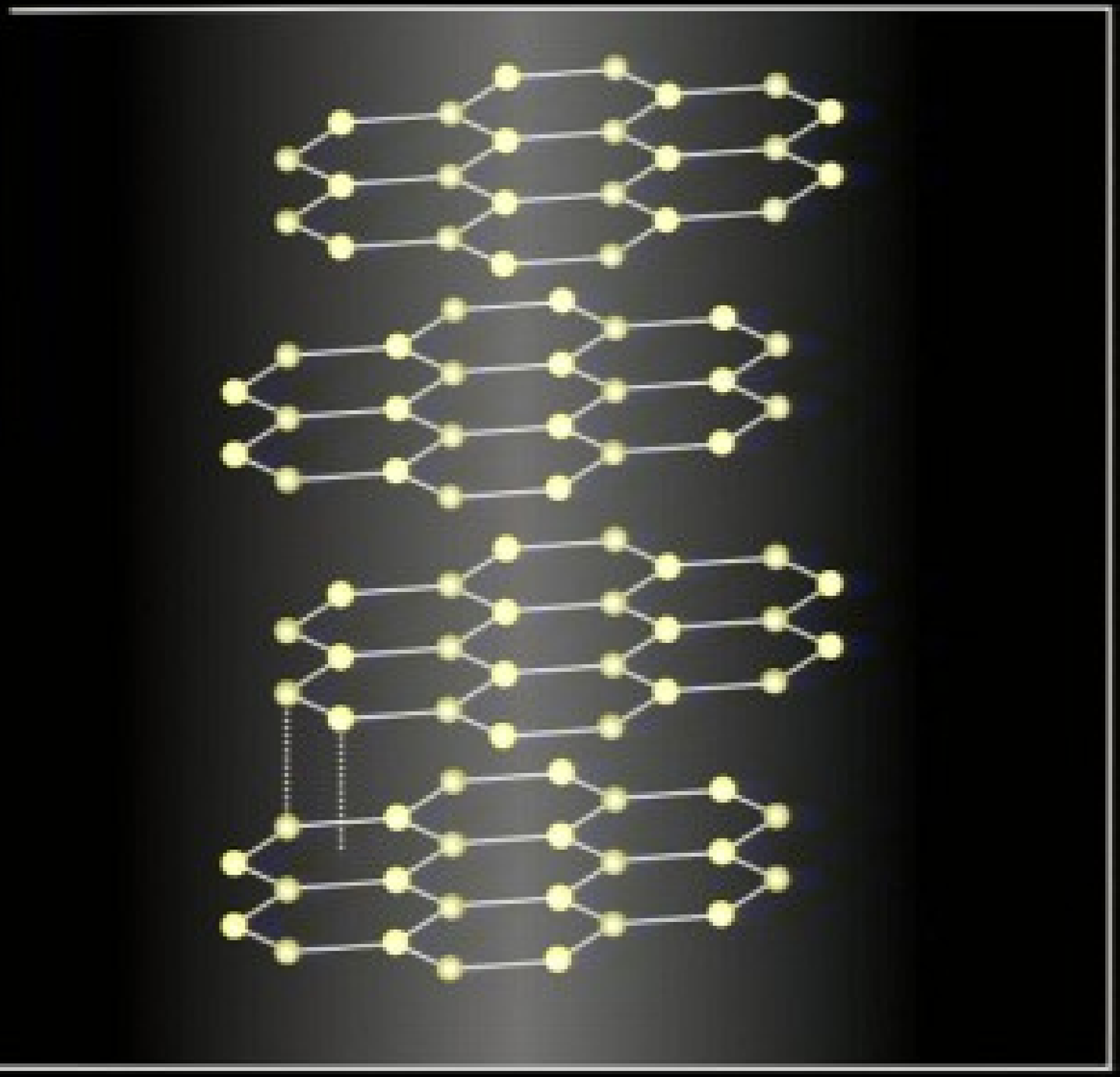
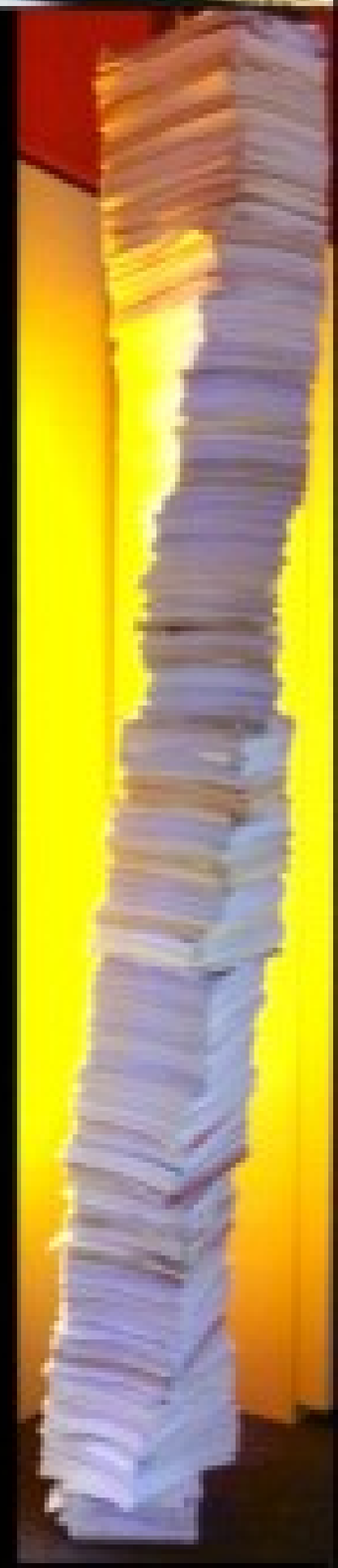
Graphene & Co.
versatile materials of tomorrow

Jurgen Smet, *Max Planck Institute for Solid State Research*

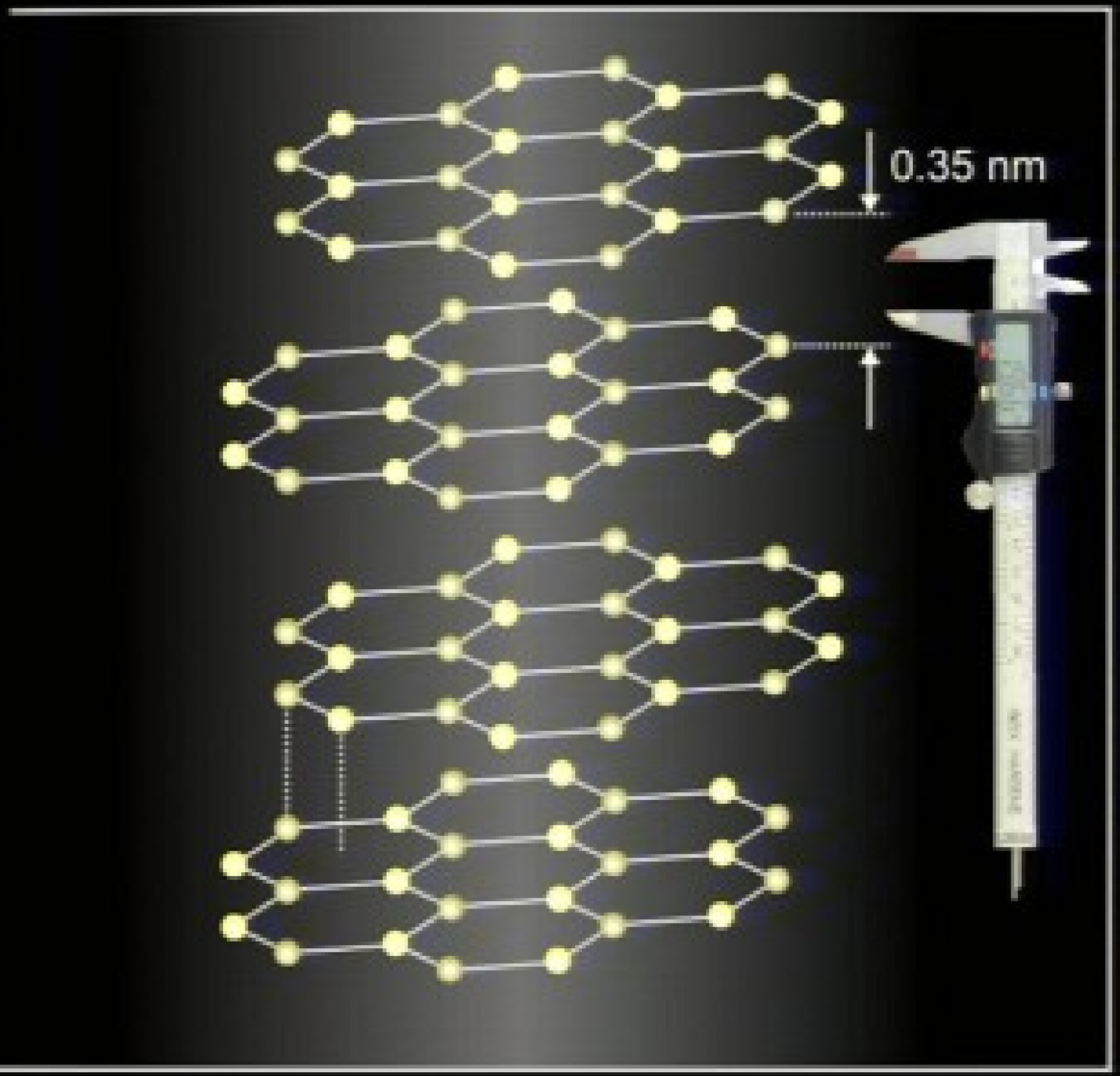
Going 2D

2D constituent of graphite

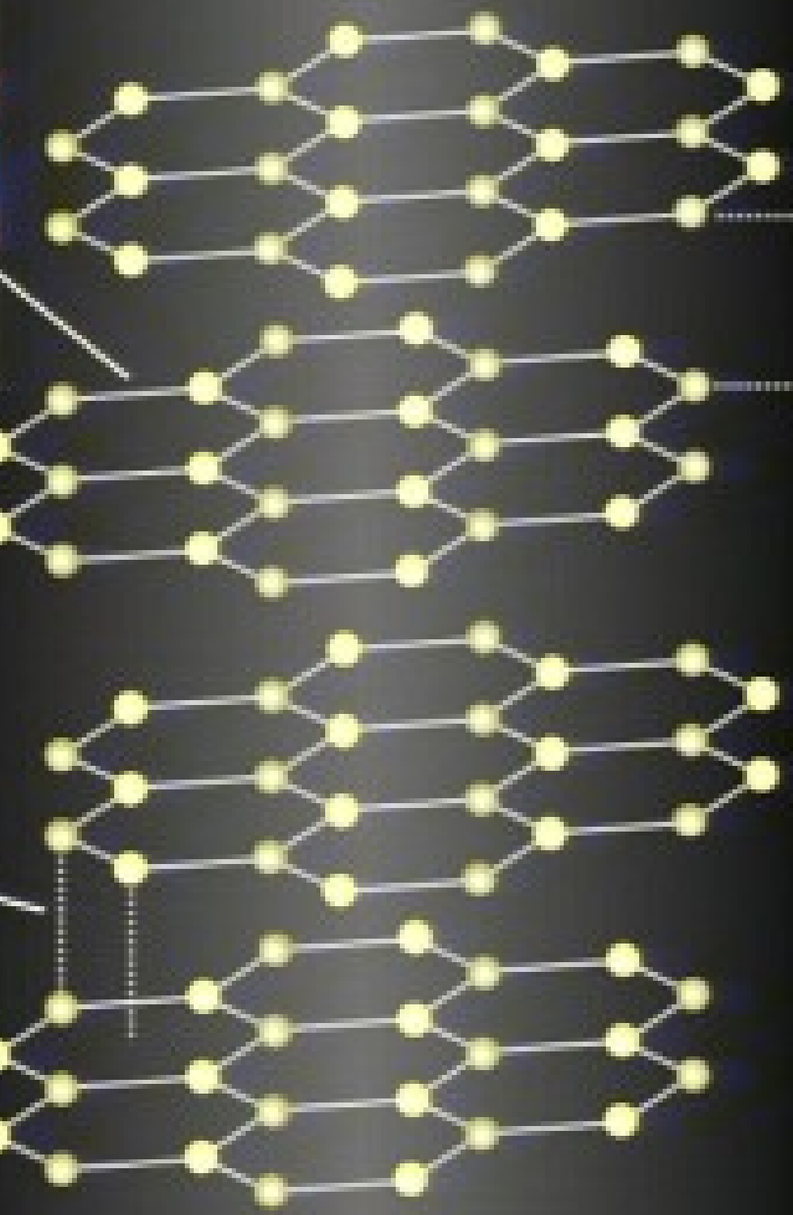


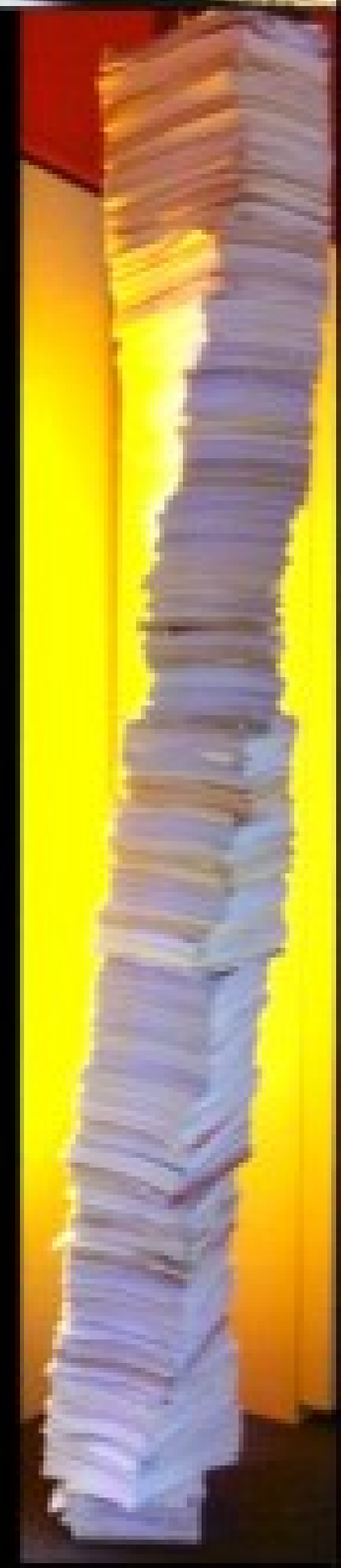


2D constituent of graphite

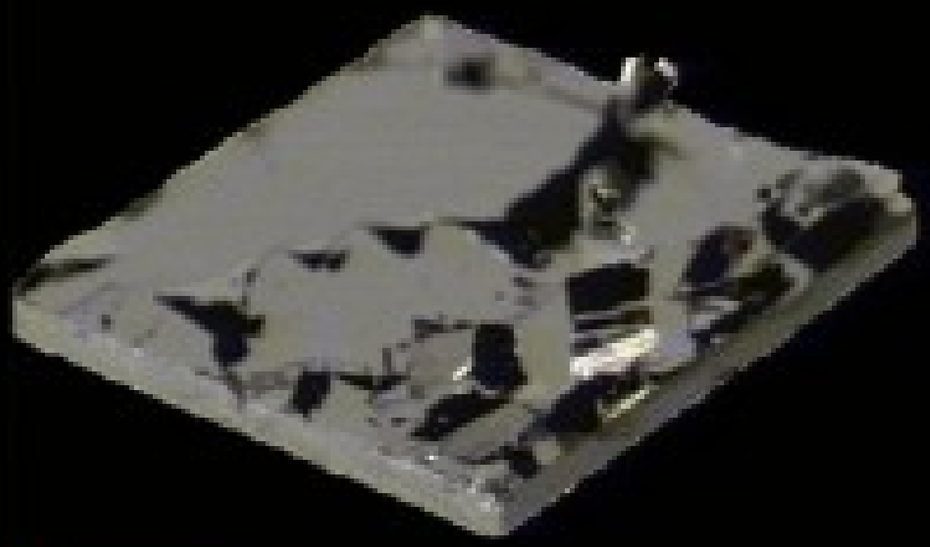


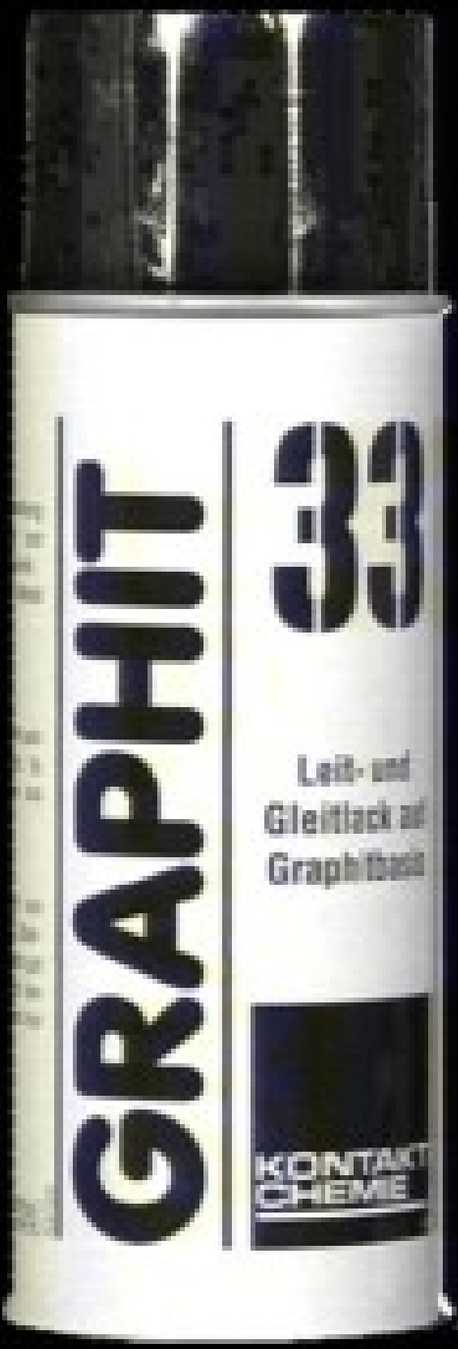
2D constituent of graphite





Recipe:
as simple as peeling





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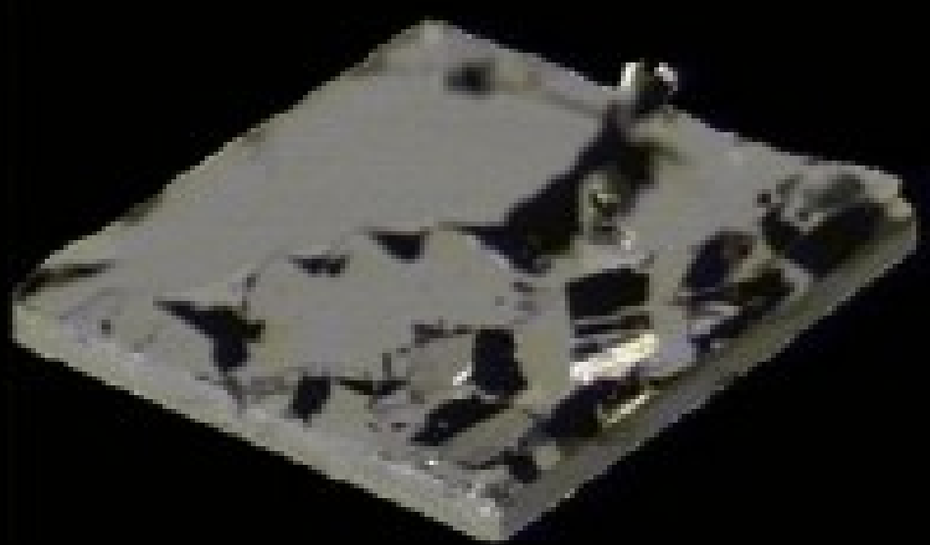
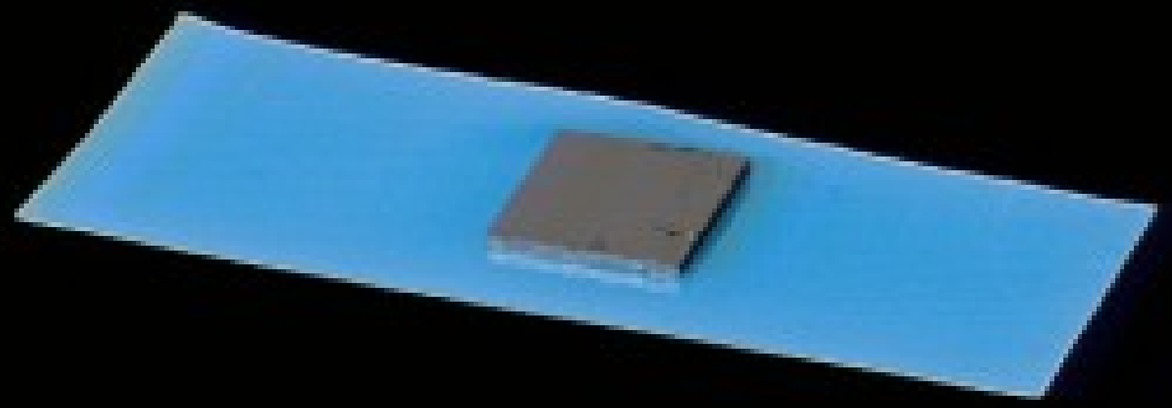
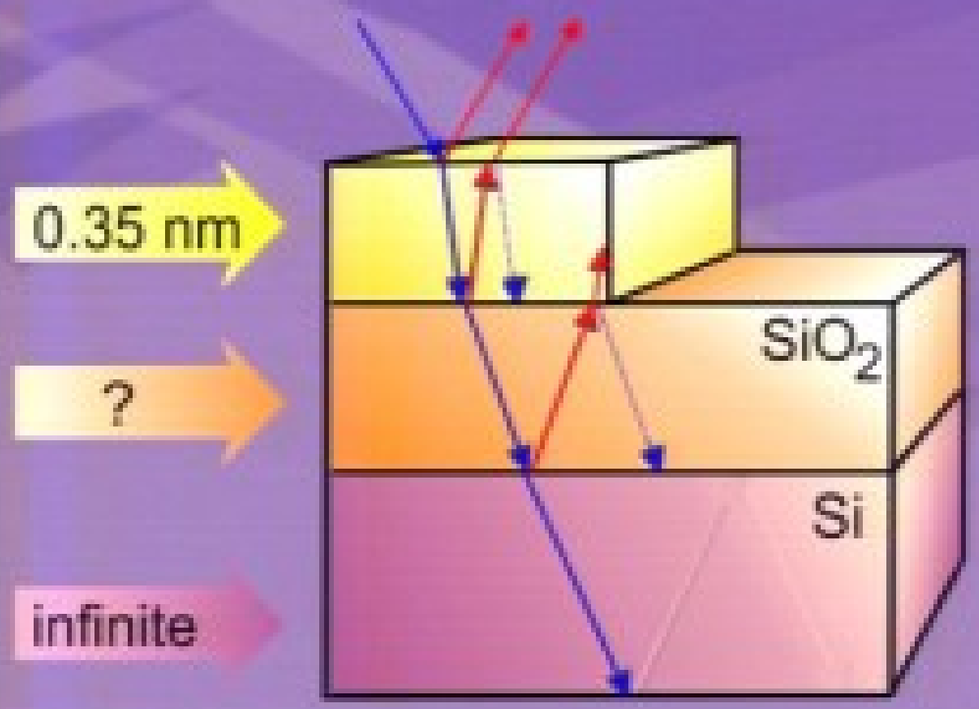


