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Materials Science & Technology

Nanostrukturierte Beschichtungen:

Wenn die Architektur wichtiger wird als die Chemie

swiss mnt network: *"Trends in Mikro-Nano"*

Hochschule Luzern Technik & Architektur
Donnerstag, 5. Dezember 2013

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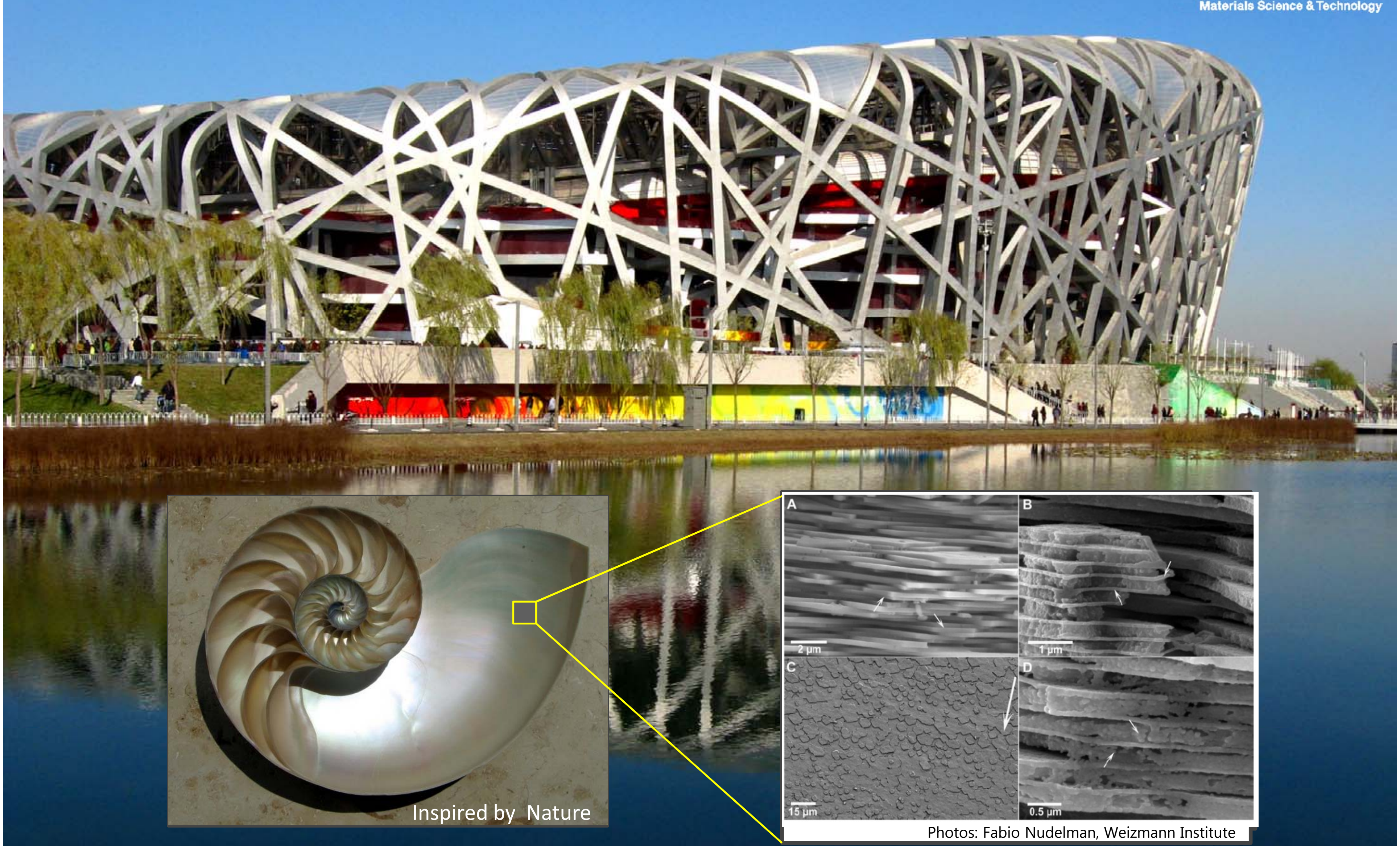
Function follows Architecture



Photos: Fabio Nudelman, Weizmann Institute

… novel materials and coatings with well defined architectures on the nano-scale.