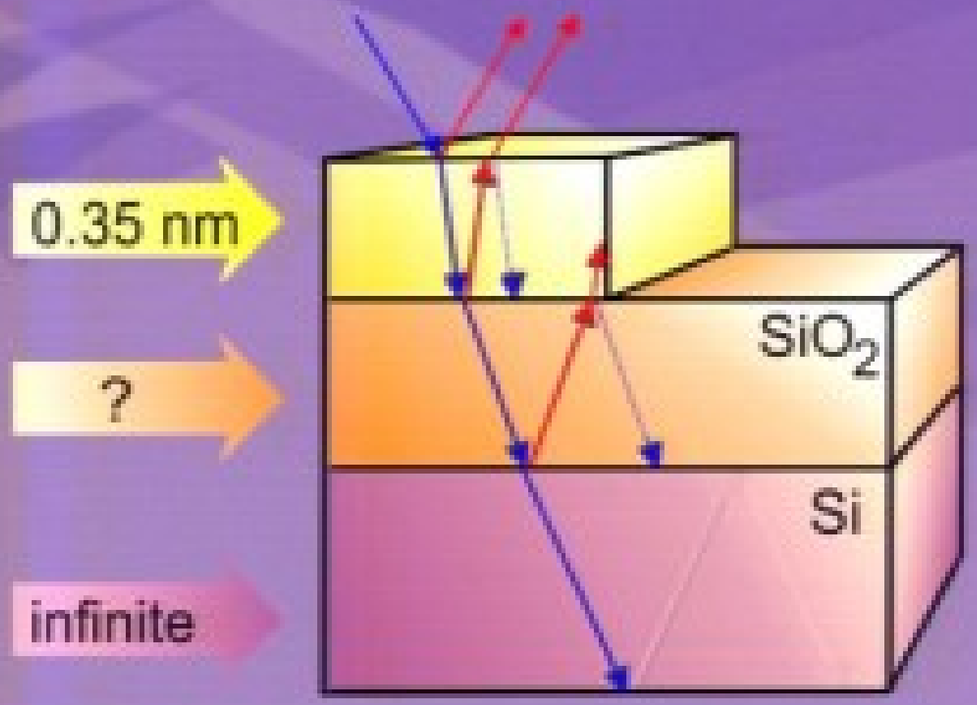


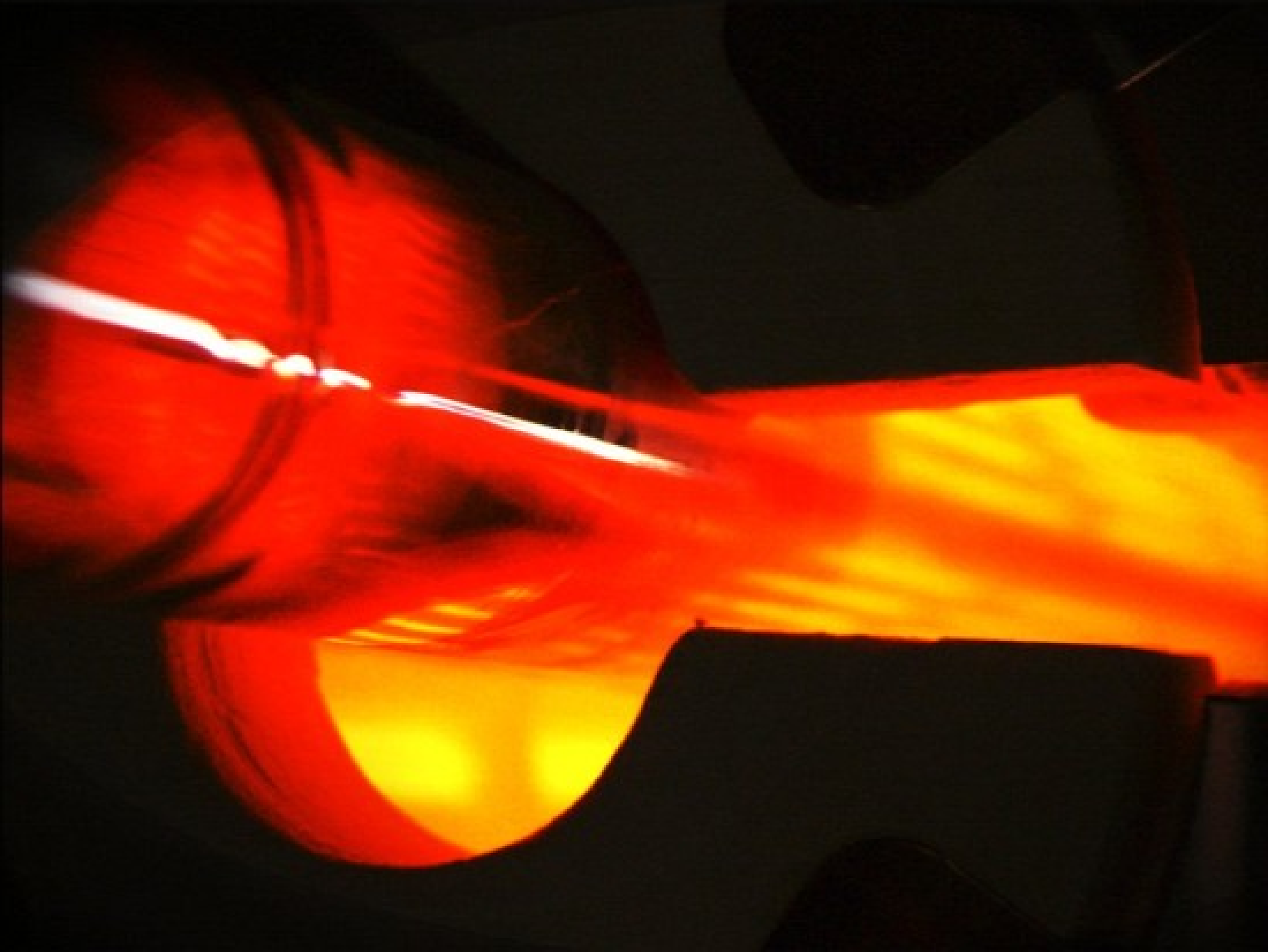
Visibility

Visibility

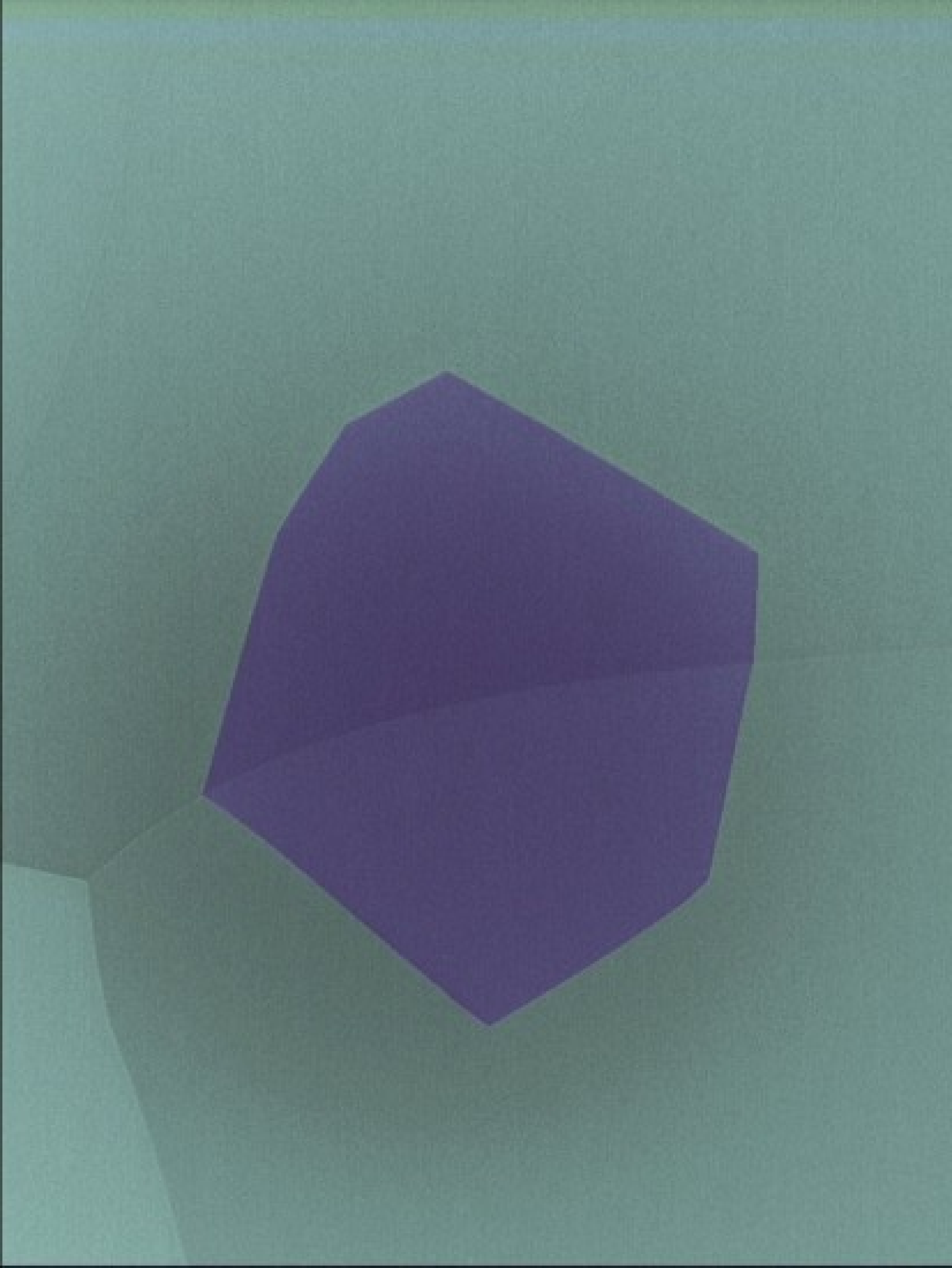


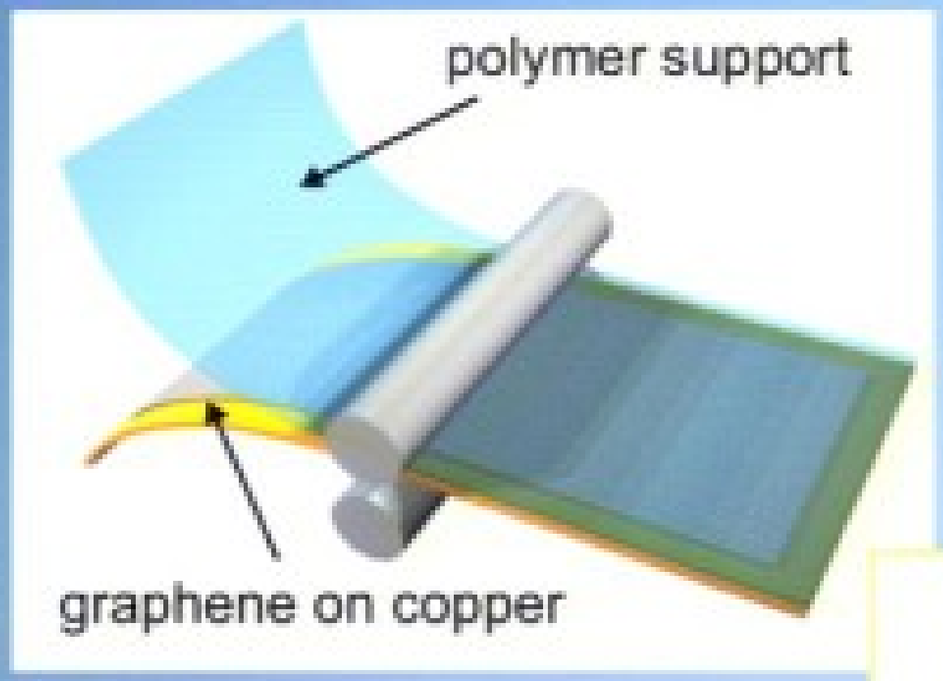
Visibility

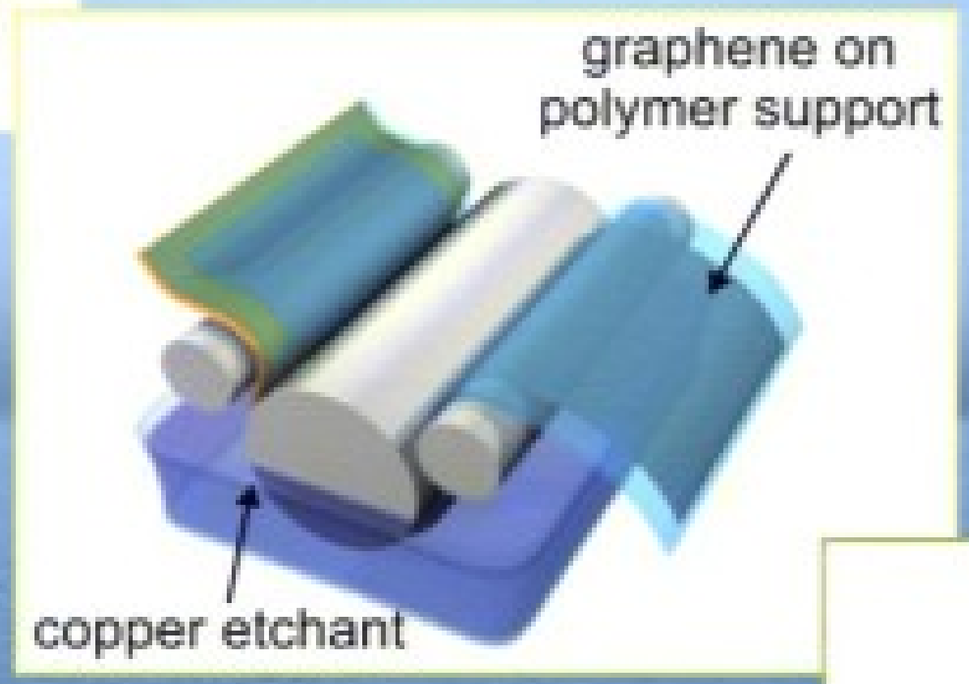


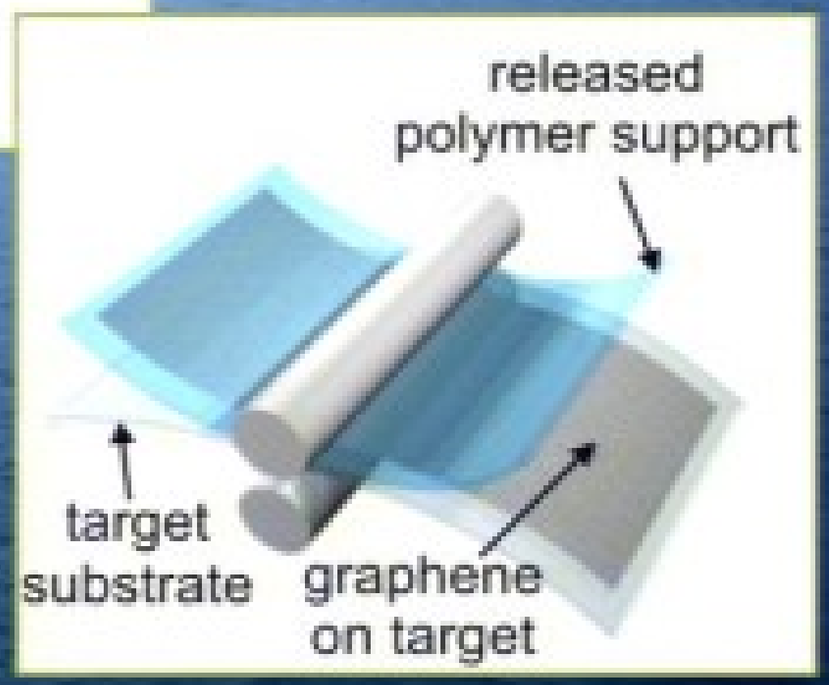


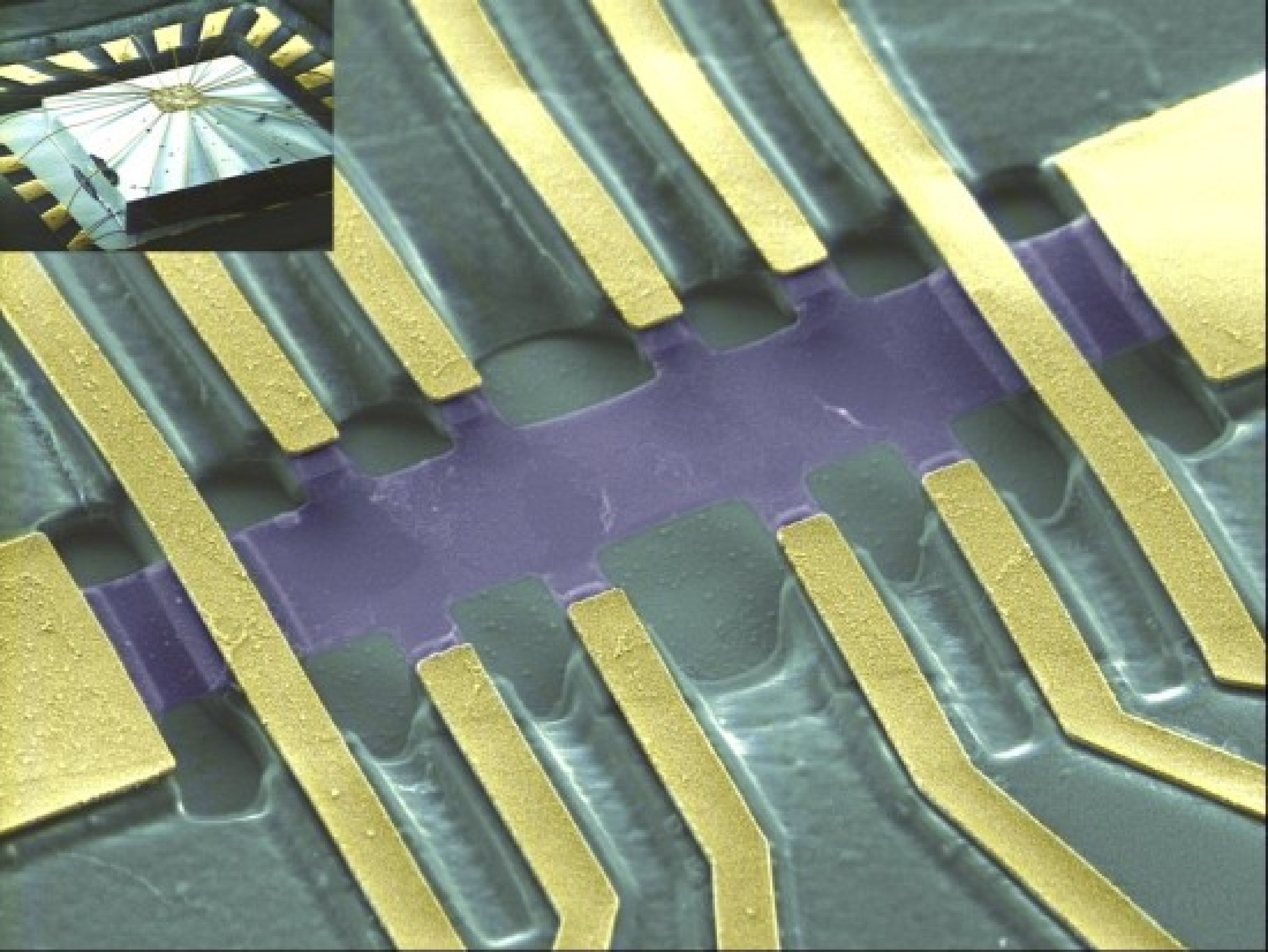

catalytic reaction
surface diffusion
self-terminating
CH_4
H_2

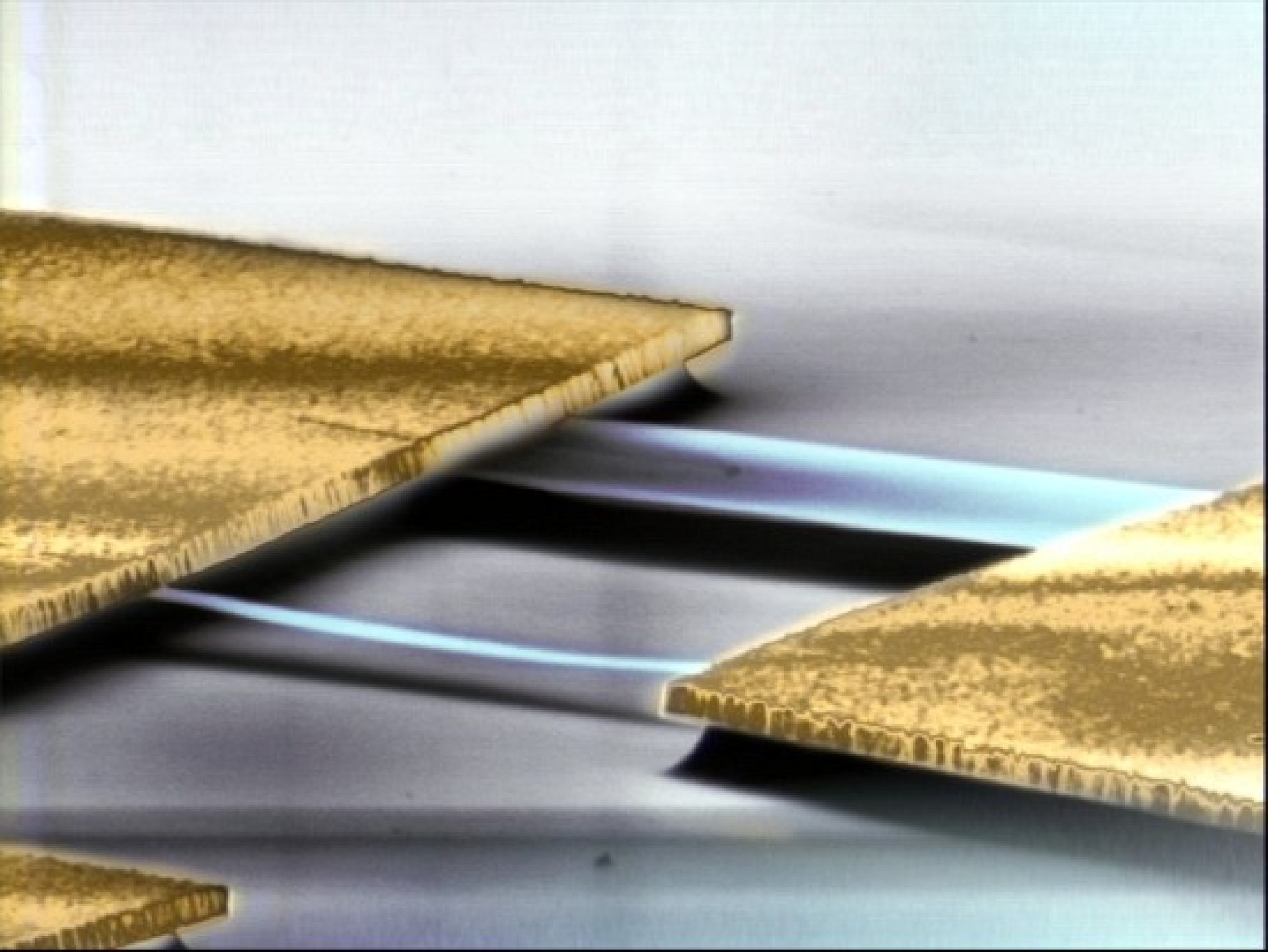



polymer support
graphene on copper

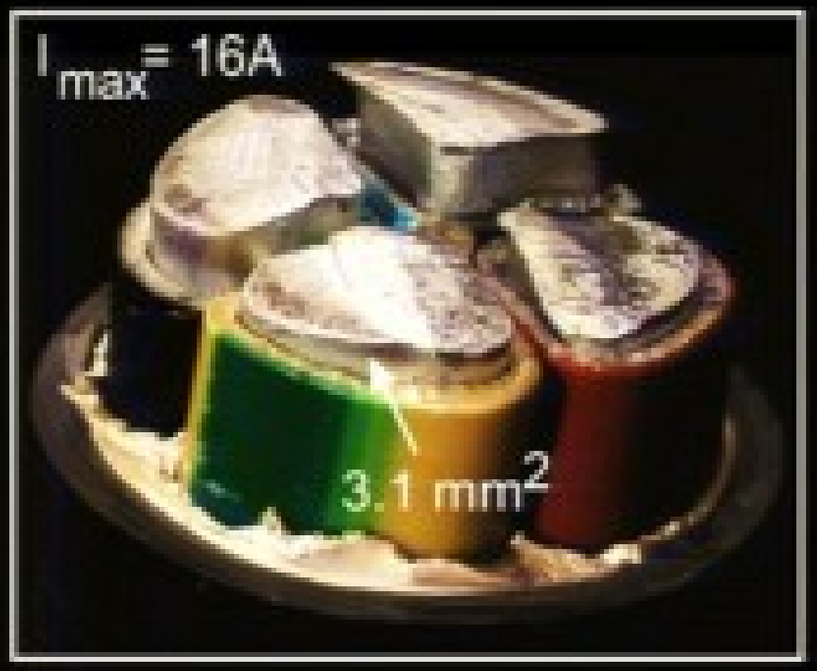

graphene on
polymer support
copper etchant


released
polymer support
target
substrate
graphene
on target

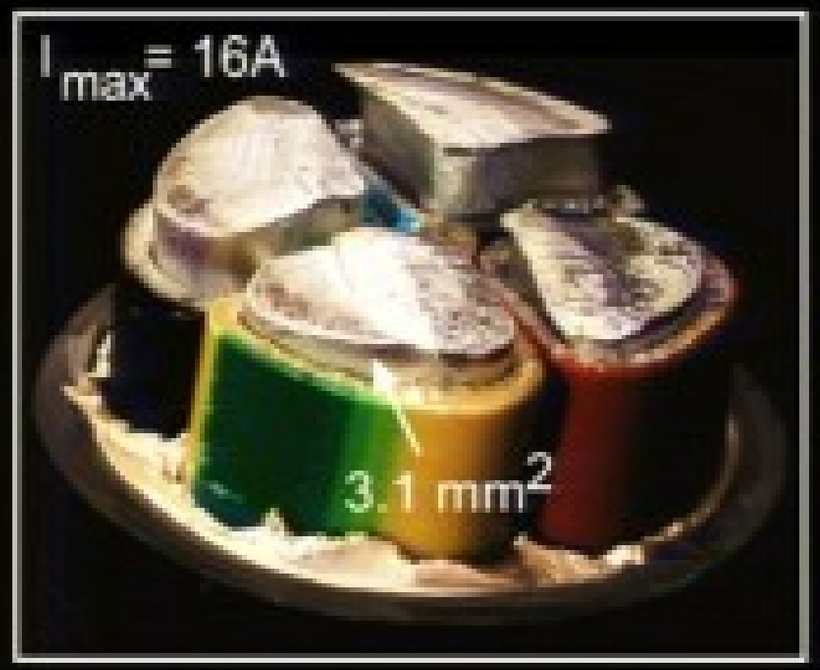


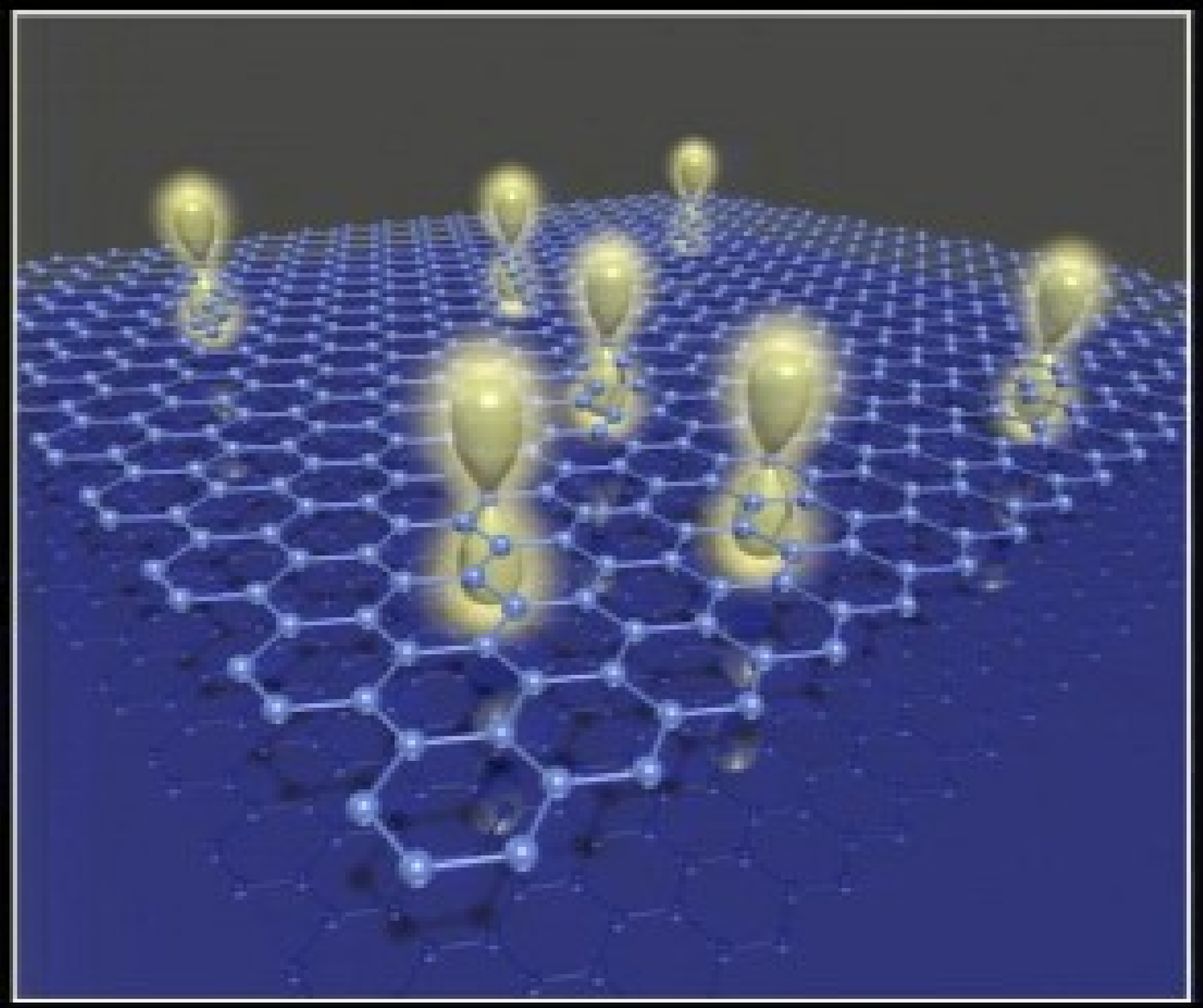


Superb conductor

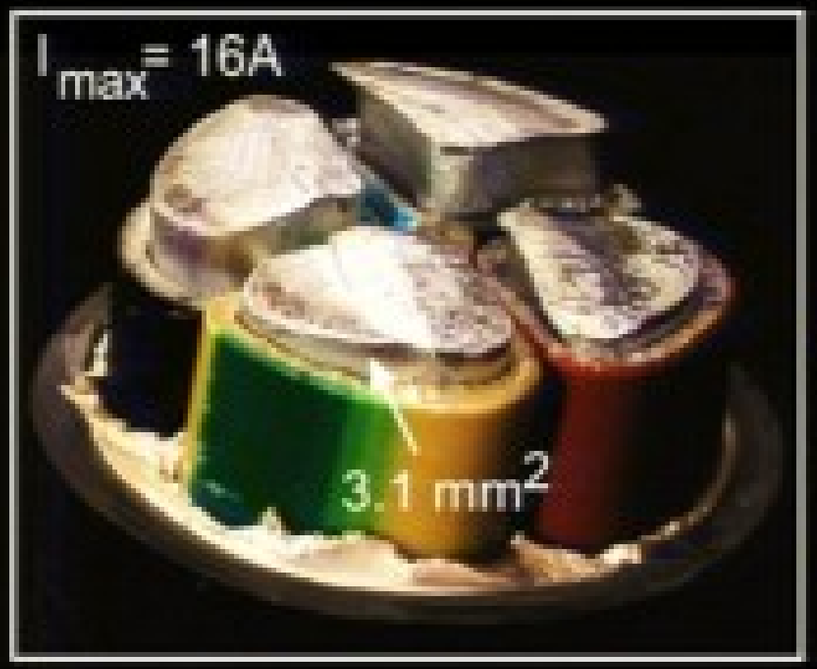


Superb conductor





Superb conductor



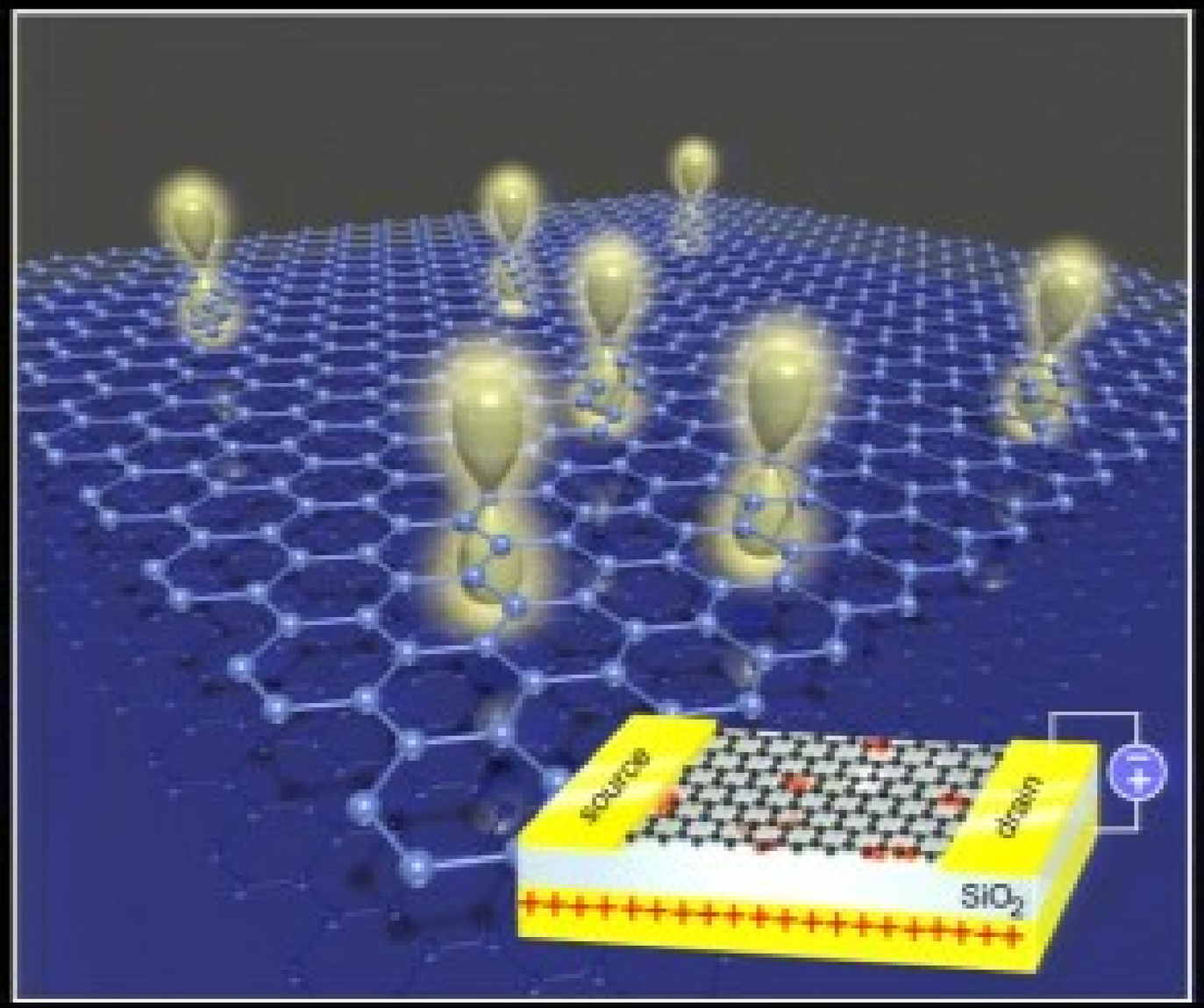
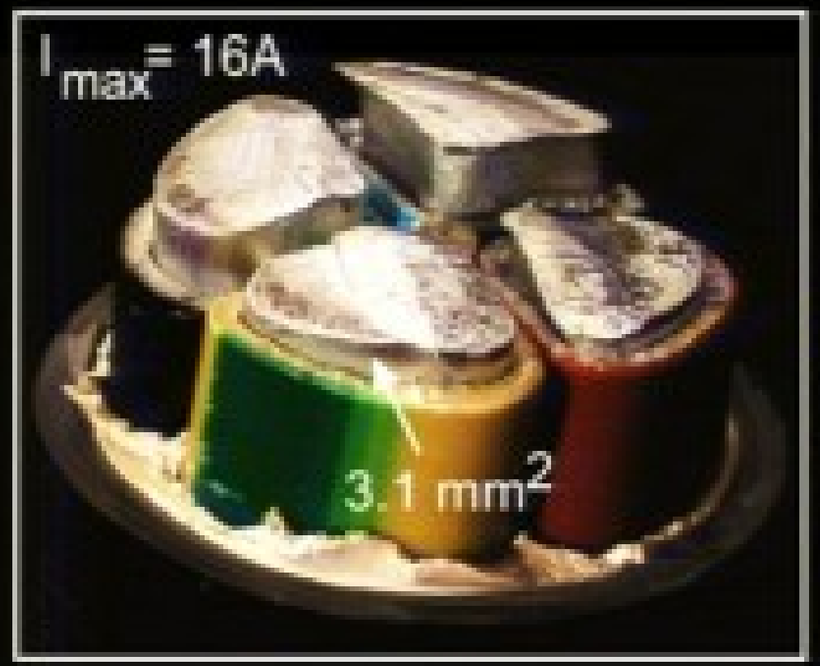


figure of merit: charge carrier mobility

Superb conductor



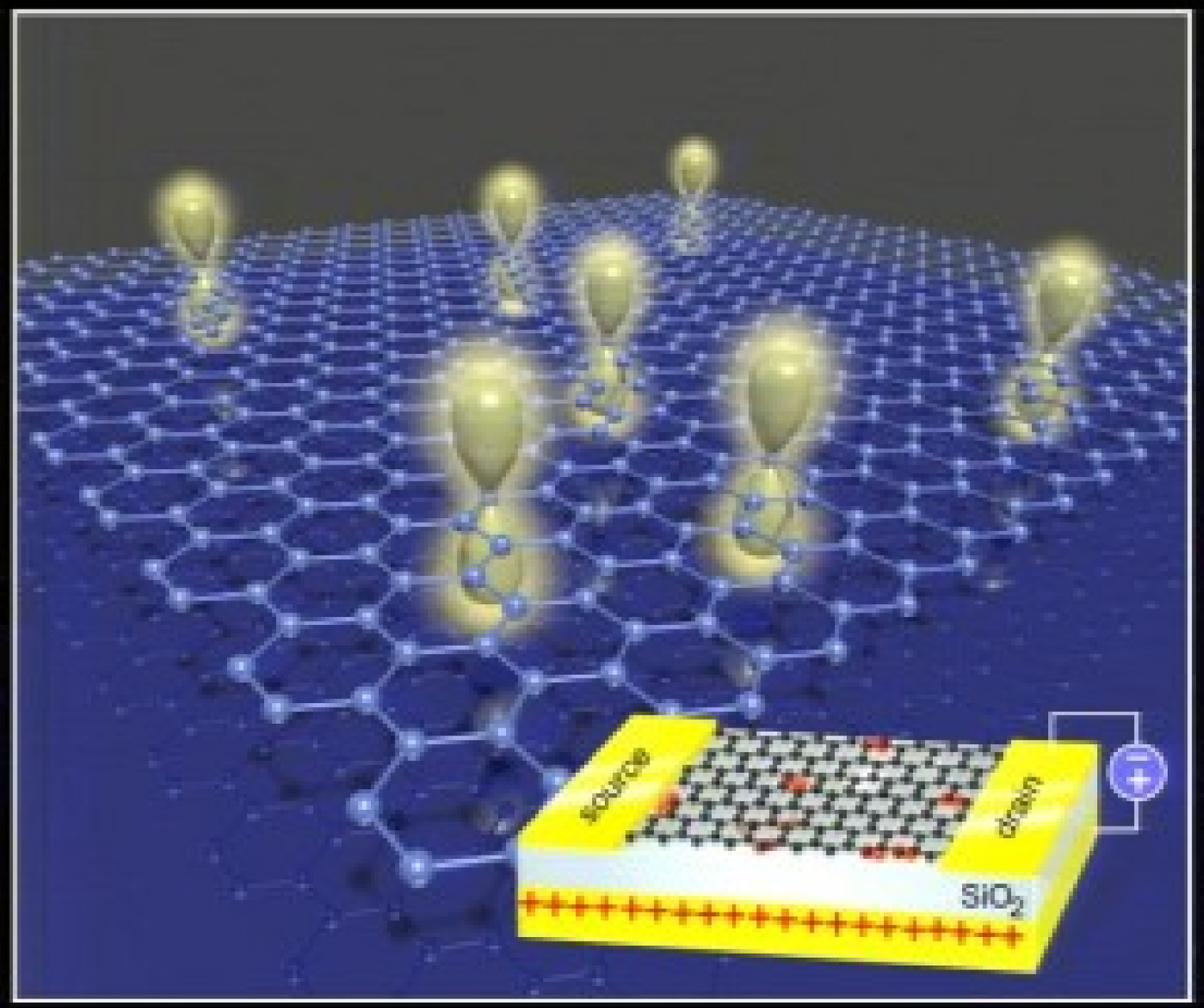
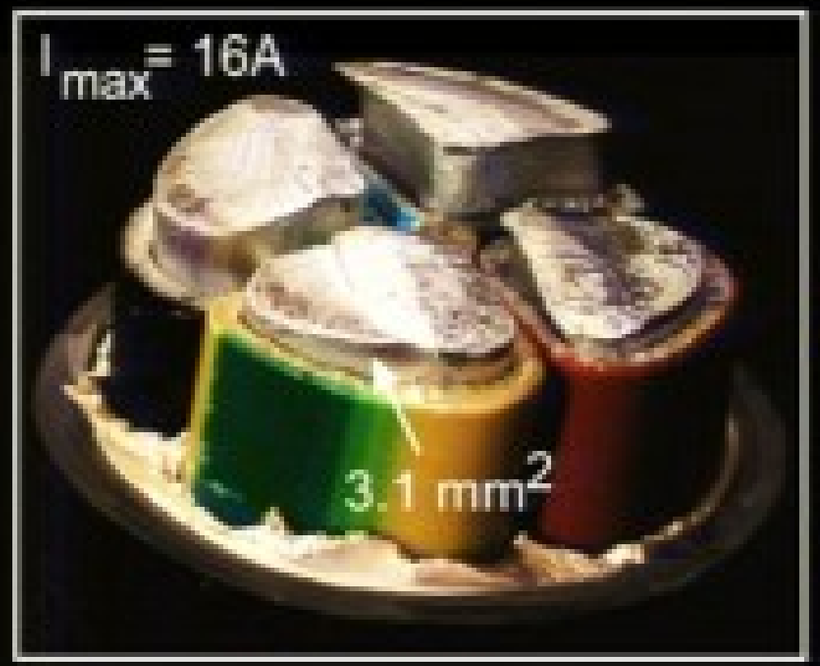
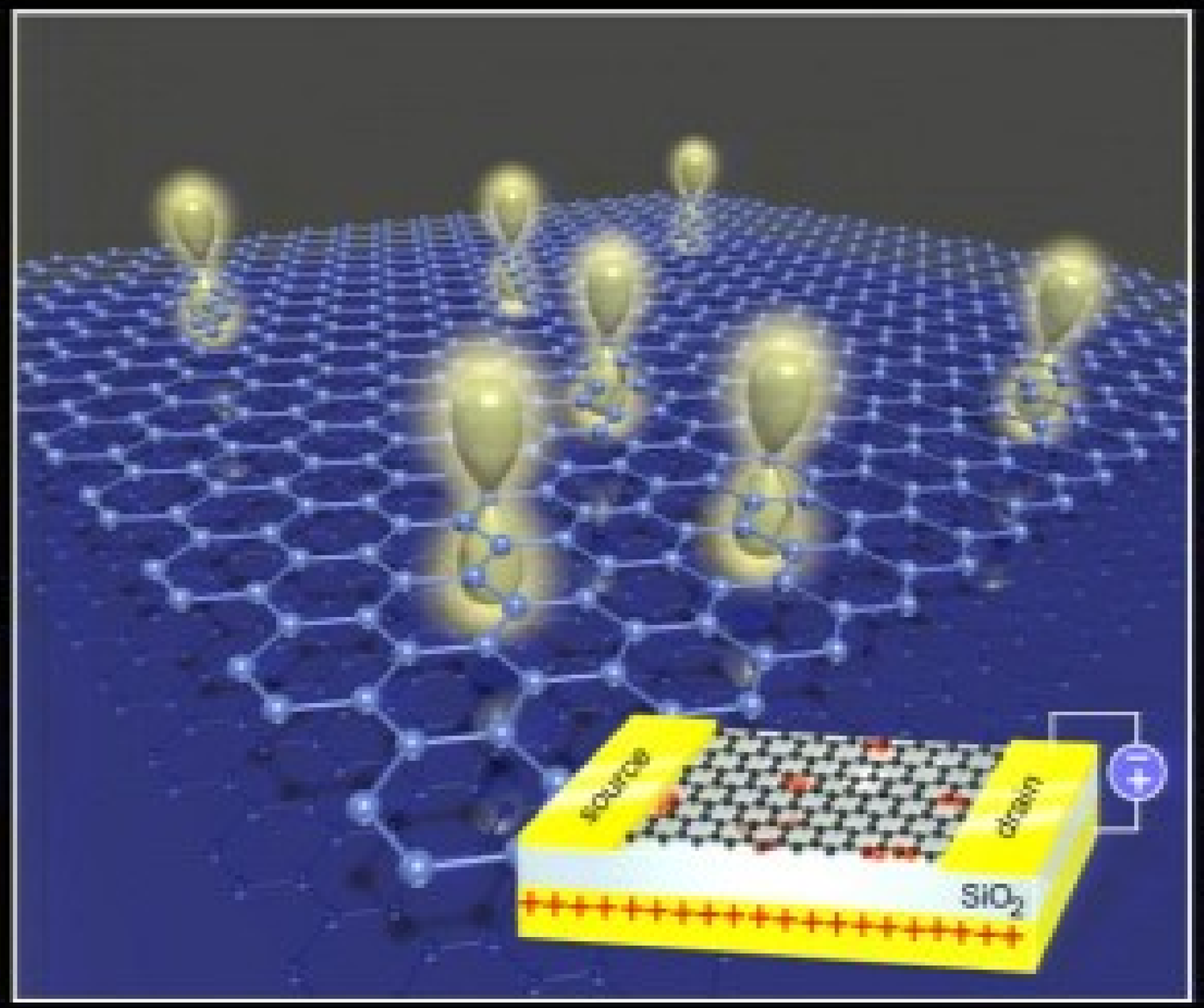


figure of merit: charge carrier mobility

$$v_d = \mu E$$

Superb conductor





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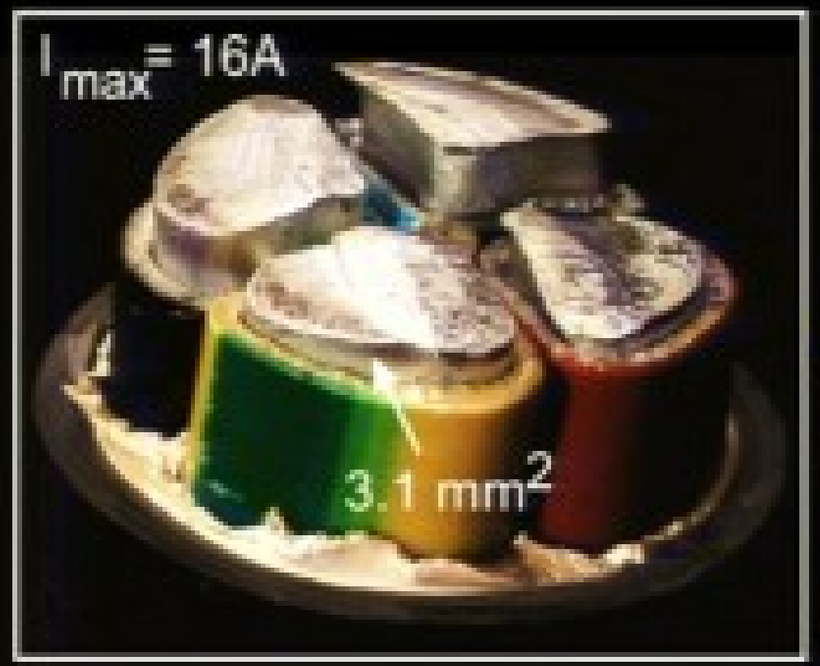


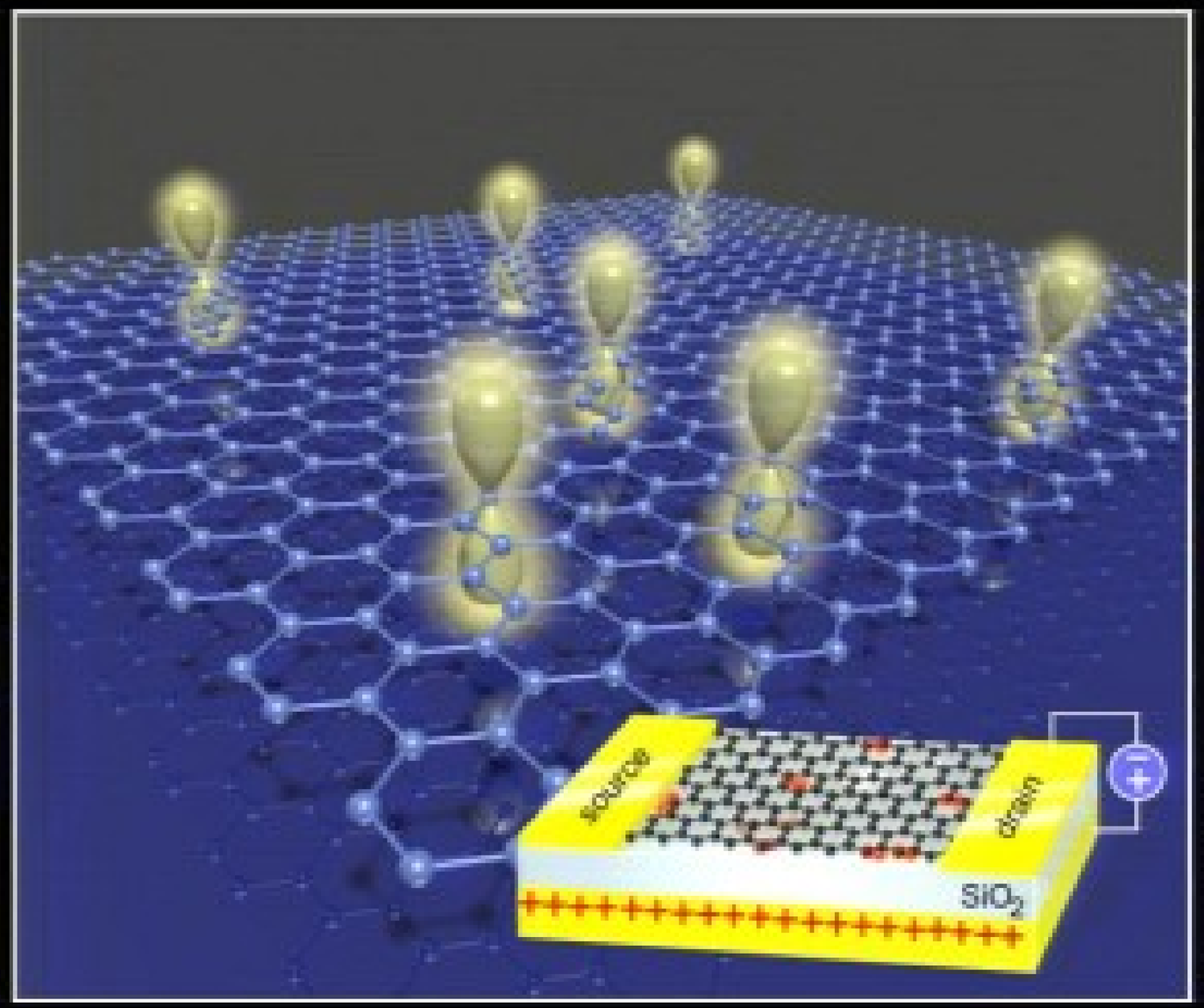
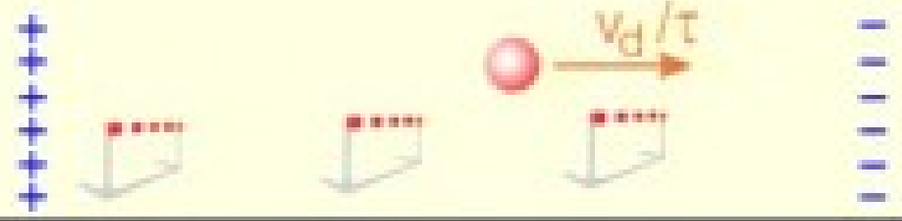


figure of merit: charge carrier mobility



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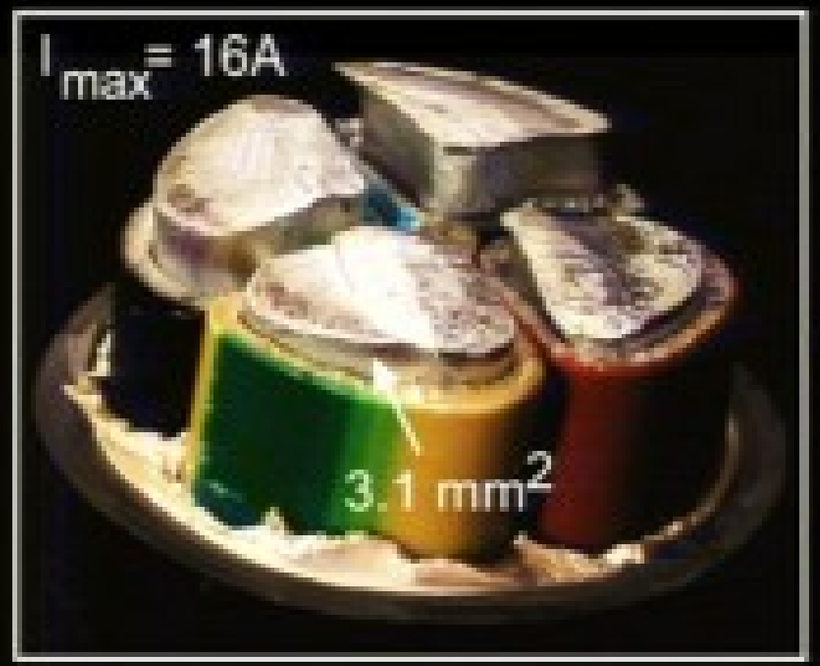

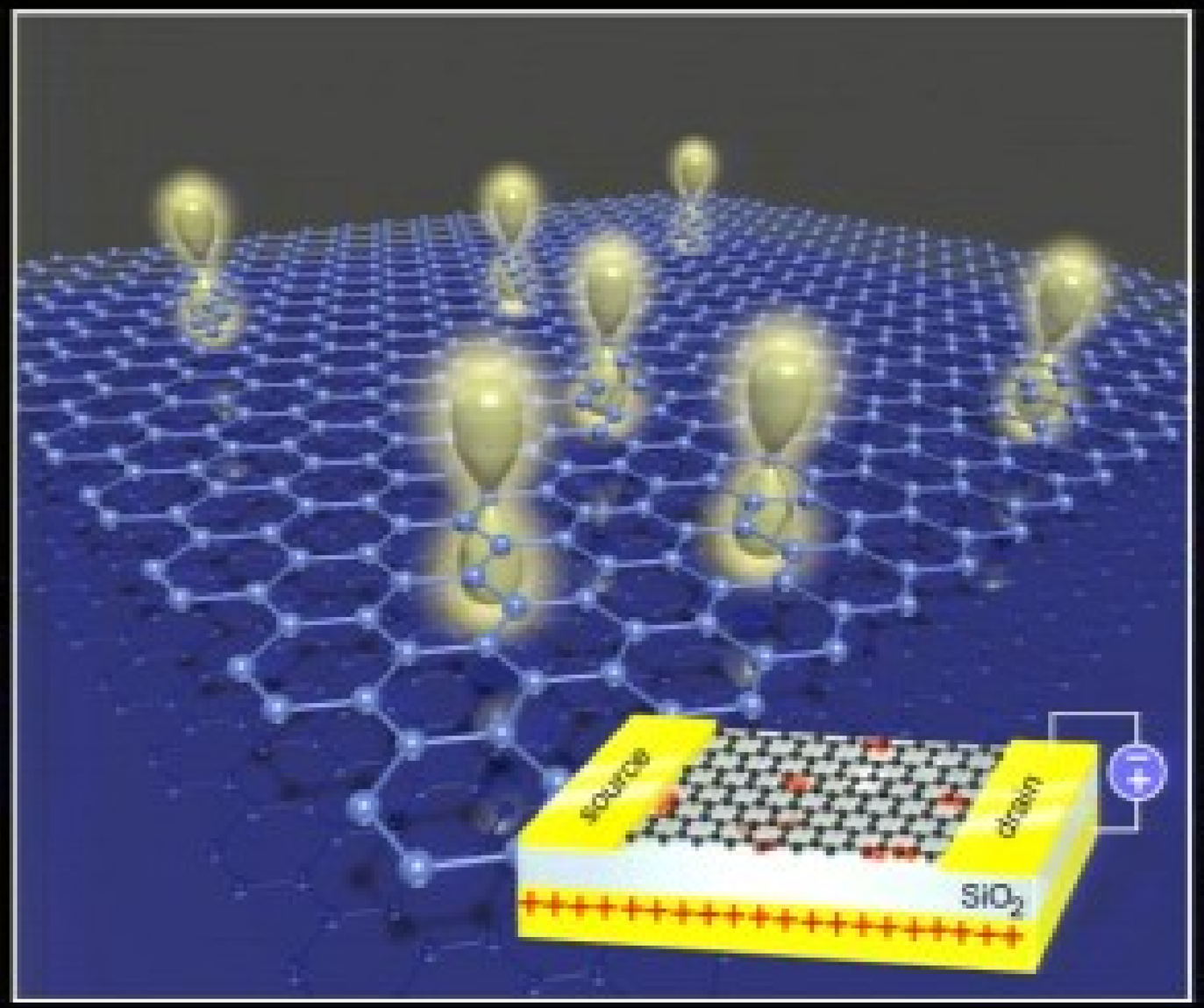

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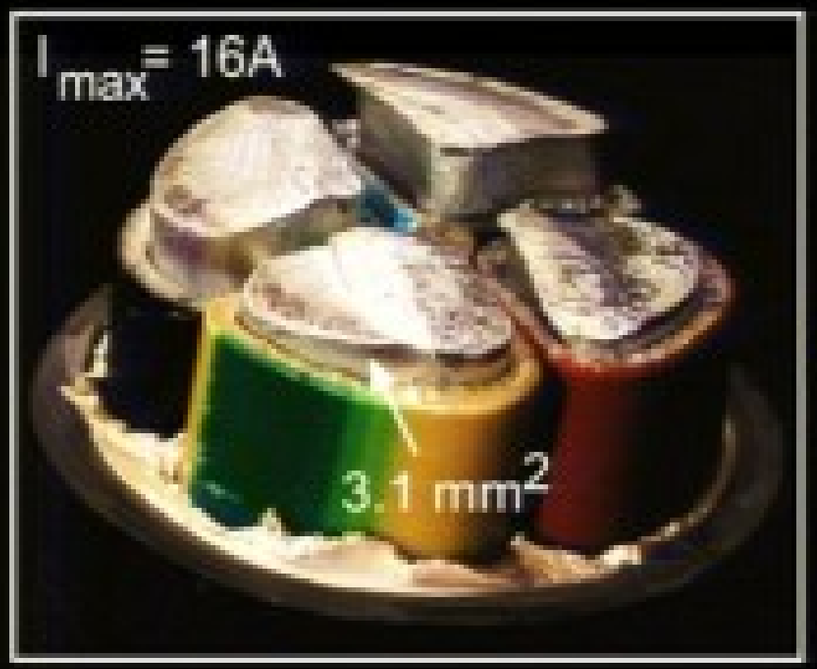
Superb conductor



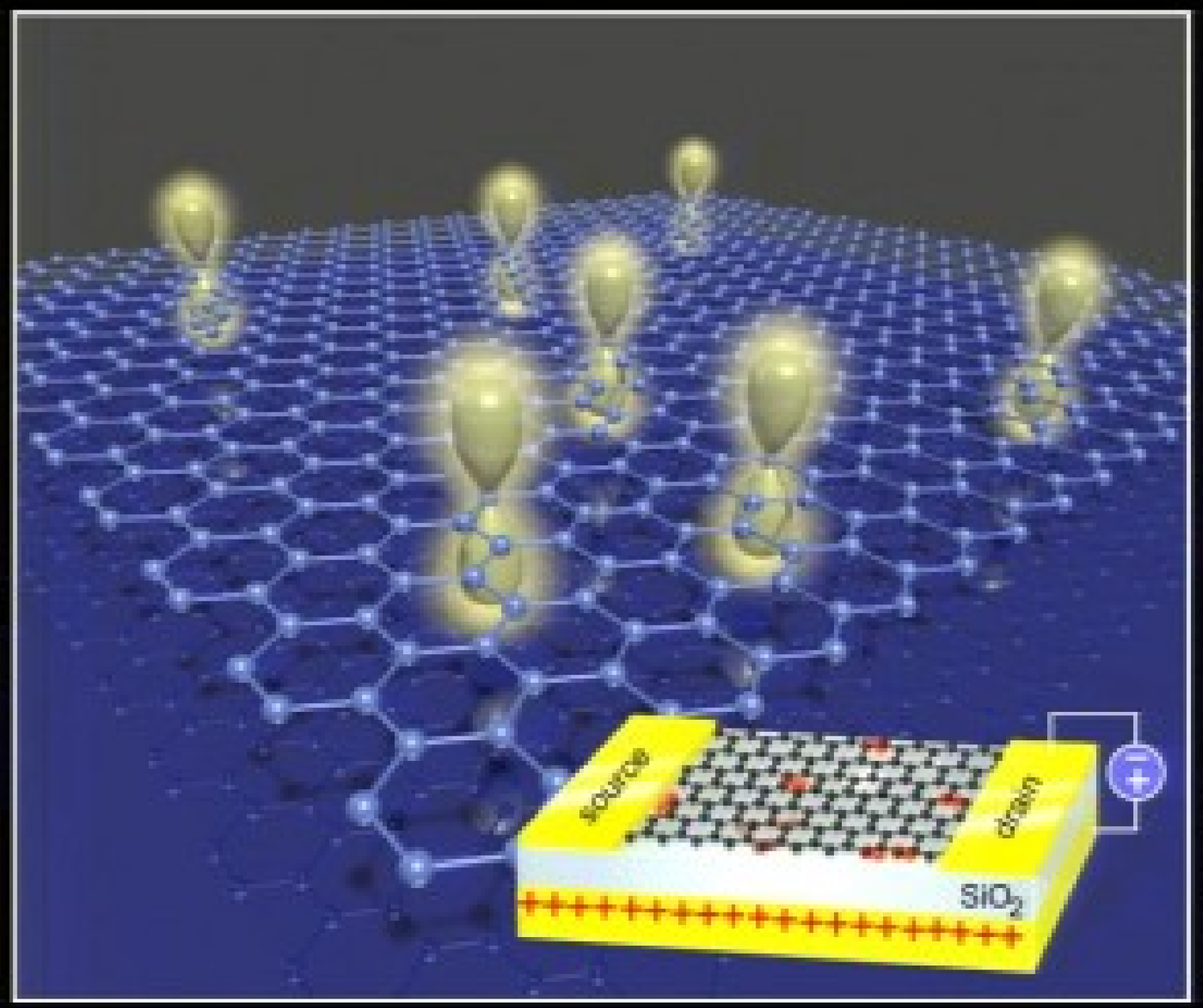


figure of merit: charge carrier mobility

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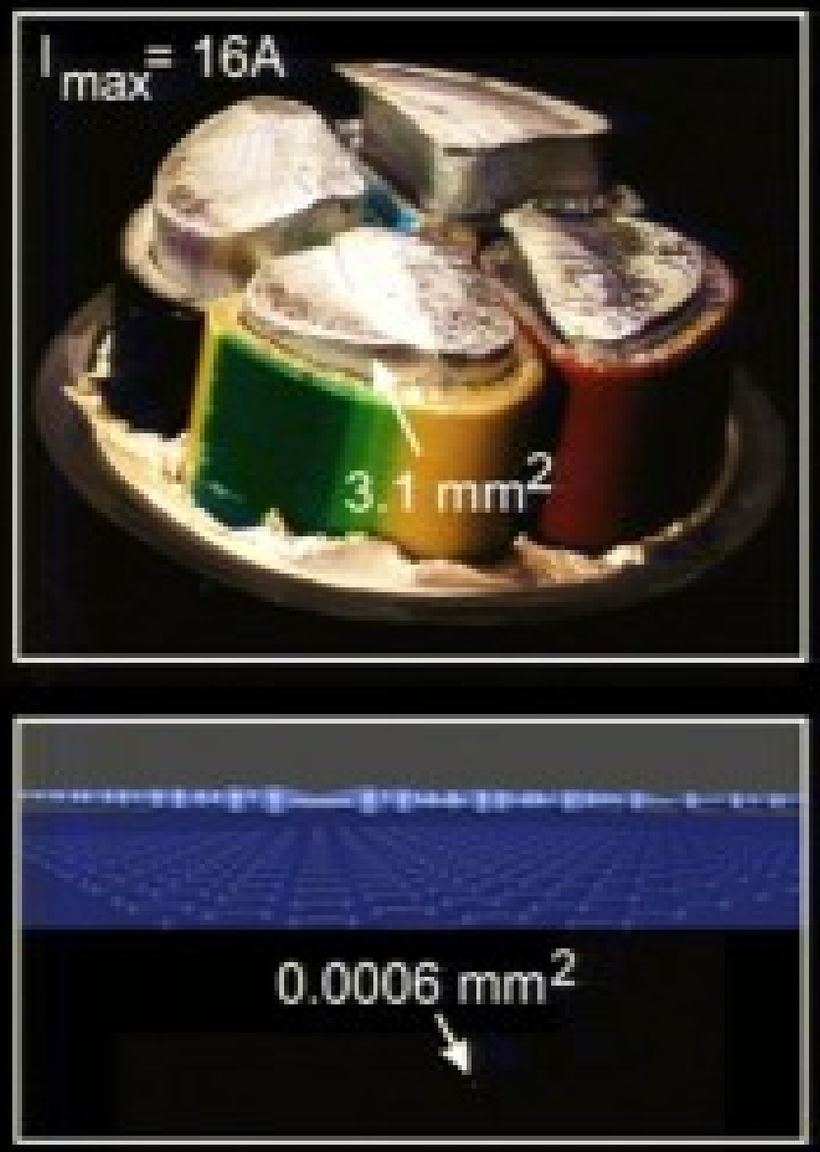
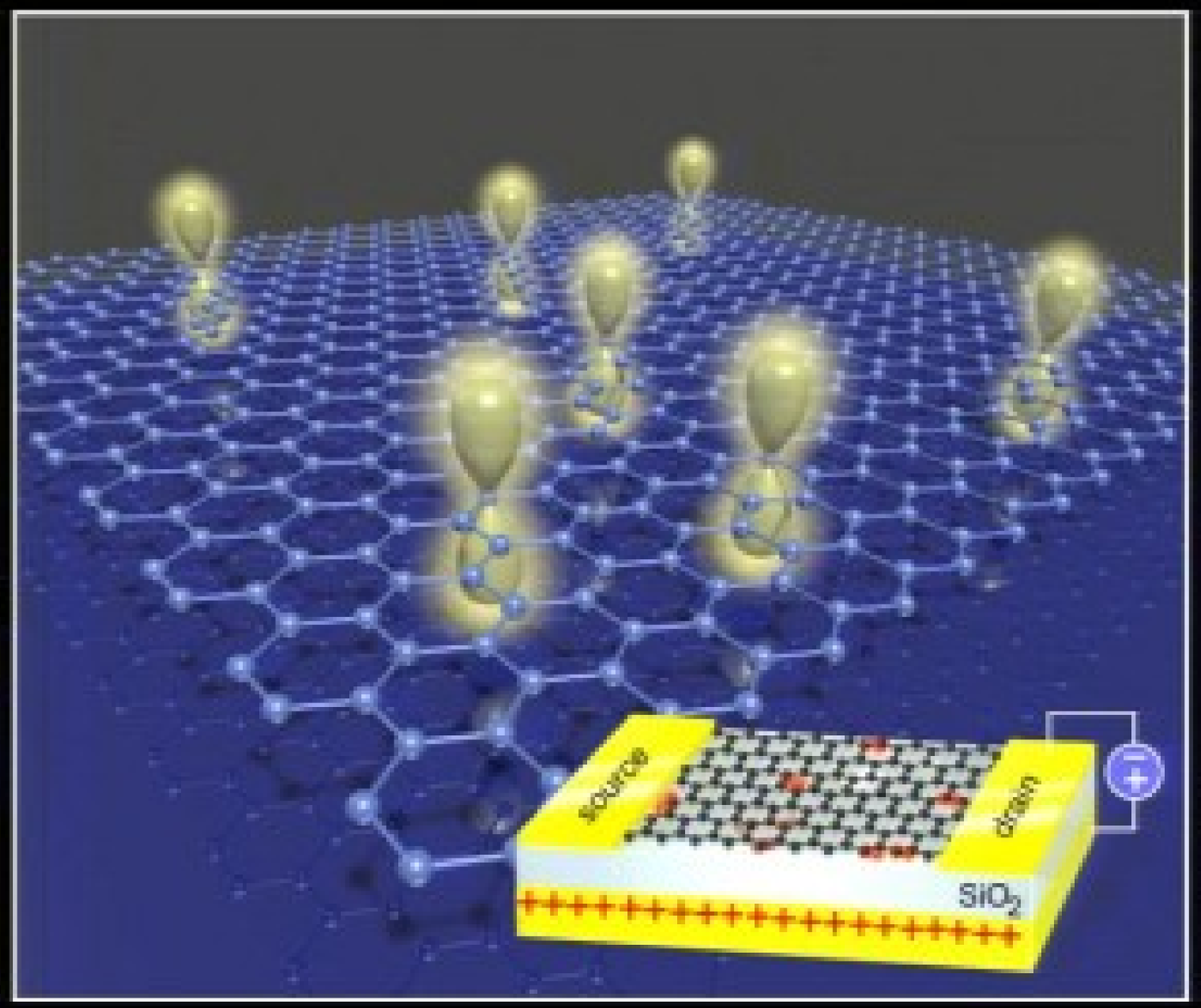
Superb conductor





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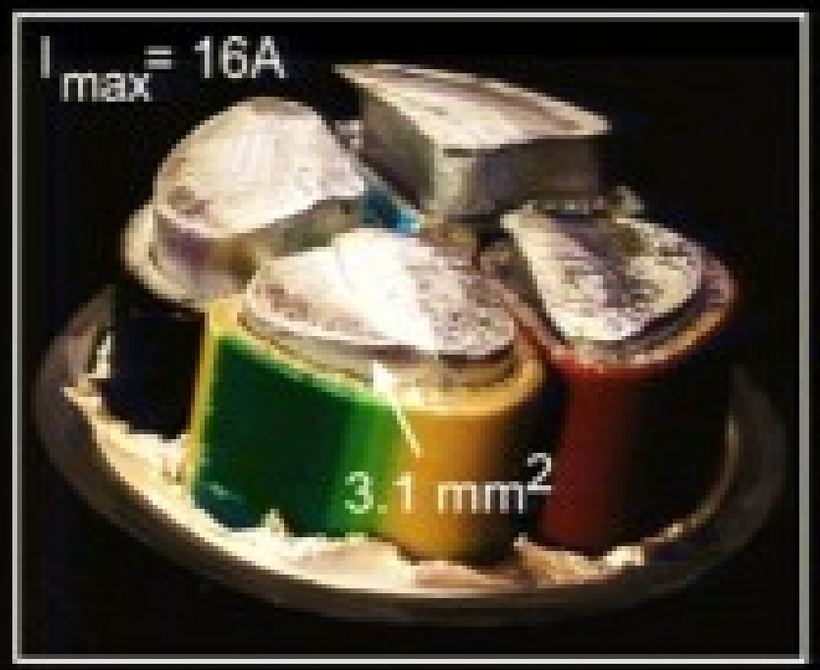
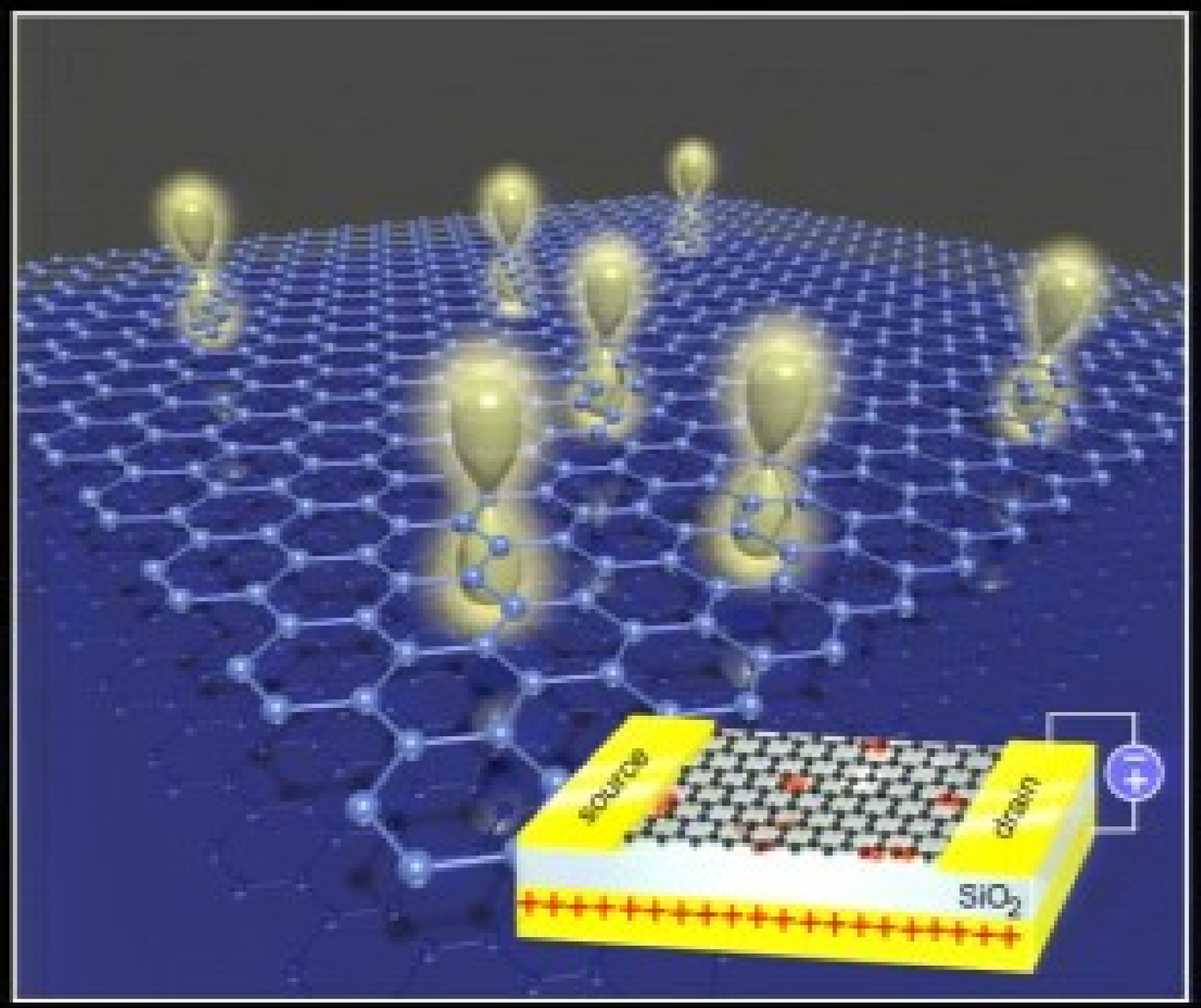
Superb conductor





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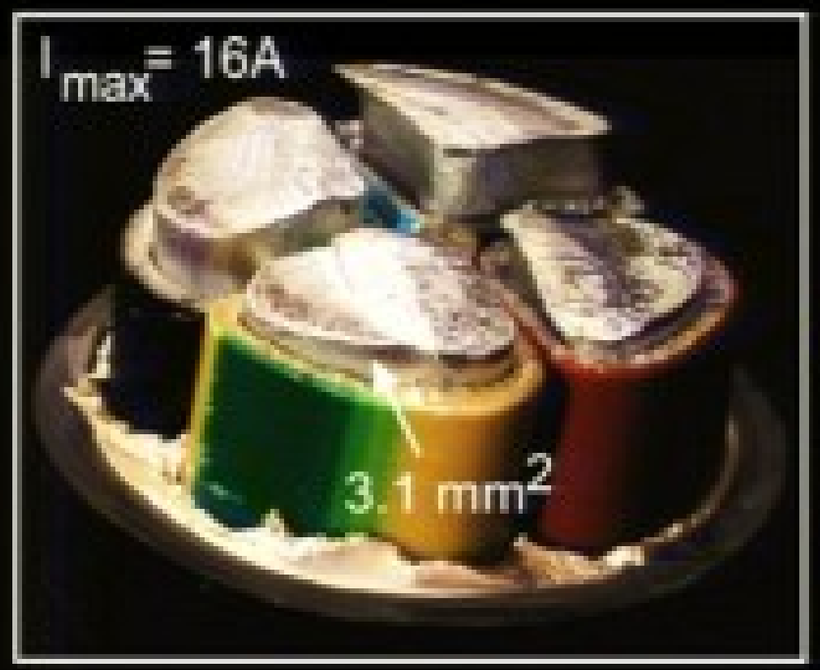
Superb conductor



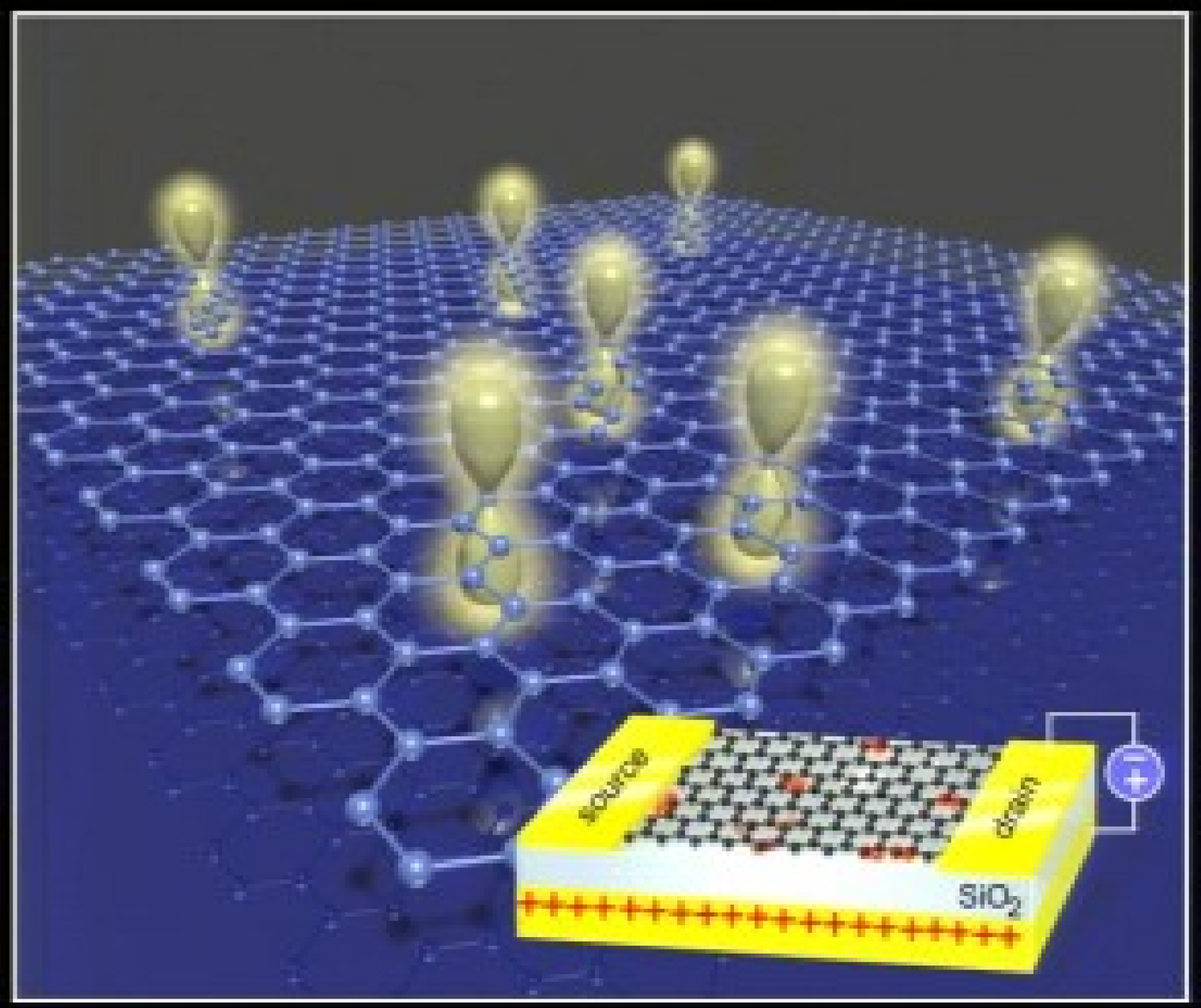
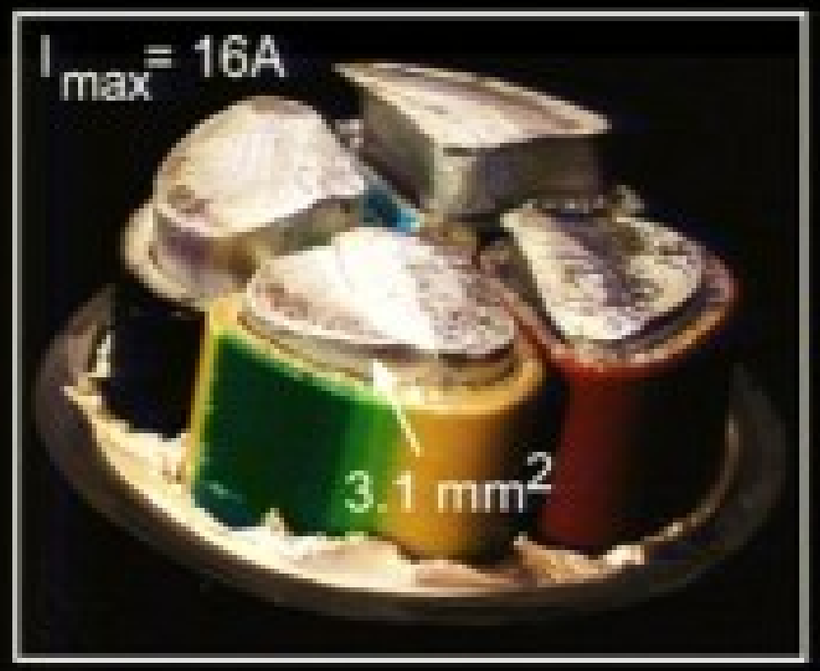


figure of merit: charge carrier mobility

$$v_d = \mu E$$

Superb conductor



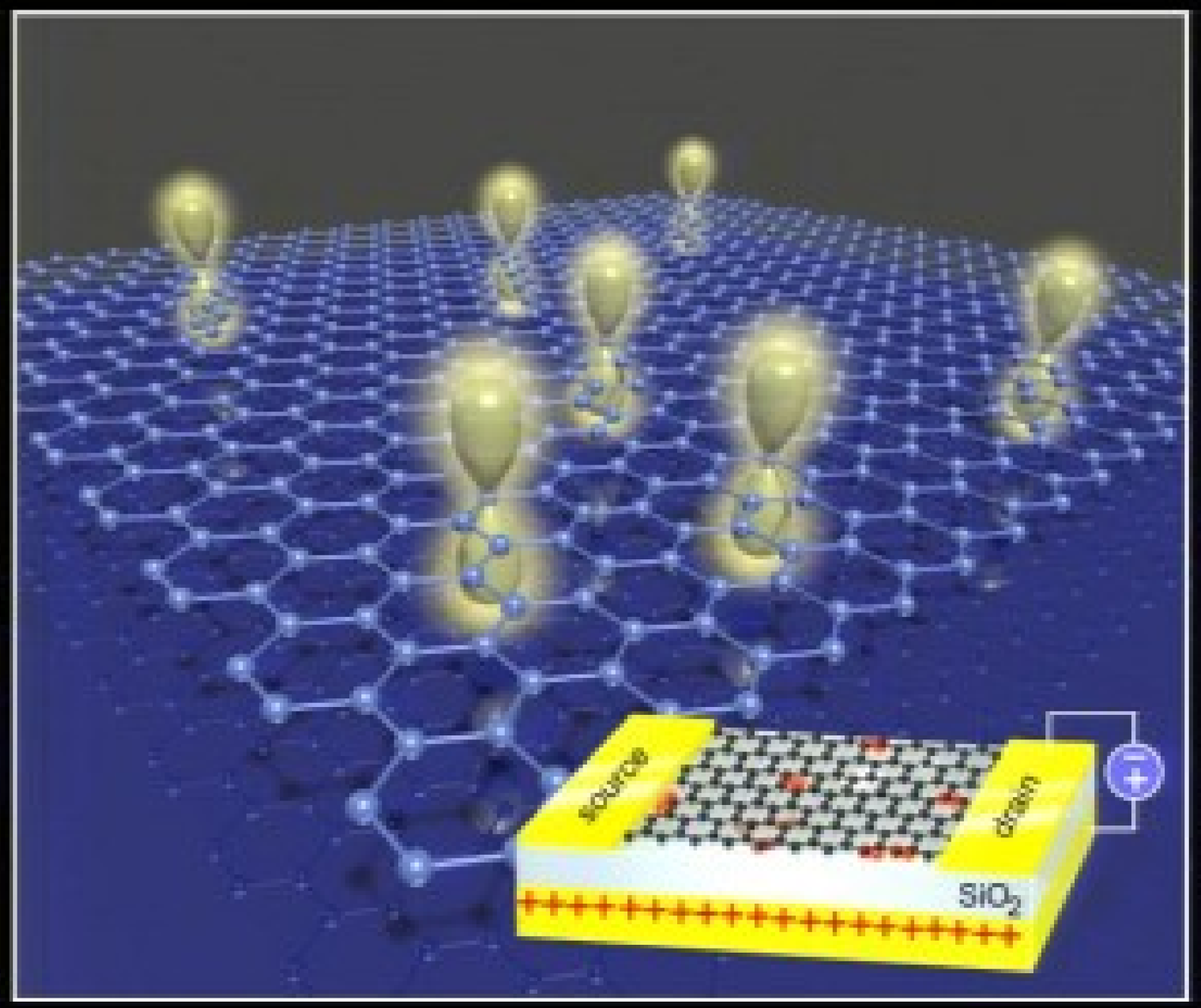
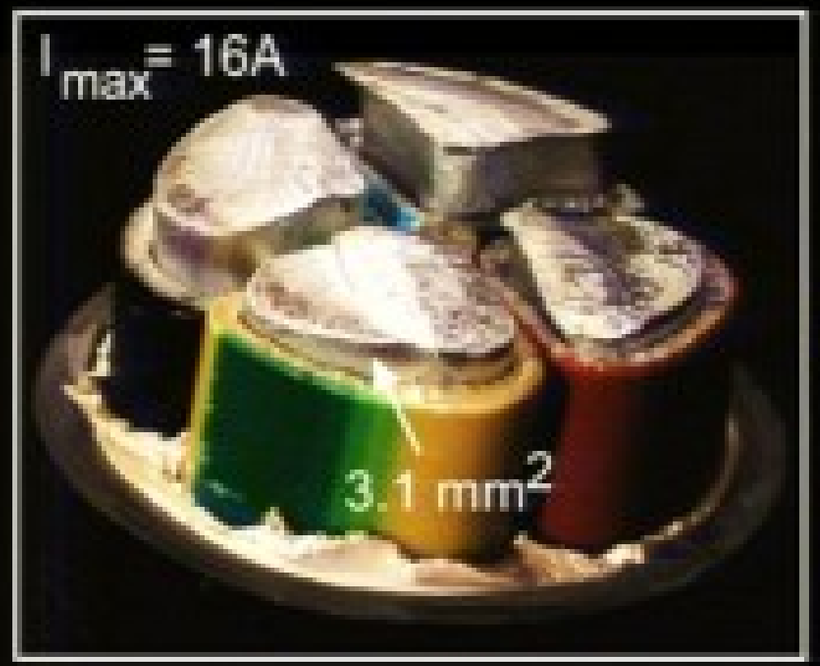


figure of merit: charge carrier mobility

$v_d = \mu E$

Superb conductor



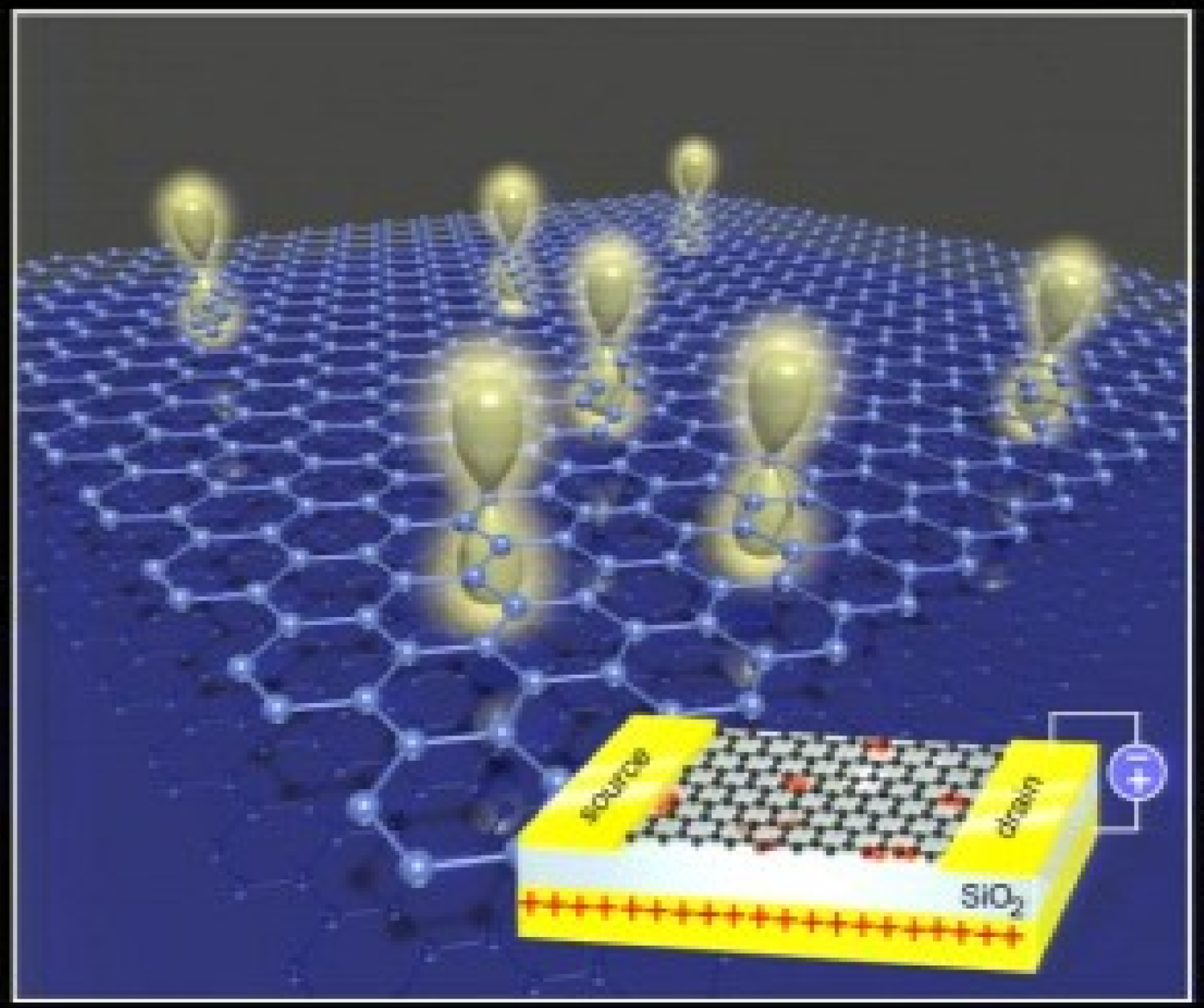
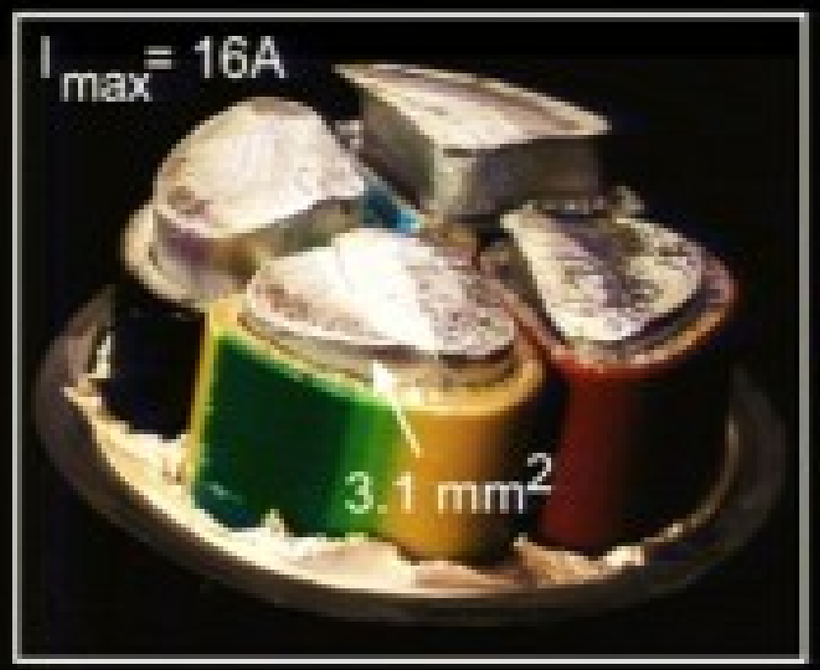


figure of merit: charge carrier mobility

$$v_d = \mu E$$

Superb conductor



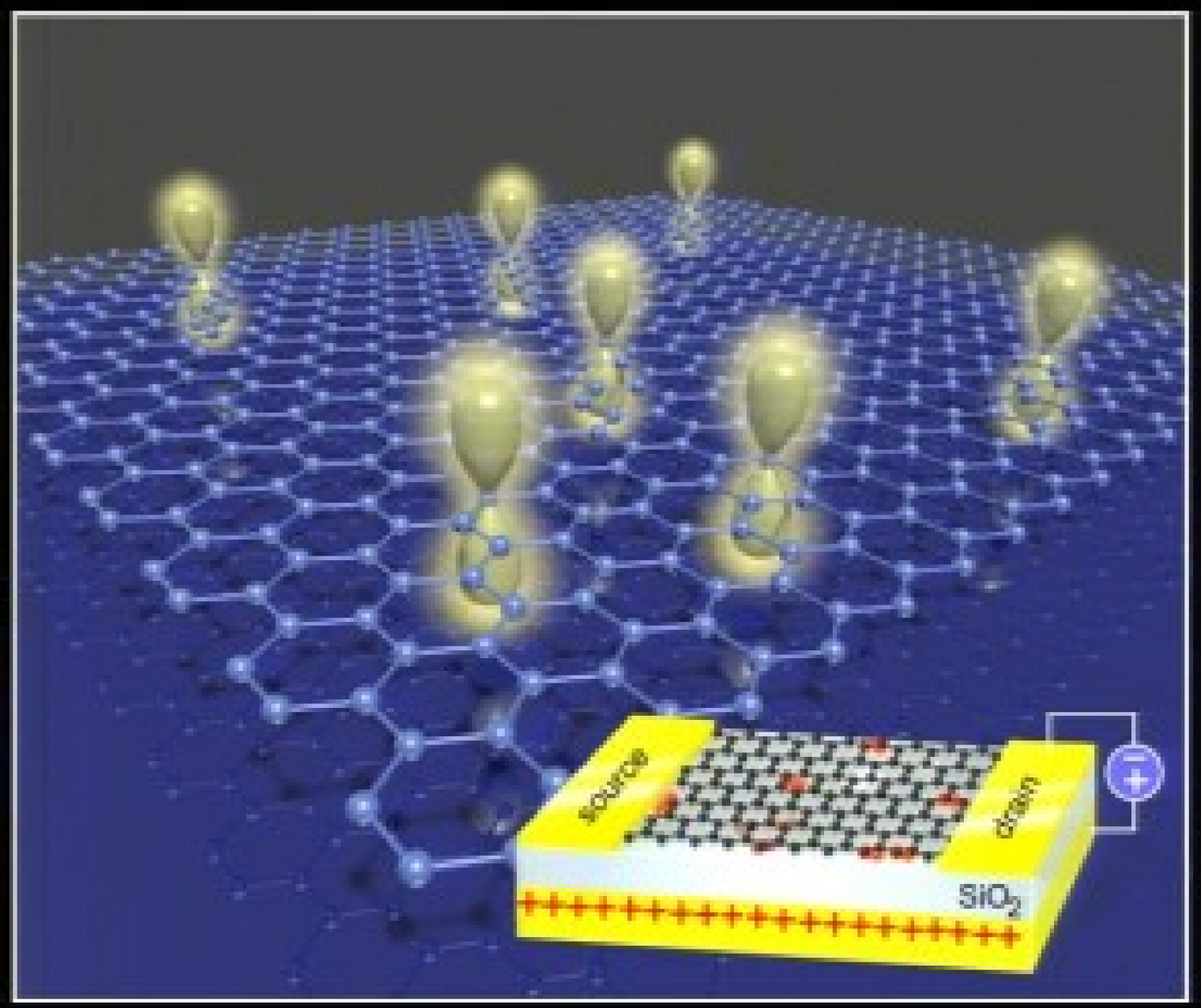
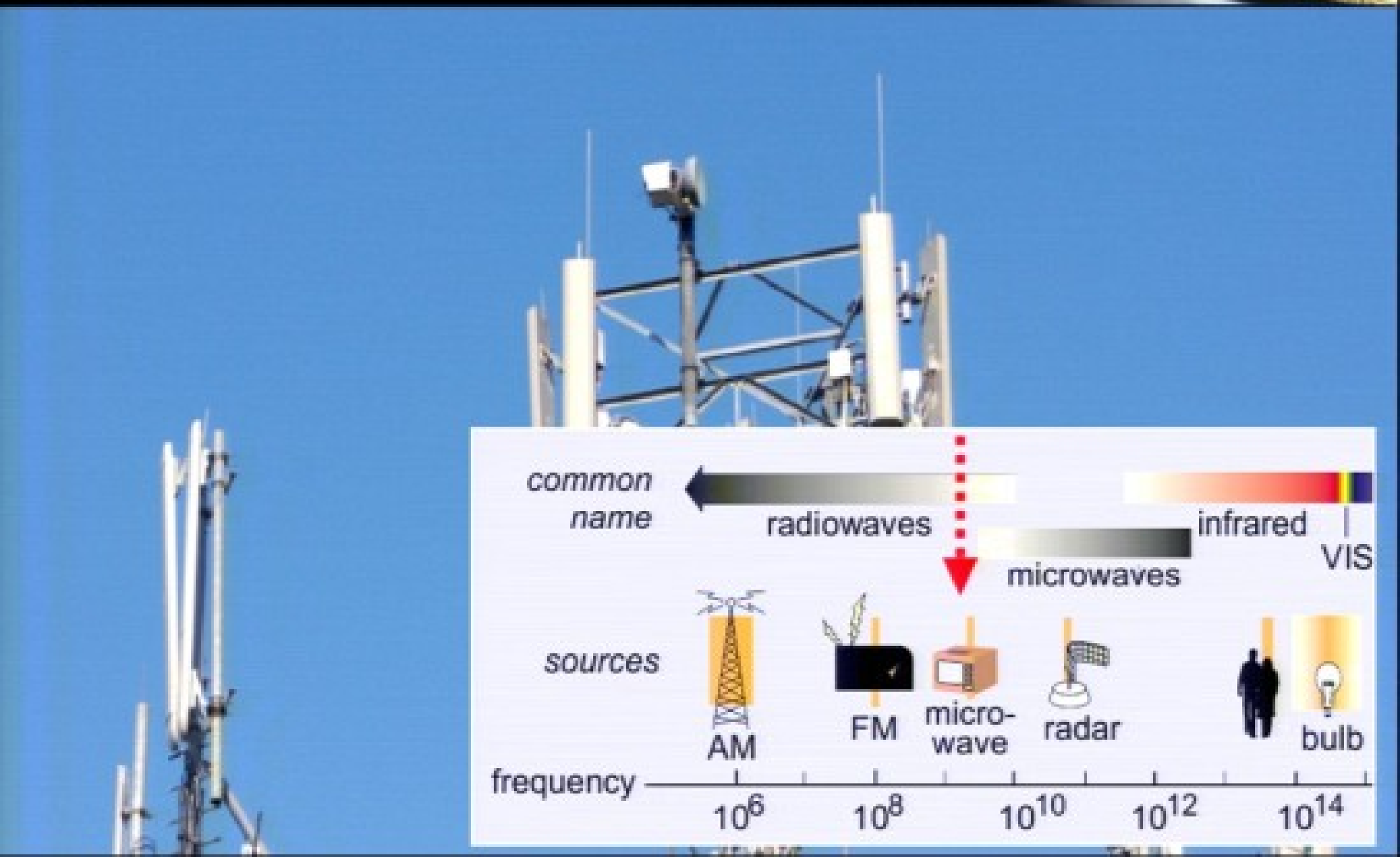


figure of merit: charge carrier mobility

$$v_d = \mu E$$

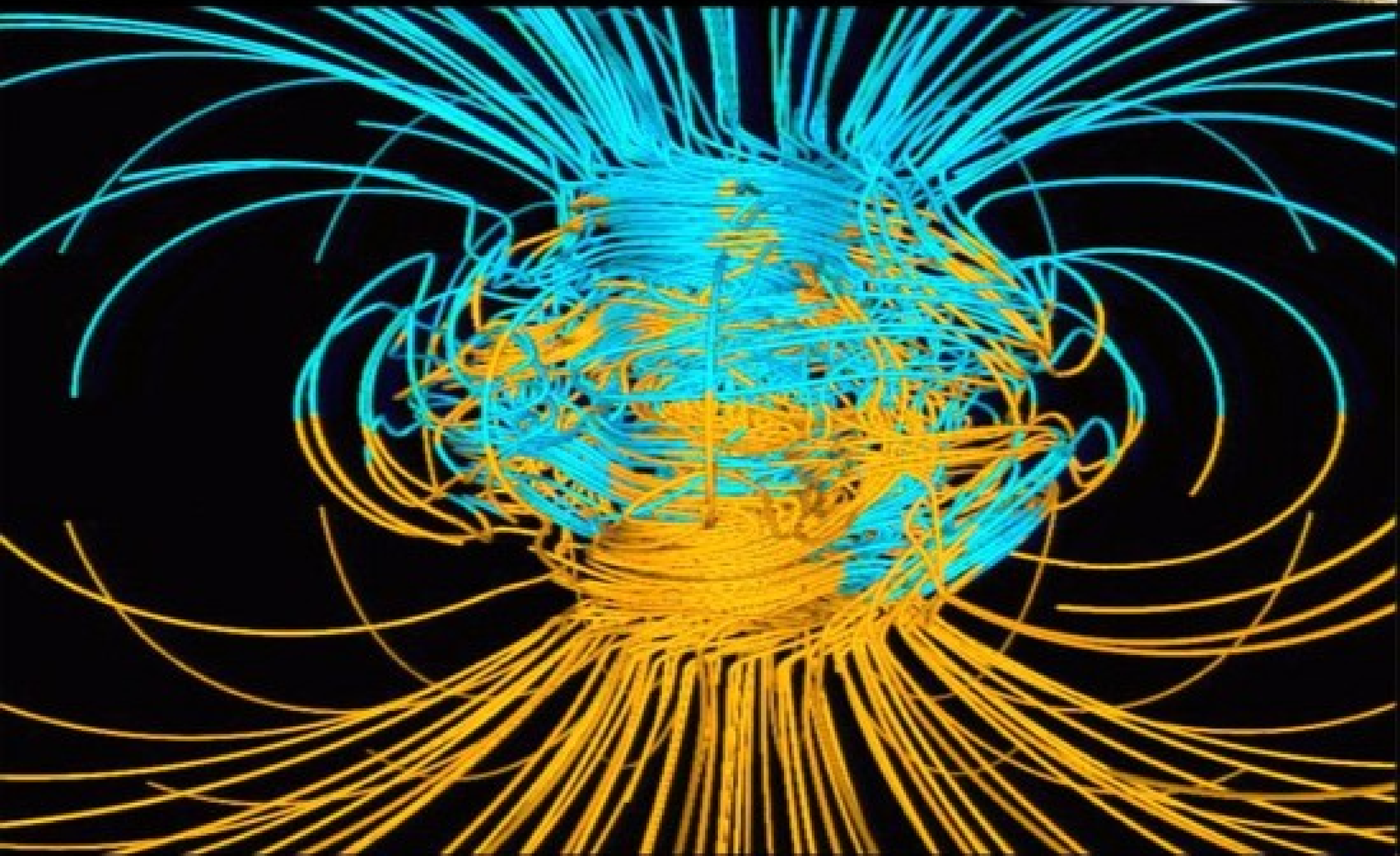
High frequency transistors

High frequency transistors

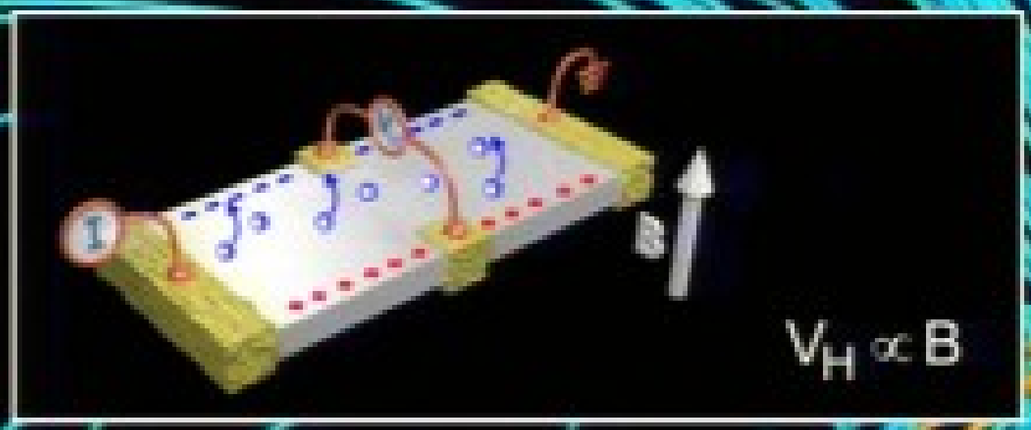


High frequency transistors

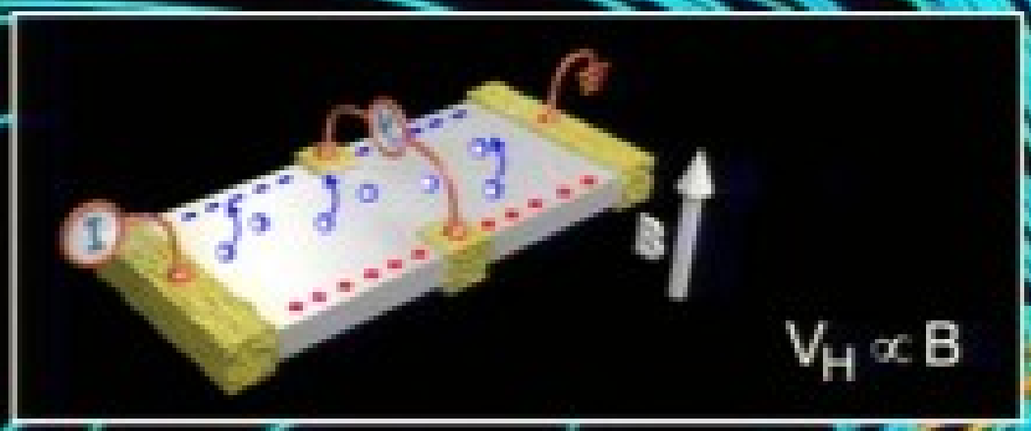
Hall and geomagnetic sensors



Hall and geomagnetic sensors



Hall and geomagnetic sensors



Applications

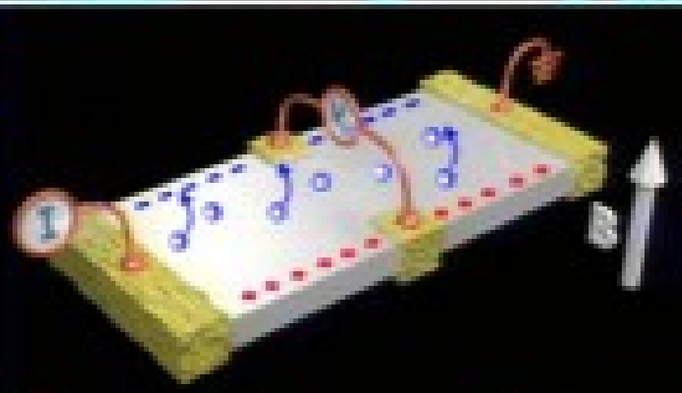
- navigation, orientation, compass

- air mouse and pointing devices
- automotive sensing:
  - proximity switching
  - position & speed detection (rpm)
  - anti-lock breaking, run flat

- speed regulation in disk drives

⋮

Hall and geomagnetic sensors



Hall voltage:

$$V_H = R_H \cdot I = \frac{B}{e \cdot n} \cdot I$$

Dissipation:

$$P = V_L \cdot I = R_L \cdot I^2 = \frac{1}{n \cdot e \cdot \mu} \cdot \frac{L}{W} \cdot I^2$$

Applications

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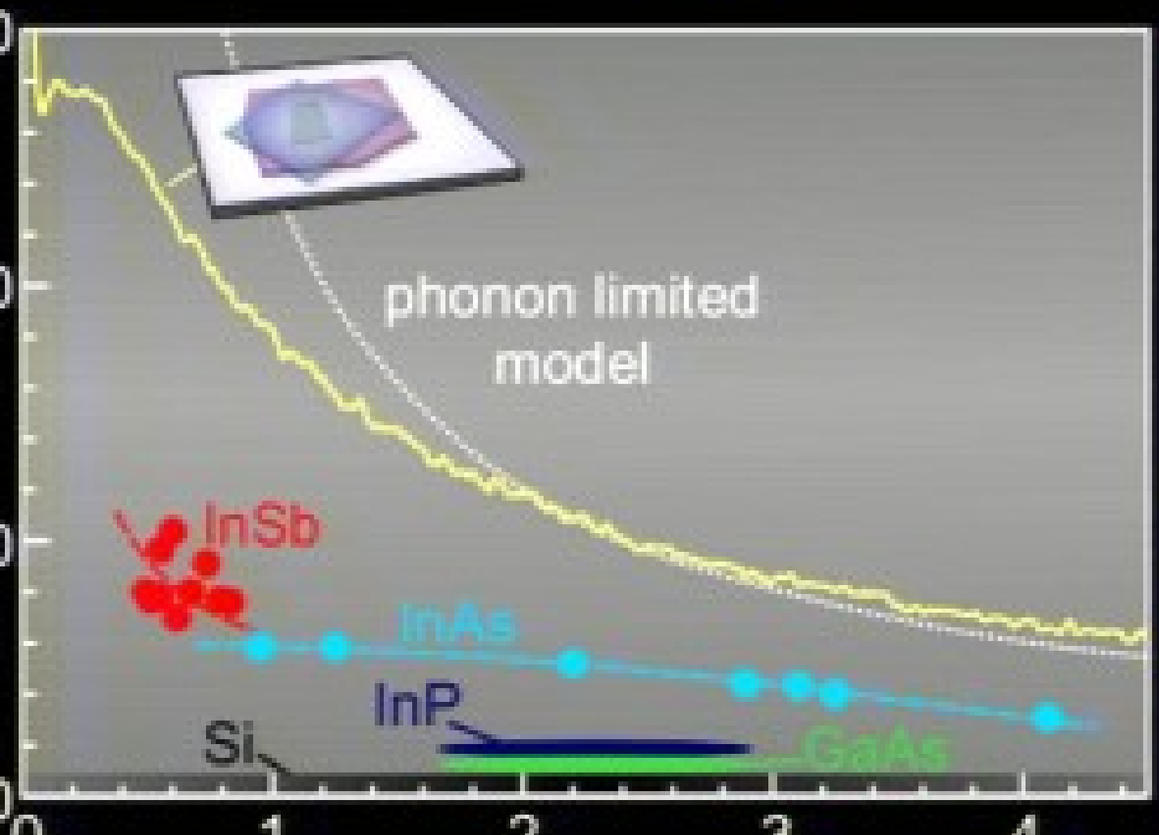
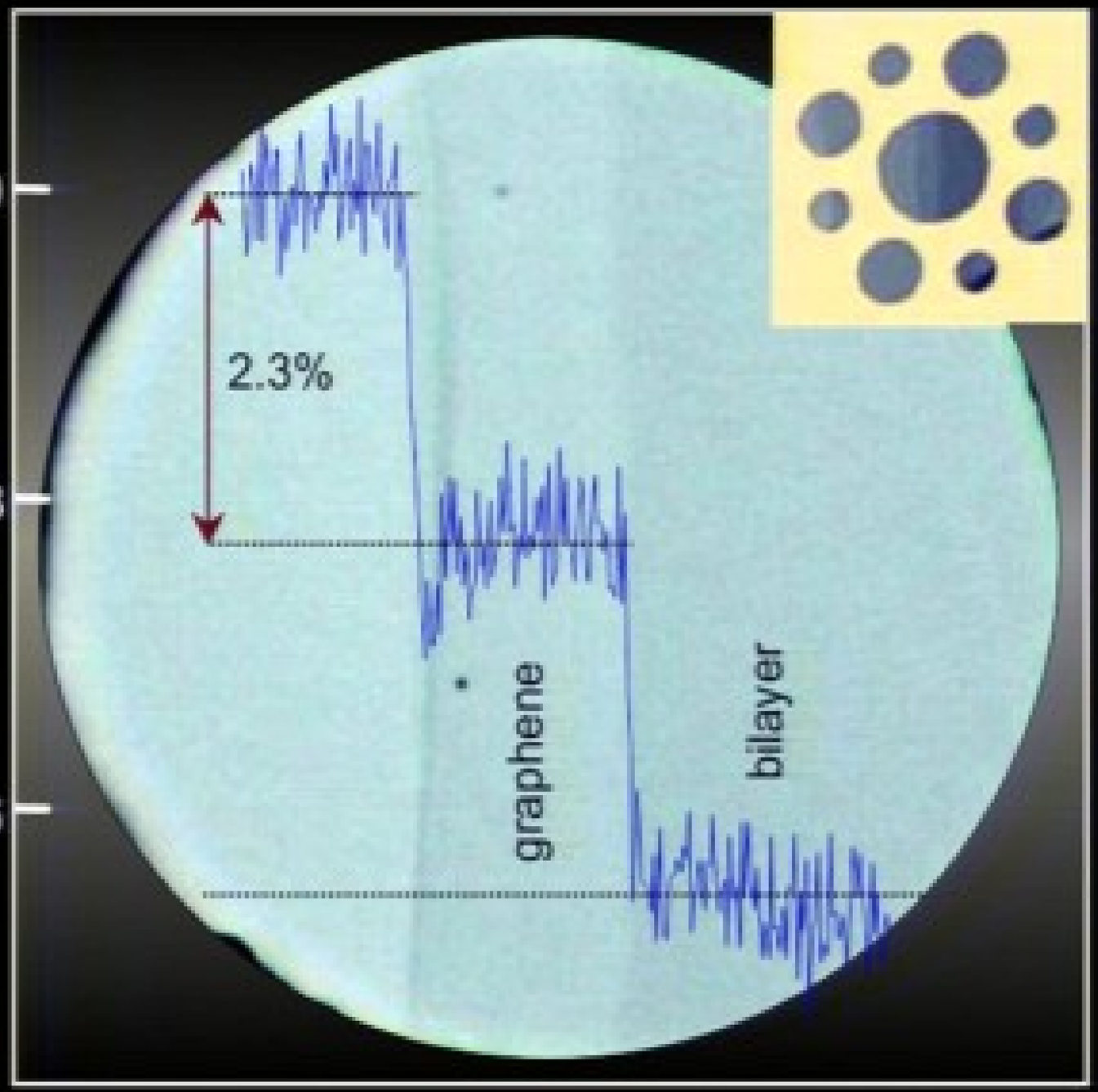


Wang *et al.*, Science 342, 614 (2013)

Transparency



R.Nair *et al.*, Science **320**, 1308 (2008)

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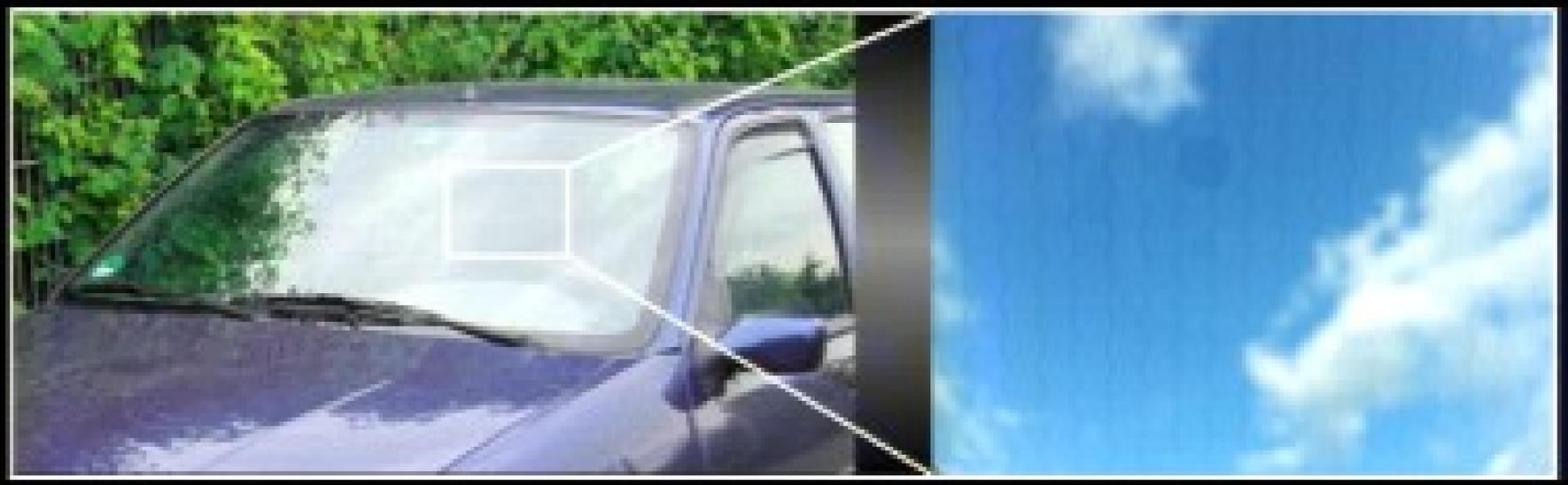
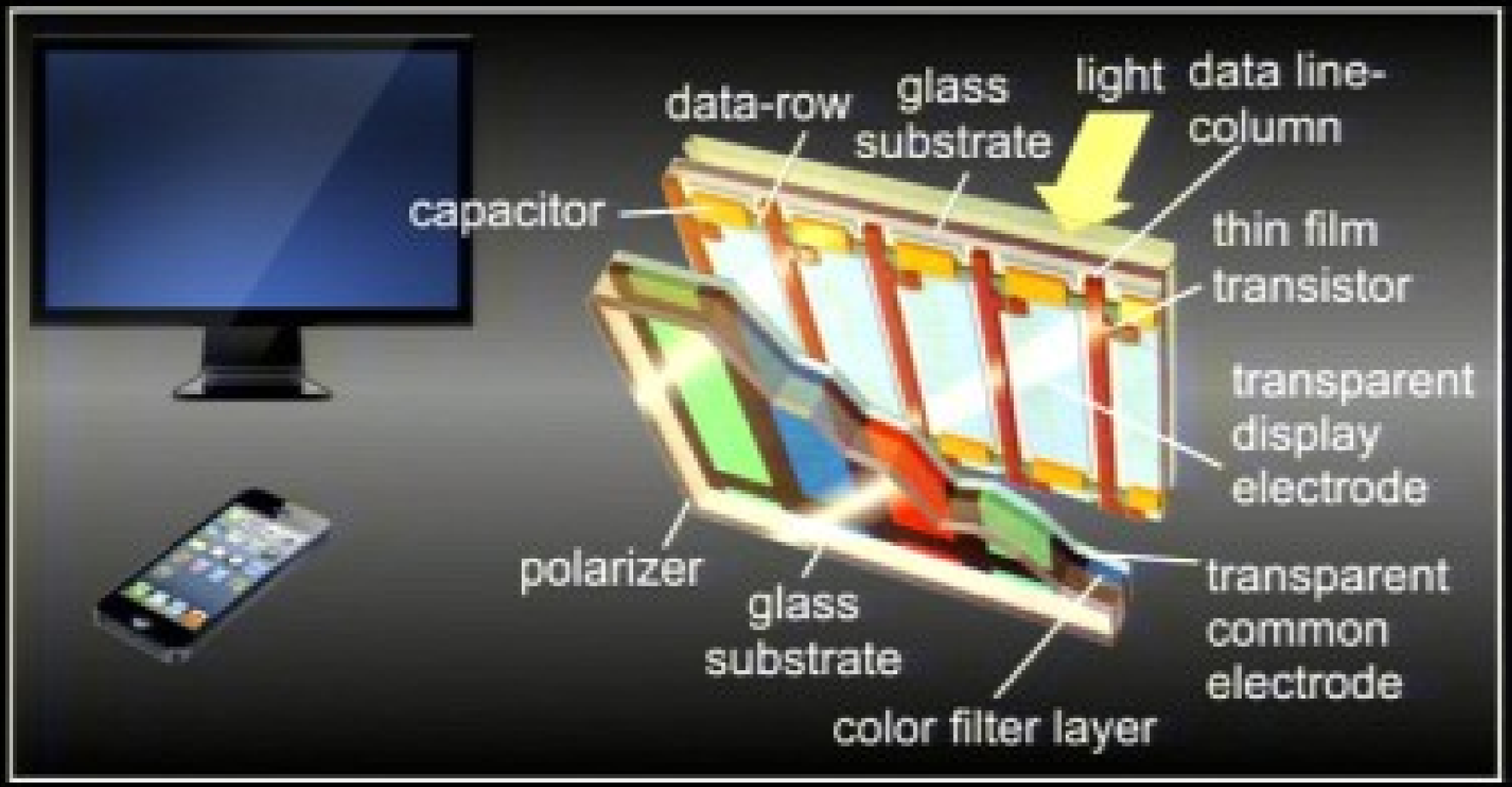


Transparency



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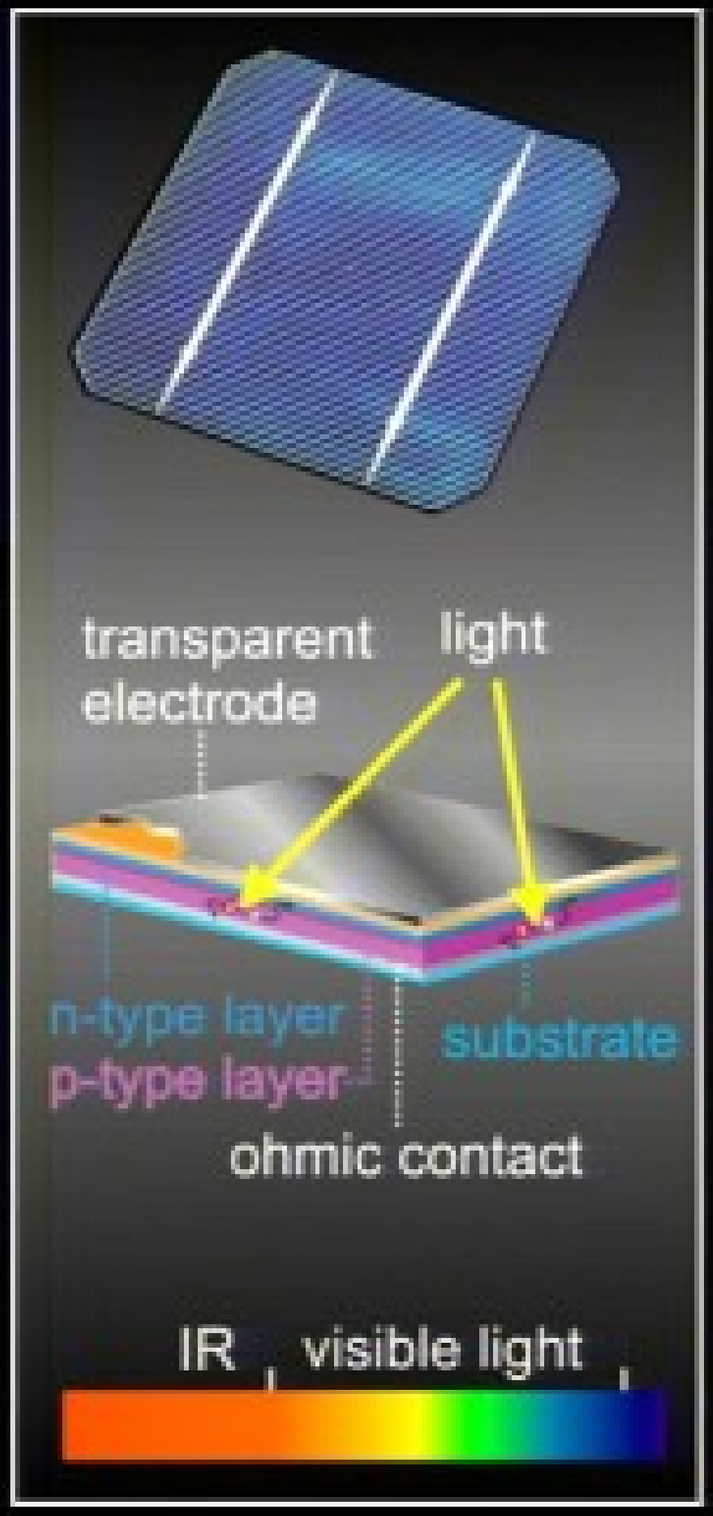
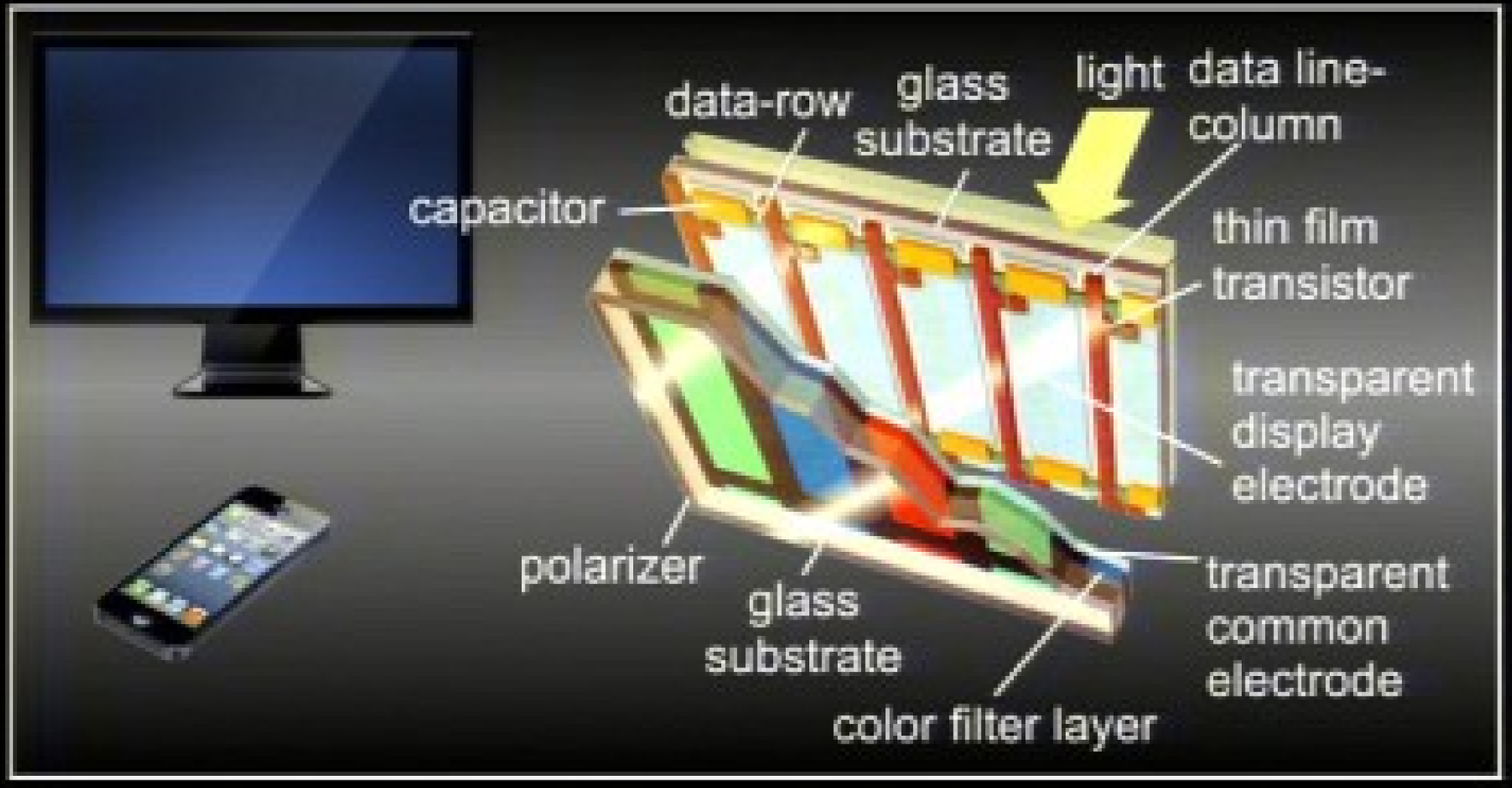
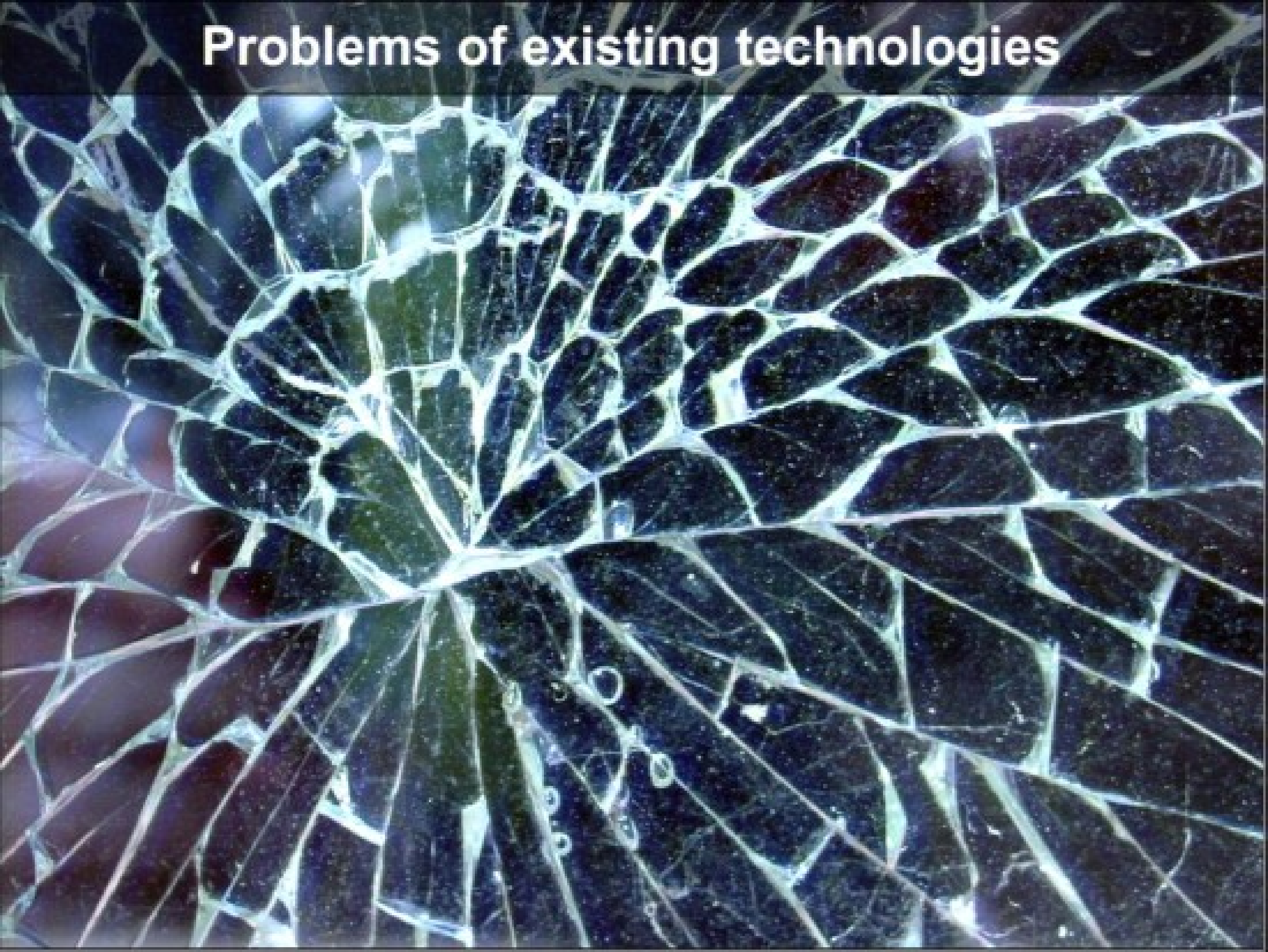




Problems of existing technologies



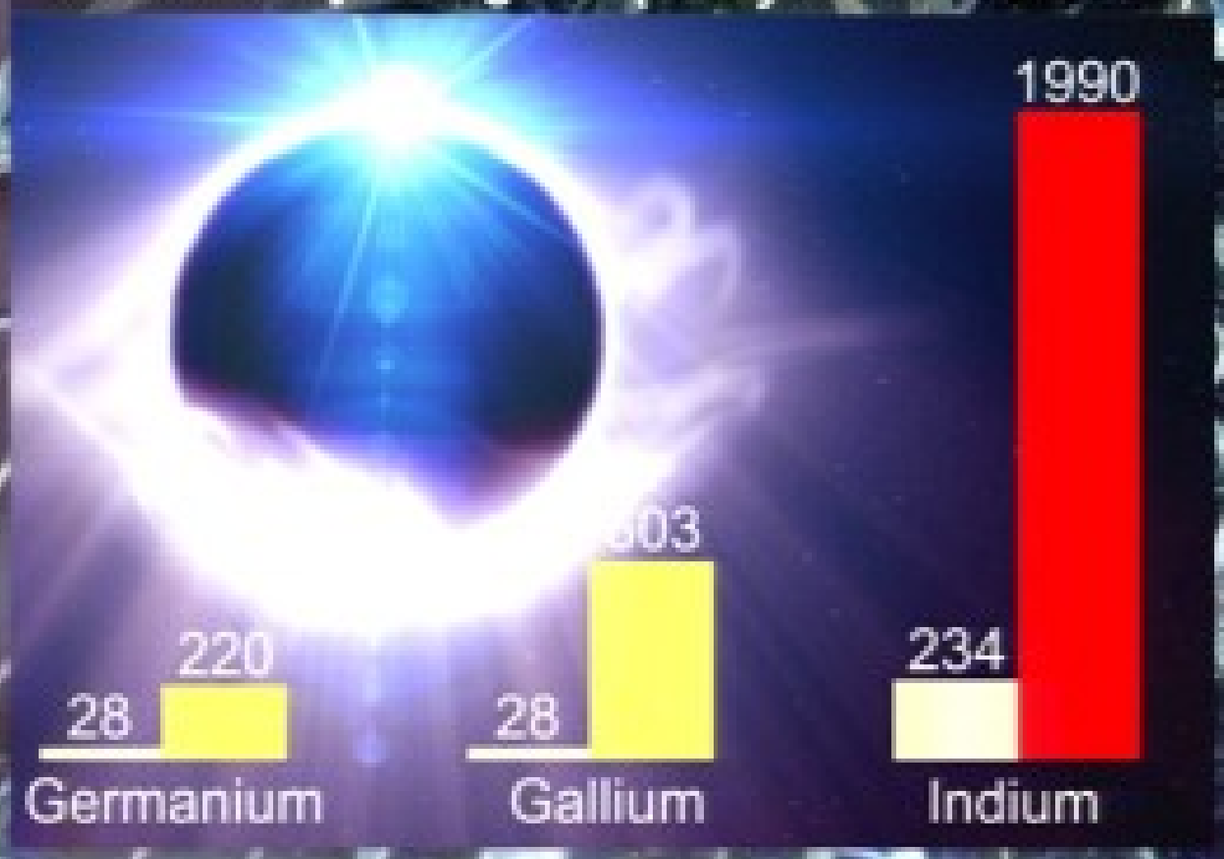
Problems of existing technologies

Flexibility

Problems of existing technologies

Flexibility

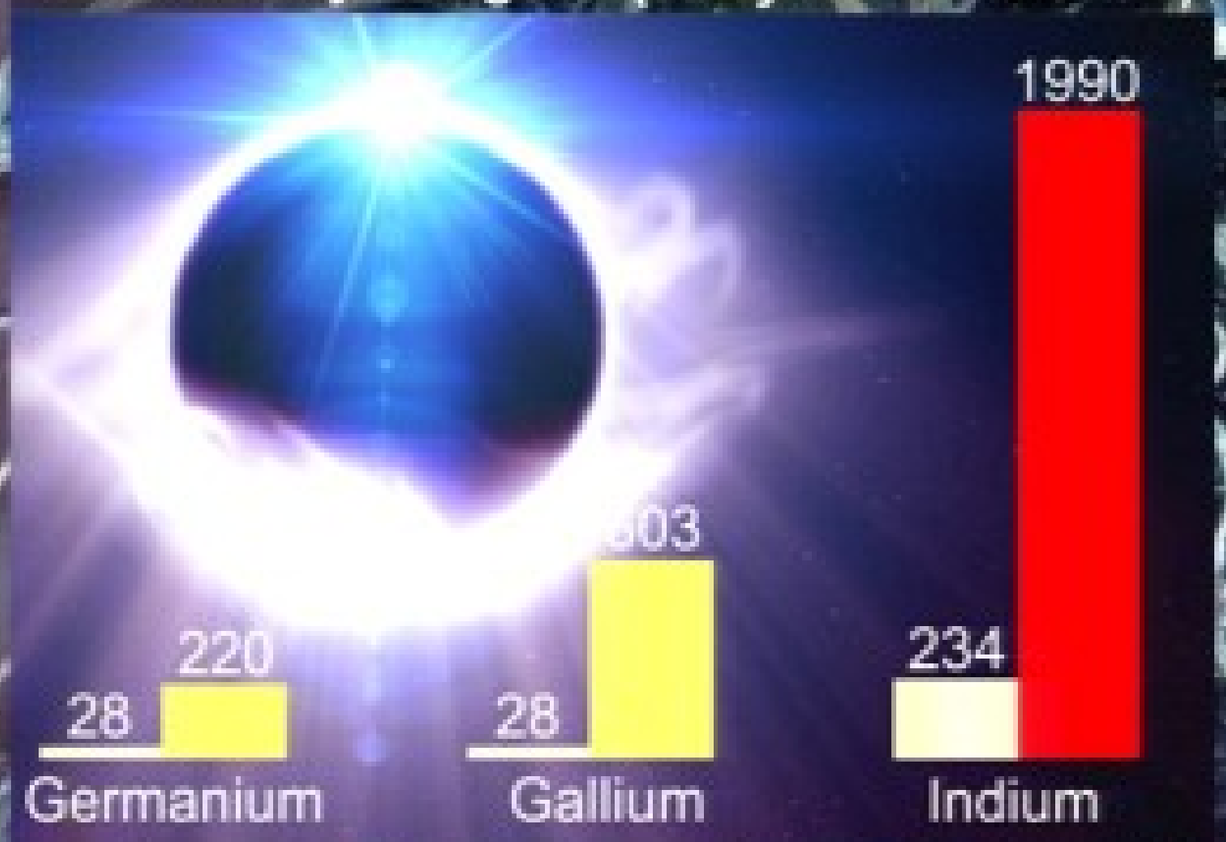
Availability/Usage (ton/year 2006-2030)



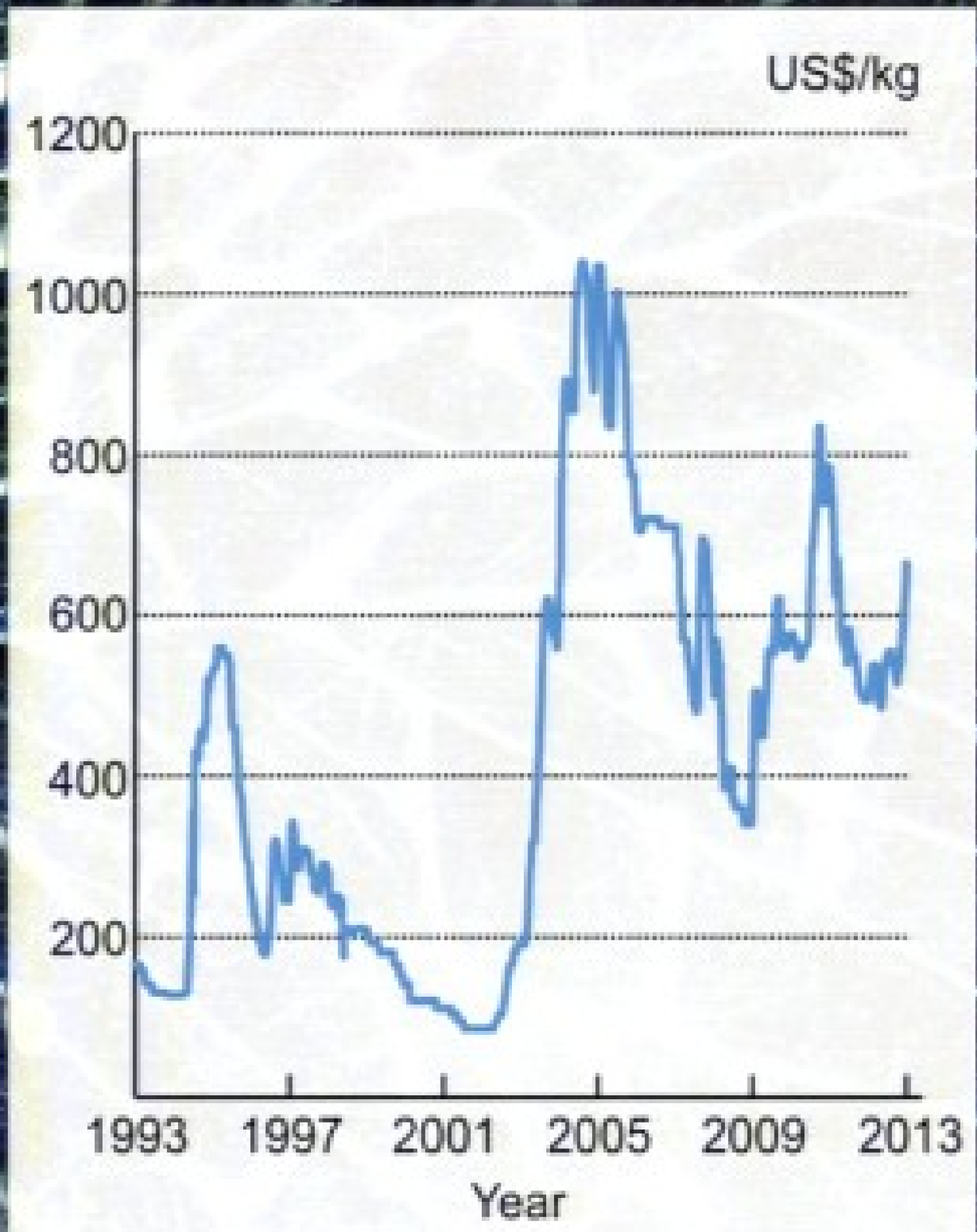
Problems of existing technologies

Flexibility

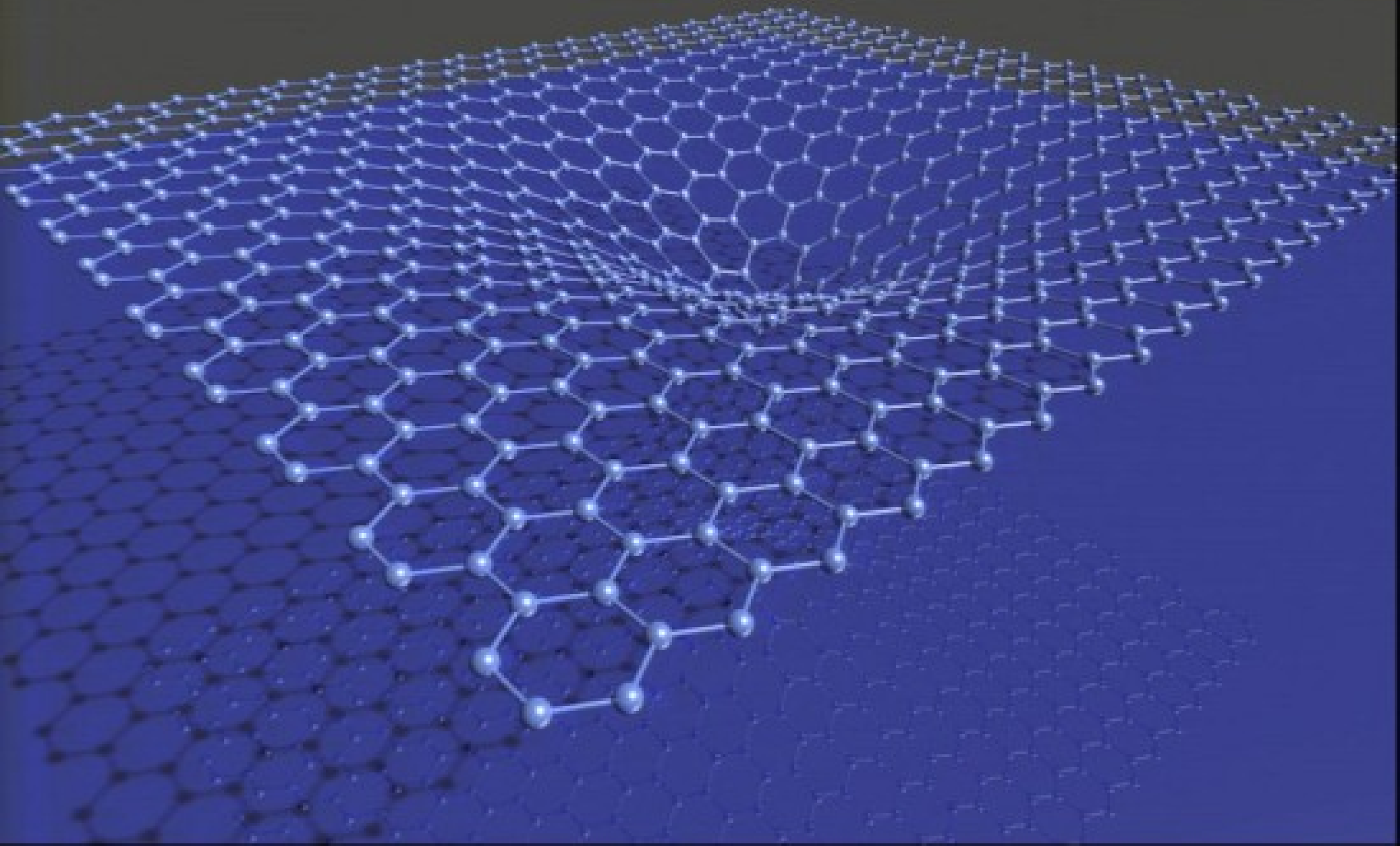
Availability/Usage (ton/year 2006-2030)



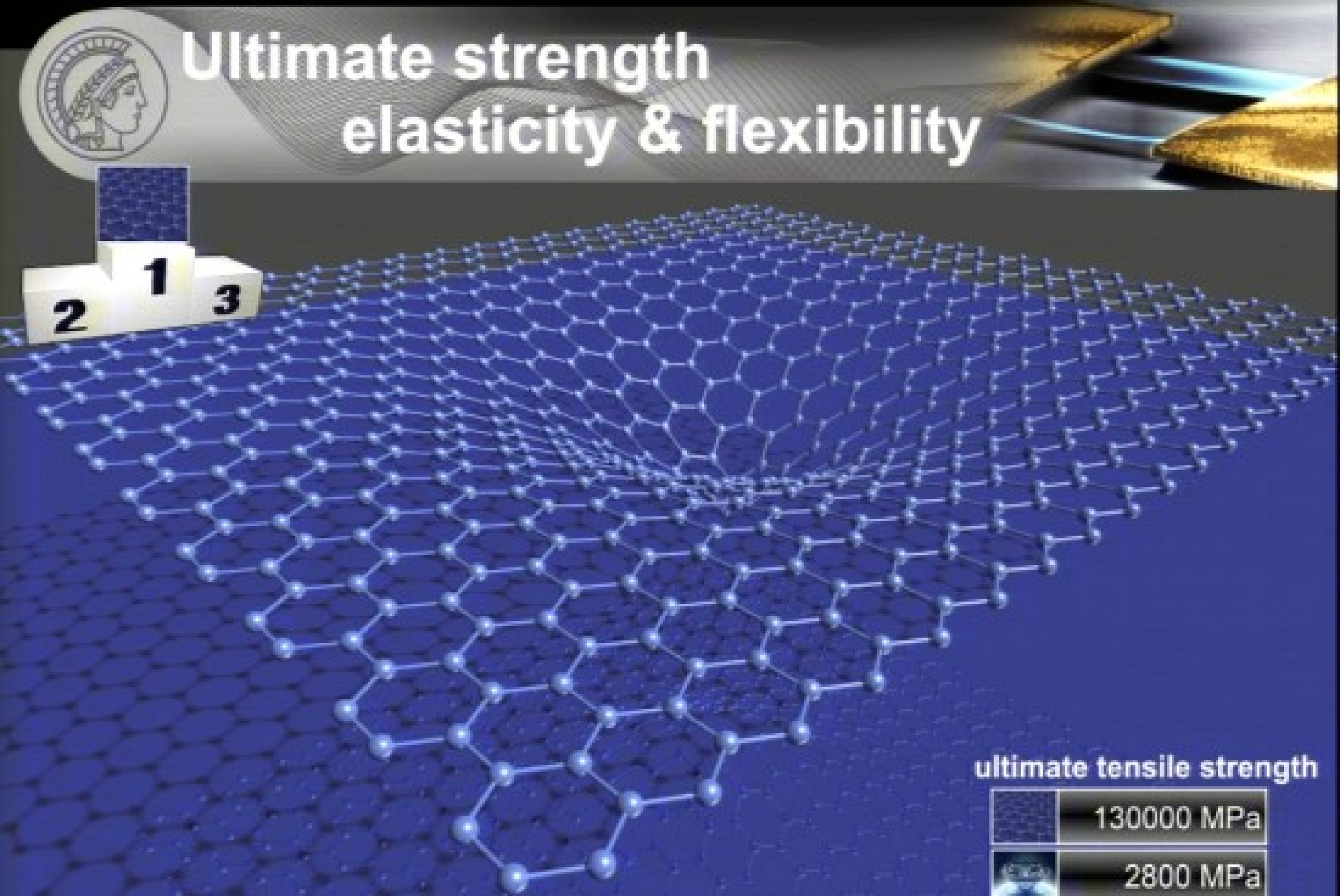
Price stability



Ultimate strength
elasticity & flexibility



Ultimate strength
elasticity & flexibility



ultimate tensile strength

	130000 MPa
	2800 MPa
	400-5000 MPa

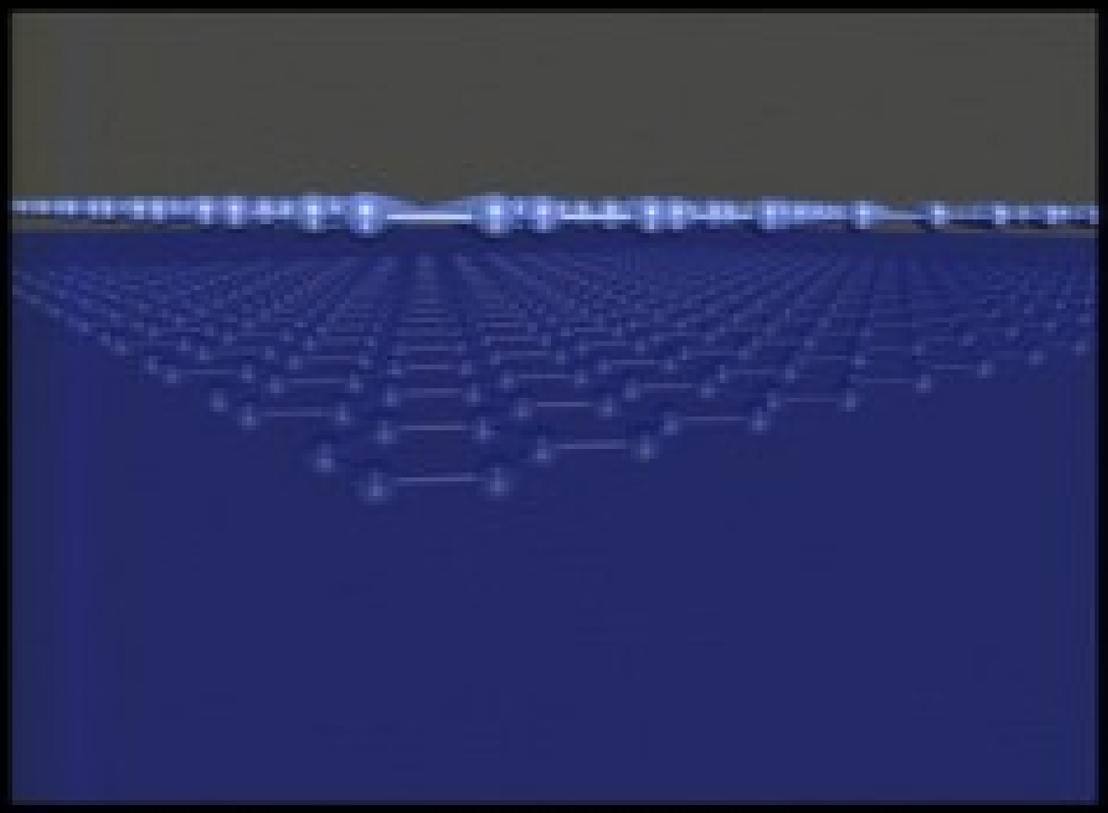
Ultimate strength
elasticity & flexibility

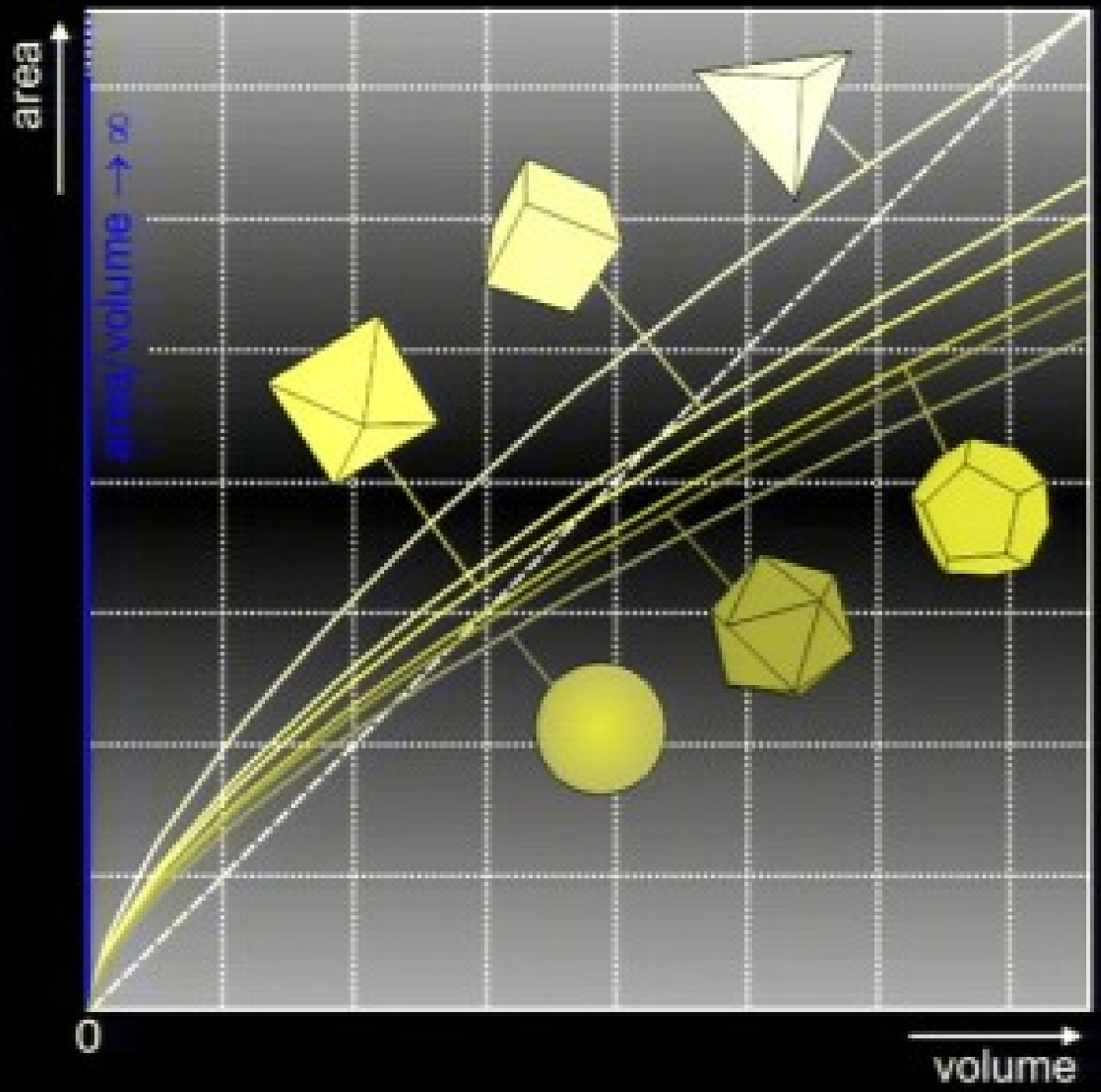
Wikipedia

ultimate tensile strength

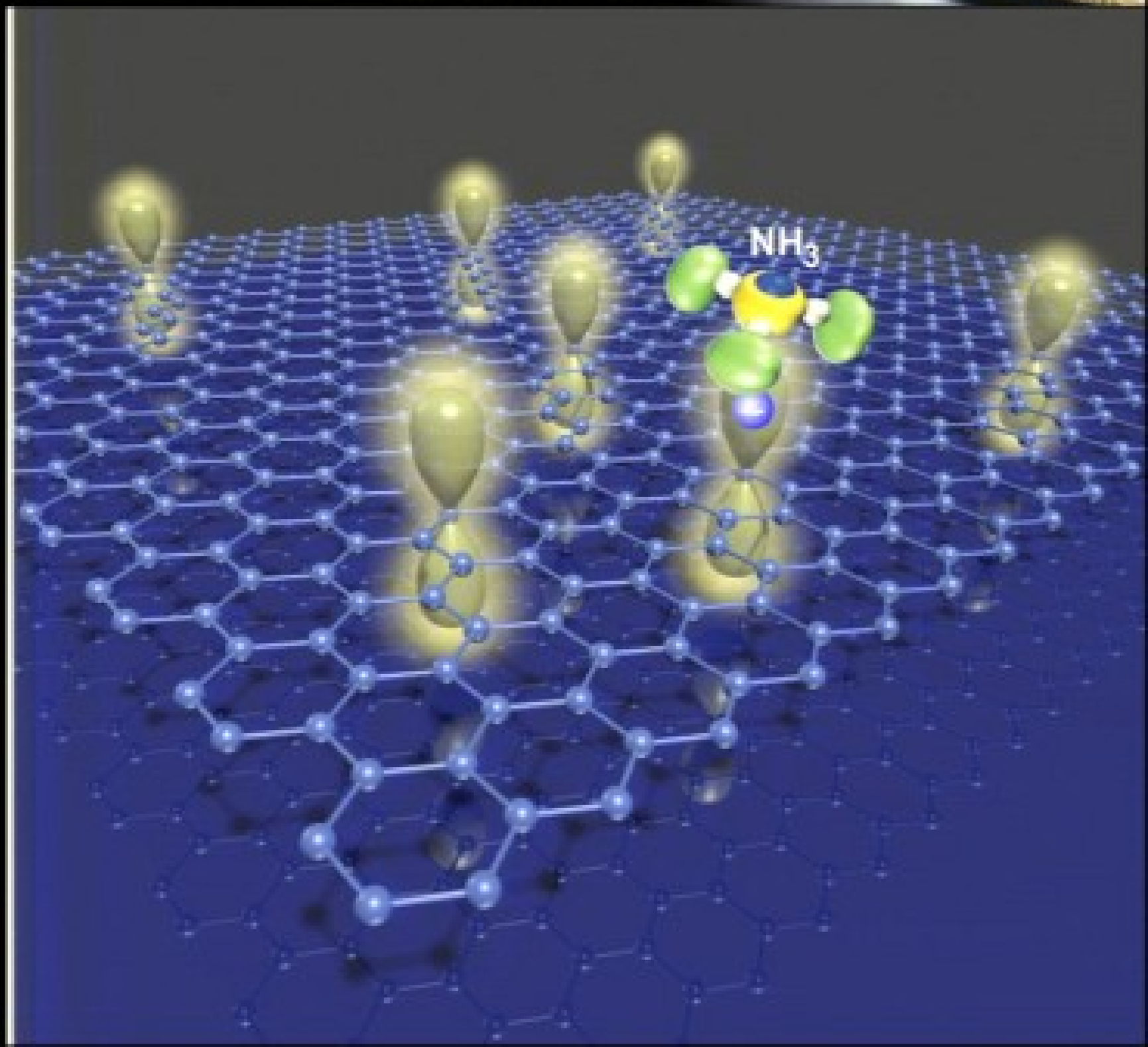
	130000 MPa
	2800 MPa
	400-5000 MPa

It is only surface!

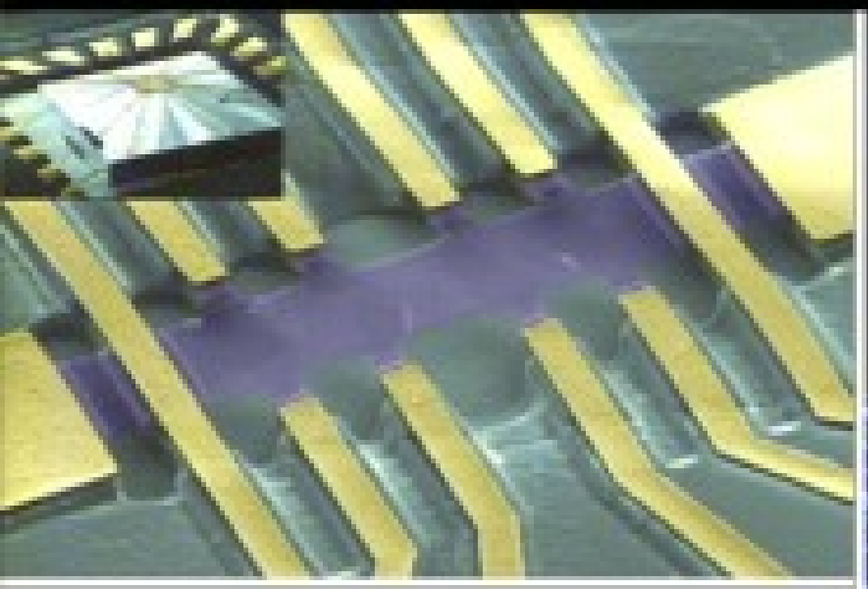


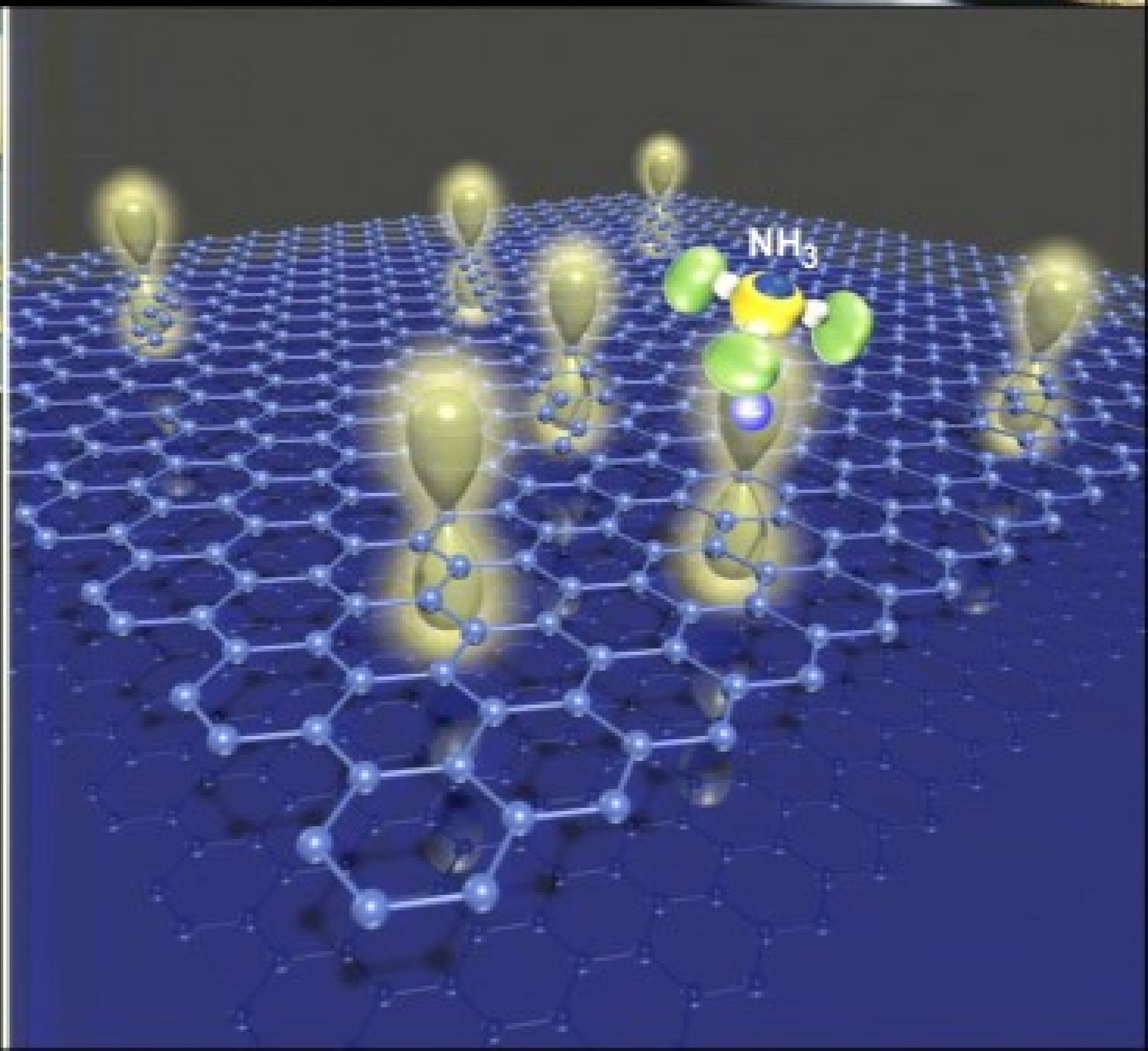


Gas Sensing

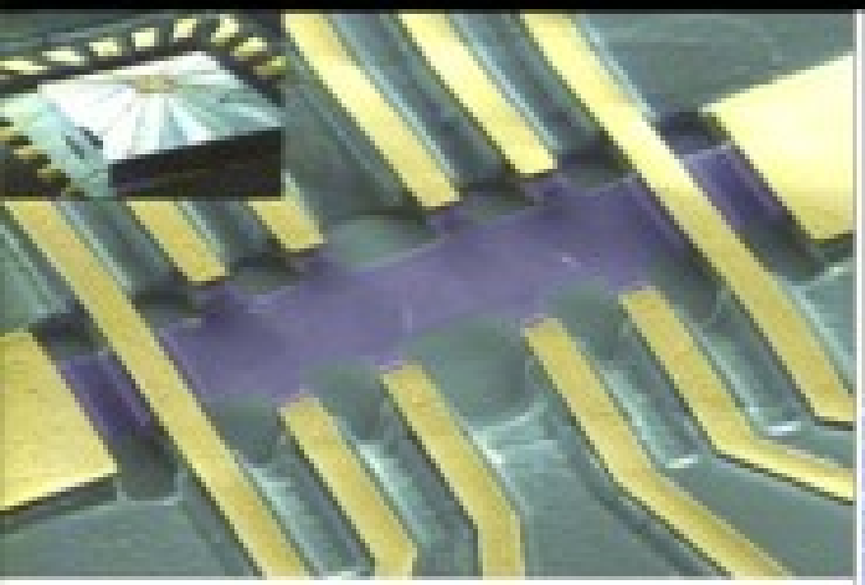


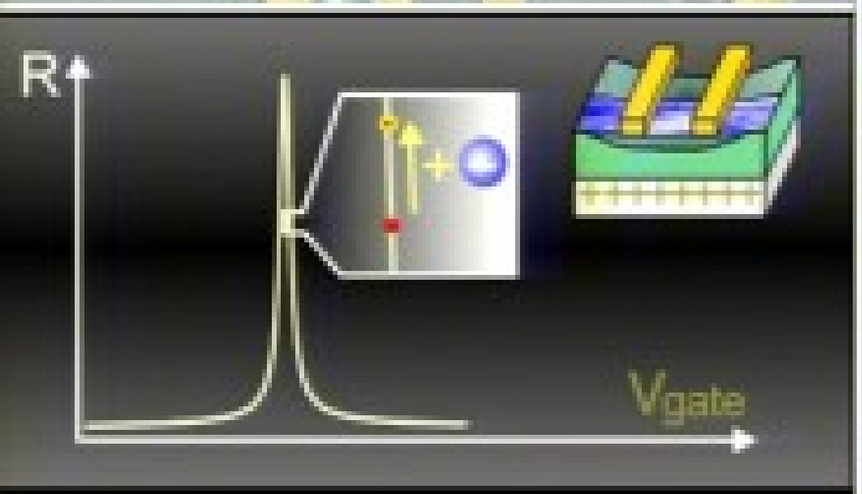
Gas Sensing

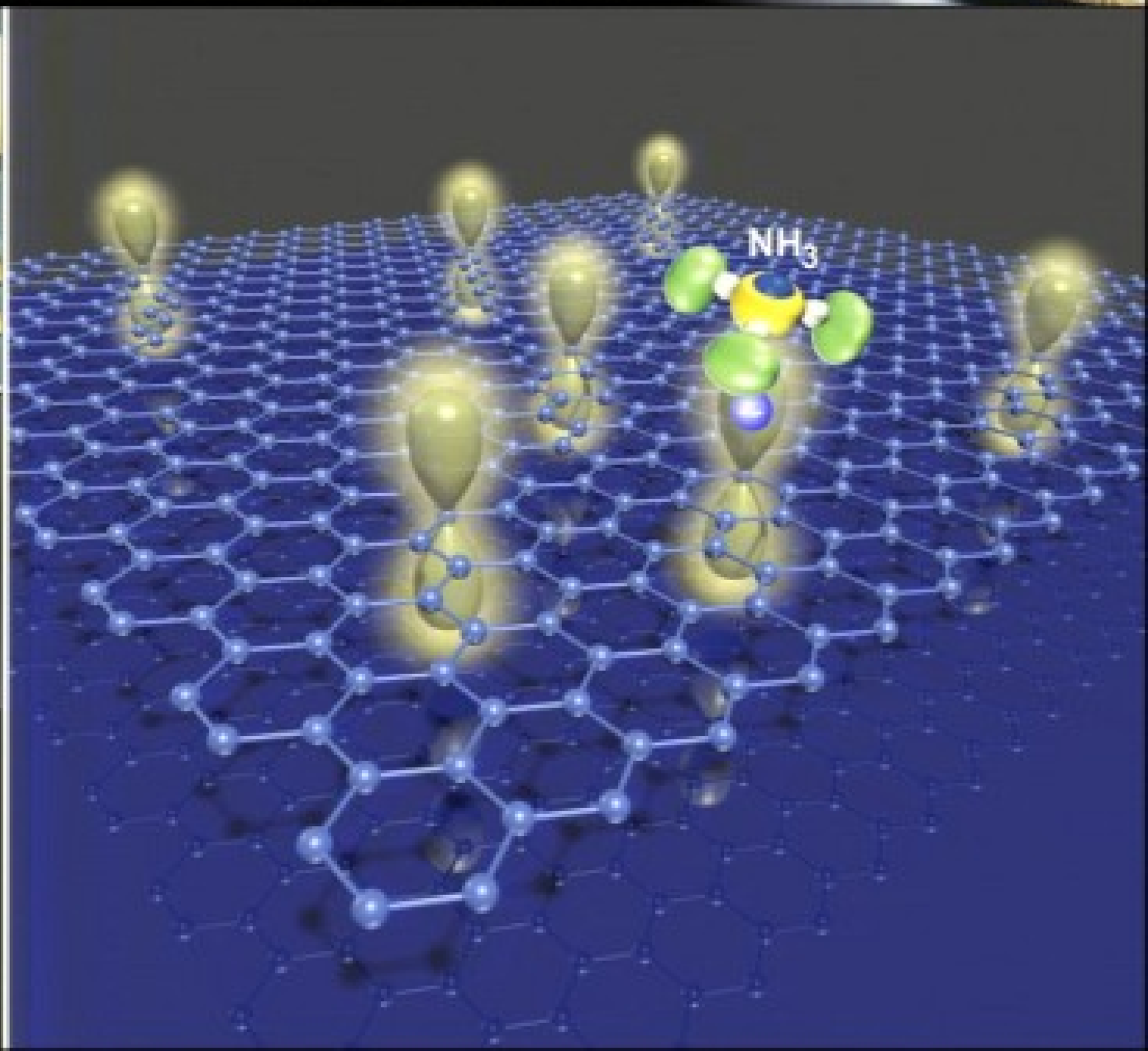




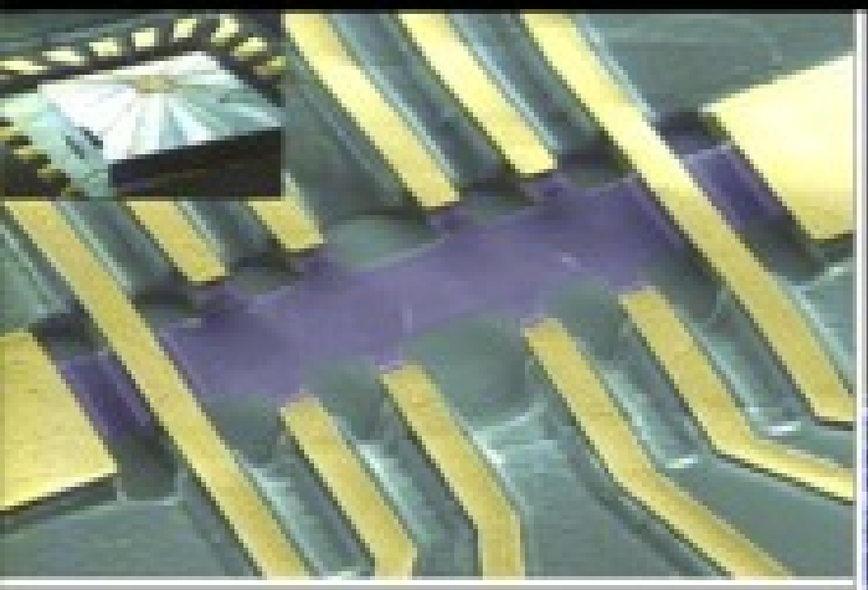
Gas Sensing

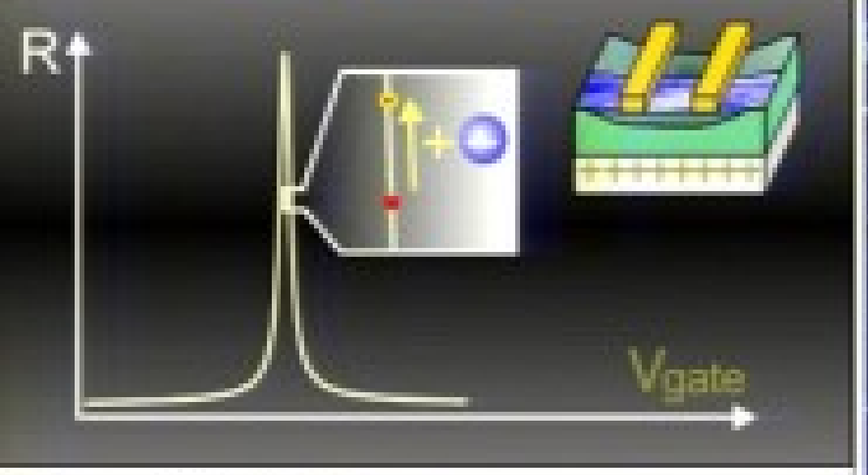




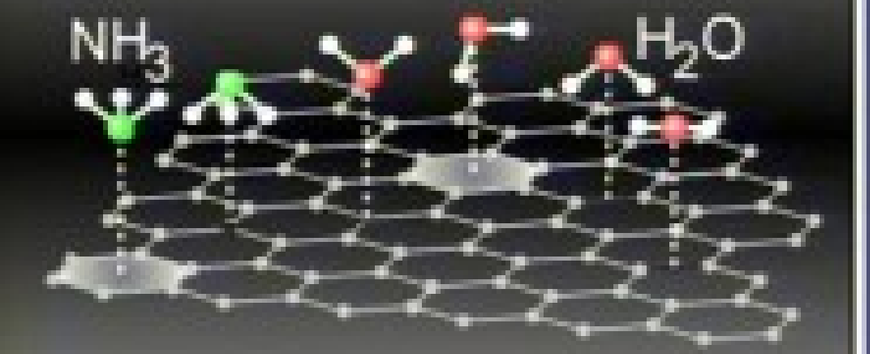


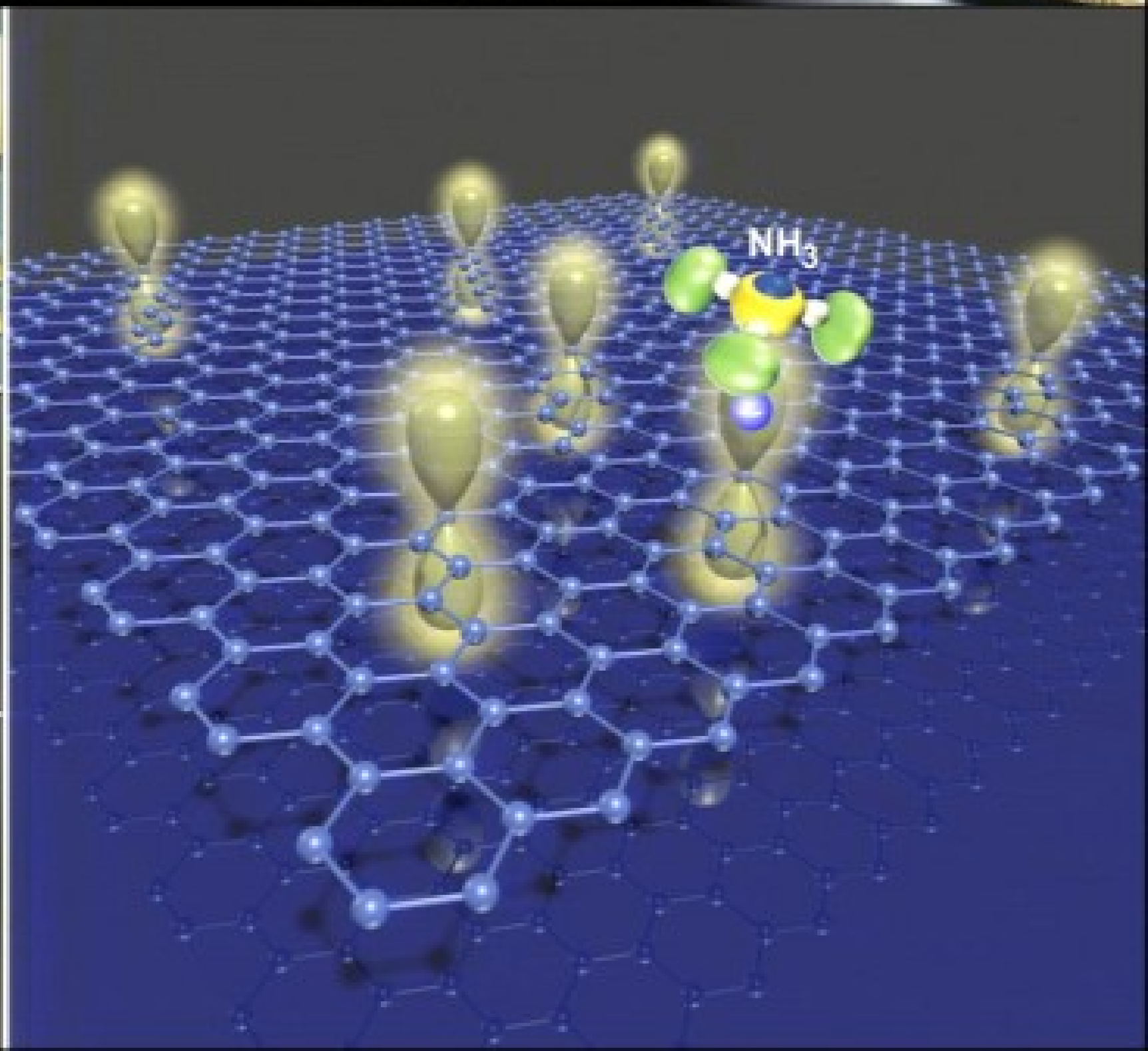
Gas Sensing

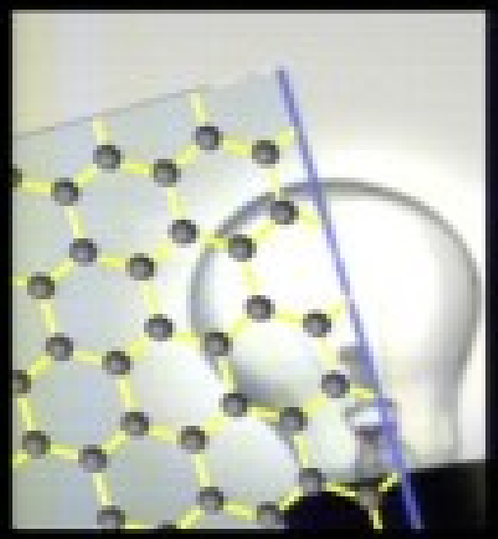
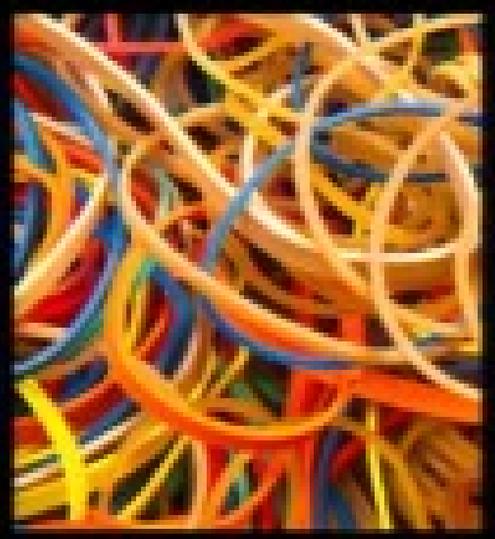


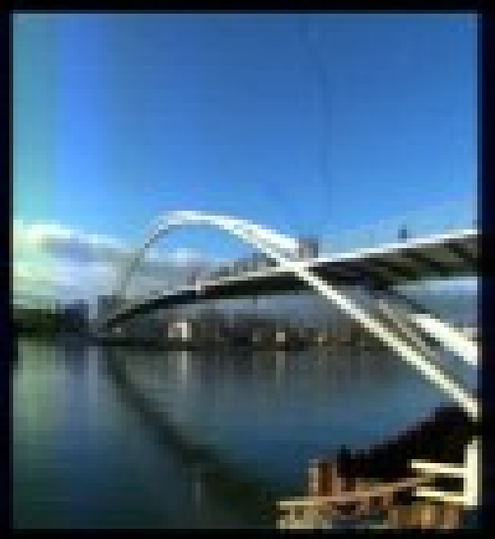


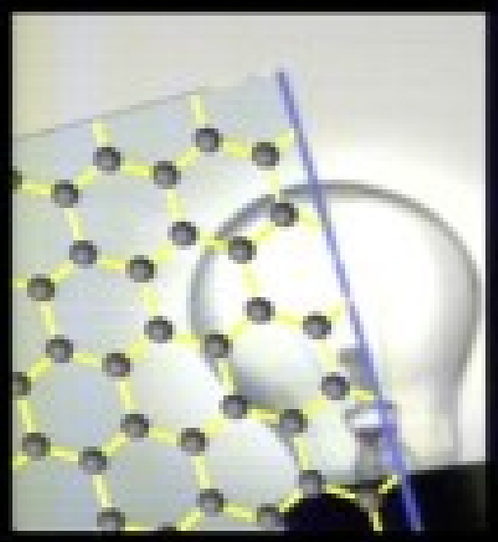
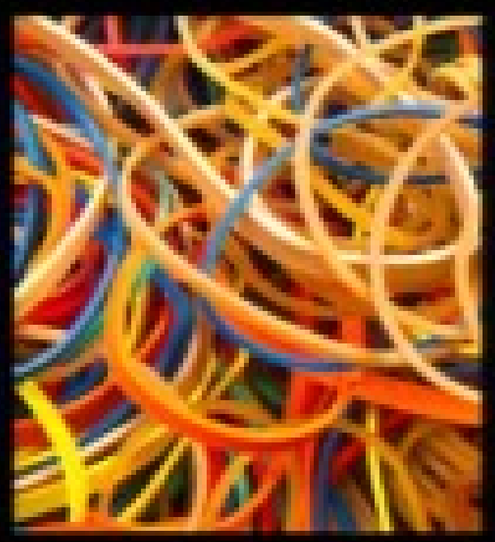
Specificity?

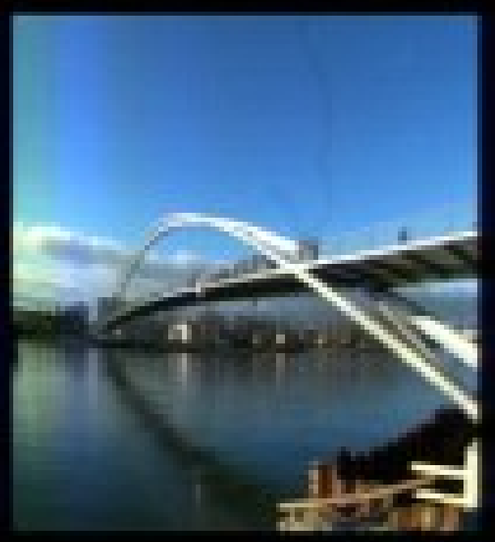


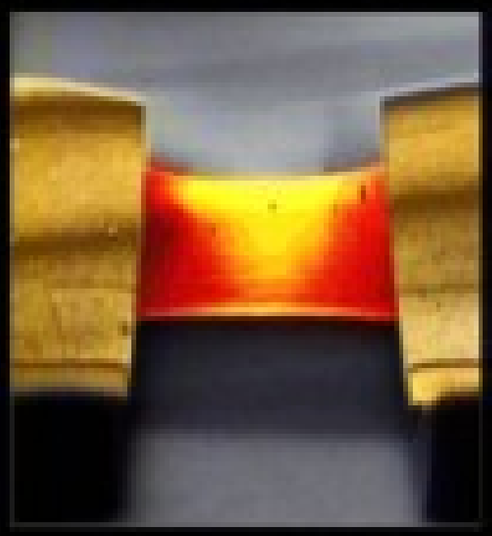


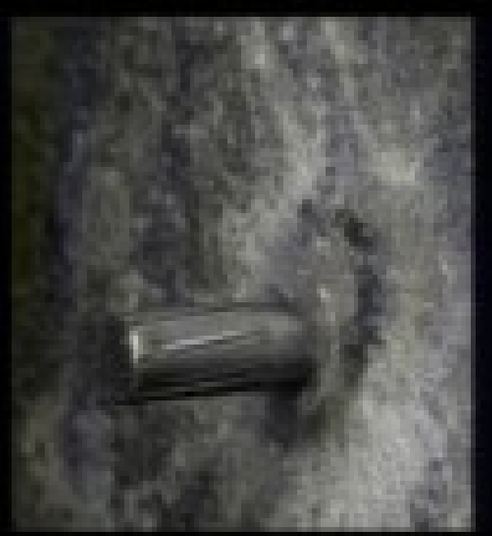





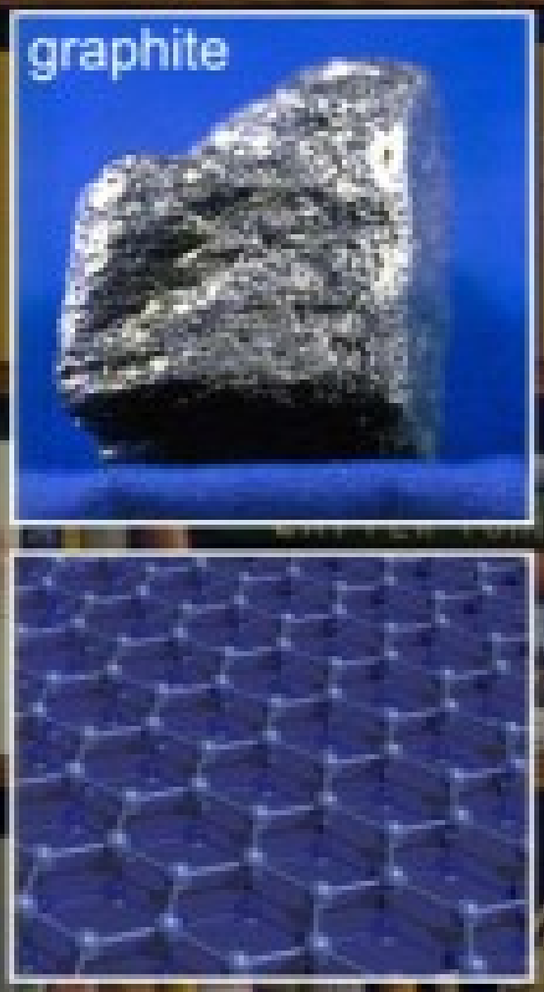






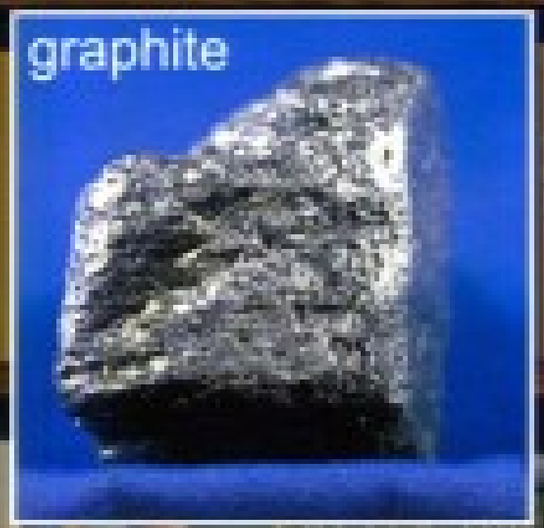



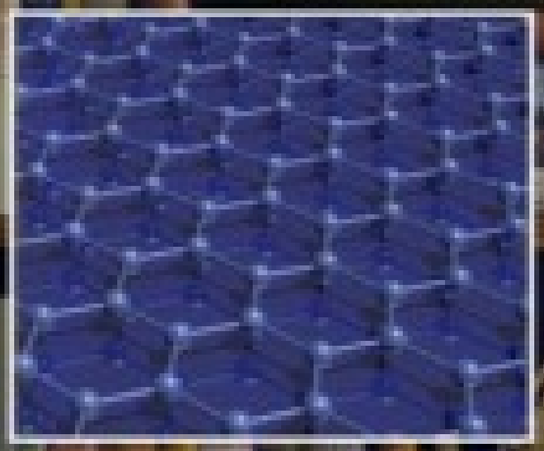



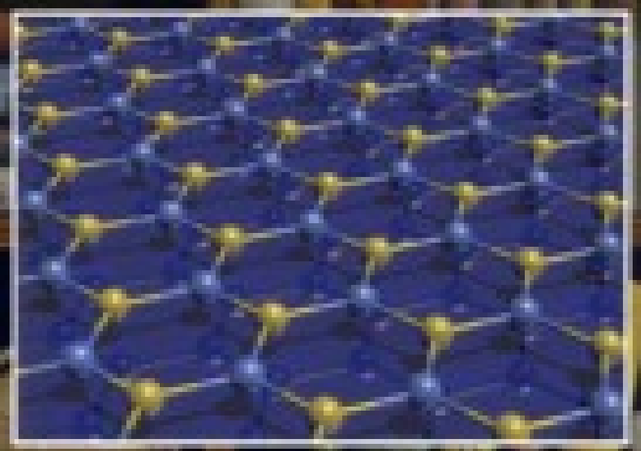
Expanding the 2D horizon

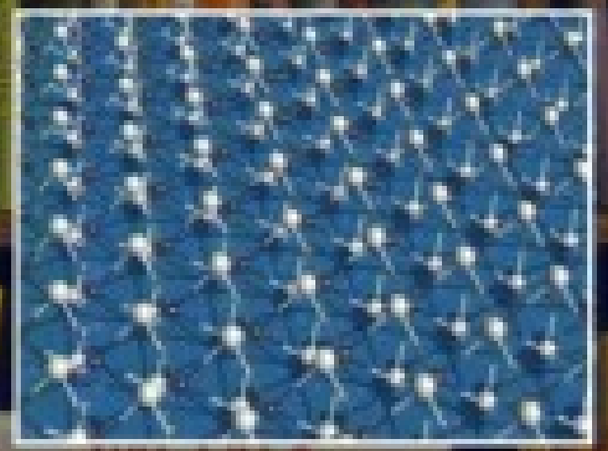


Expanding the 2D horizon









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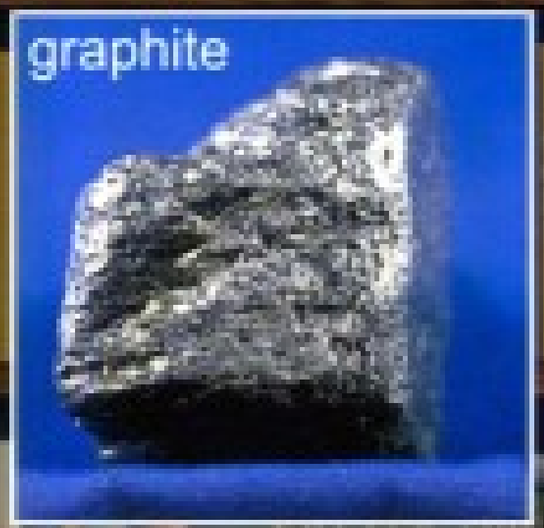
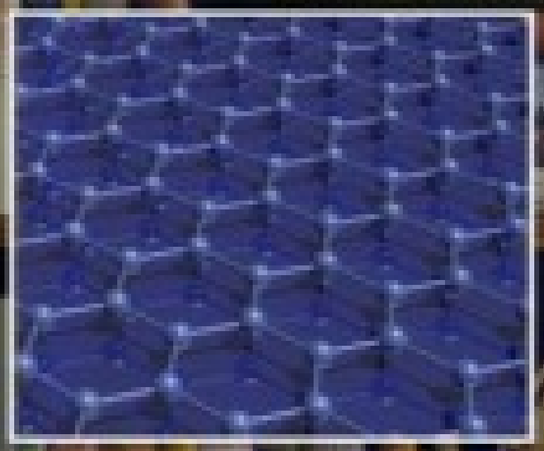
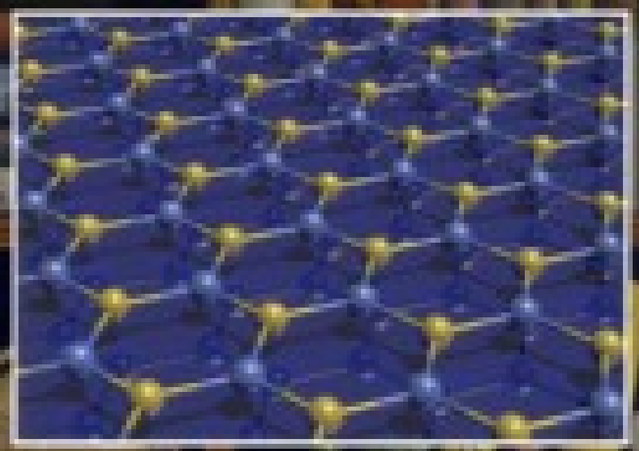
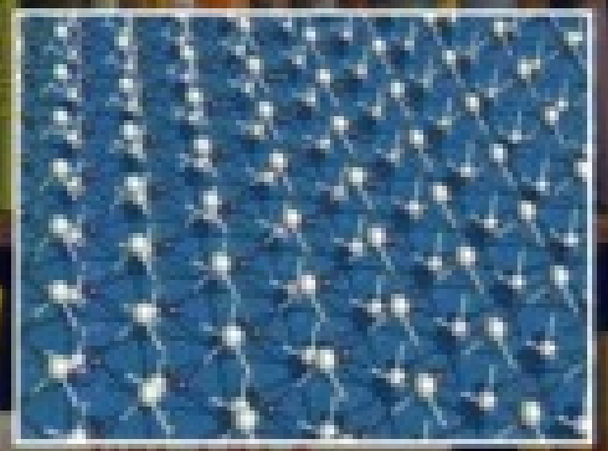


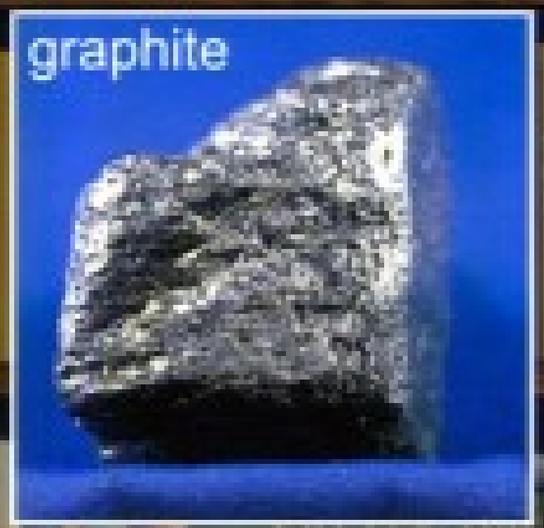


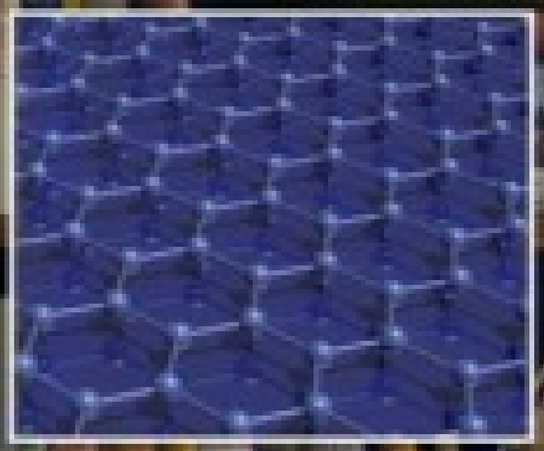


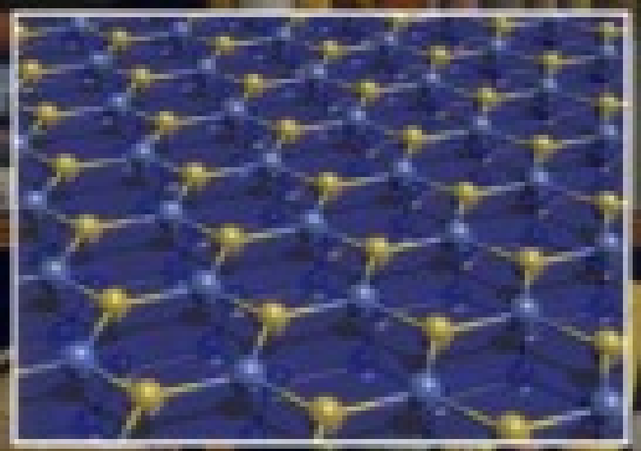


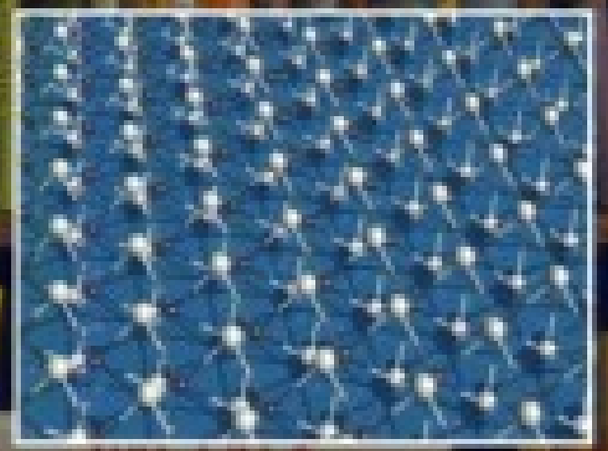
- **metals**
  $TaS_2, TSe_2, \ldots$
- **magnetic materials**
  $FeSe_2, CoSe_2, \ldots$
- **insulators**
  BN, mica ,....
- **semiconductors**
  MoS_2 , WSe_2 , NbS_2 ,....
- **superconductors**
  $FeSe_2, CoSe_2, \ldots$

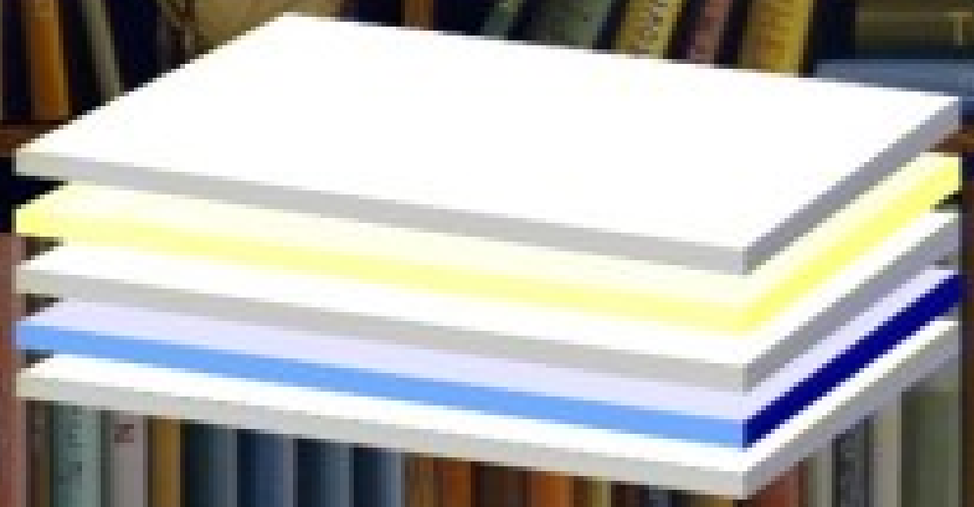
Expanding the 2D horizon











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Solid State Nanophysics Group