Nanostructured Thin Films and Coatings

Hardening via Interfaces

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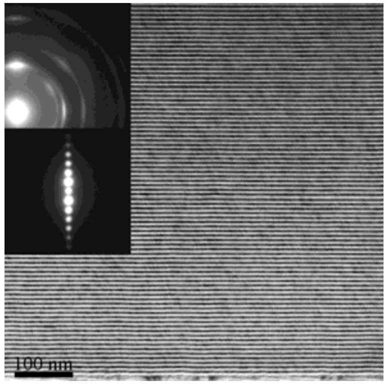
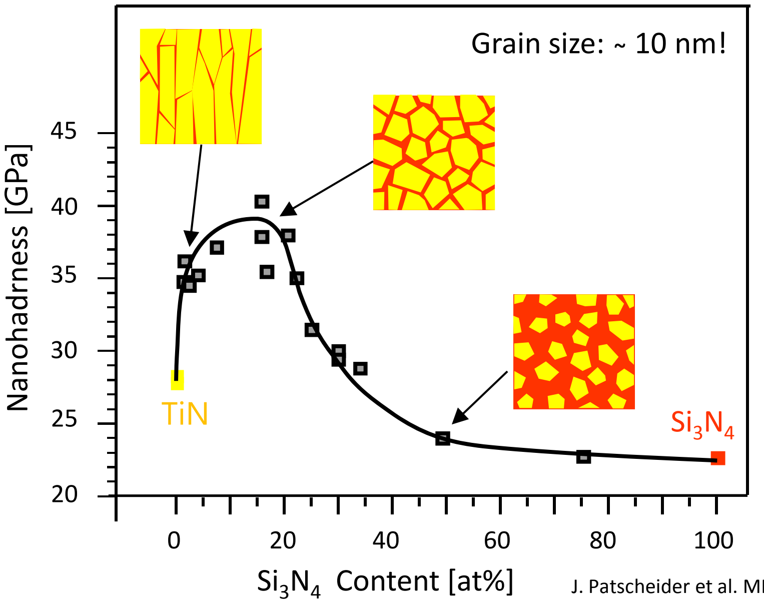
TiN/SiN_x Multilayer Coating

Hardness TiN: ~ 30 GPa



Hardness : ~ 50 GPa
d_{TiN} = 4.5 nm (dark)
d_{SiNx} = 2.8 nm (bright)
University of LULEÅ (S)

Superhard n-c:TiN/Si_3N_4 Coatings



J. Patscheider et al. MRS Bulletin **28/3**, 180 (2003), APL **96**, 071908 (2010)

Ti°, Si°, N_2, Ar
$T_{dep.}$ = 200 – 350°C
U_{bias} = - (70 – 120V)

Nanostructured Thin Films and Coatings

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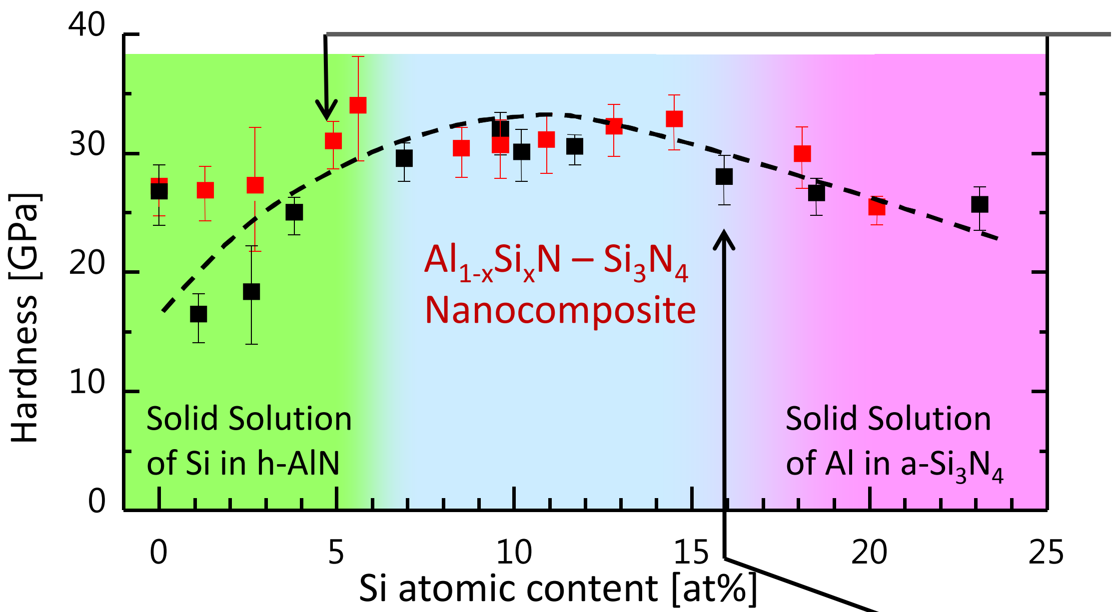
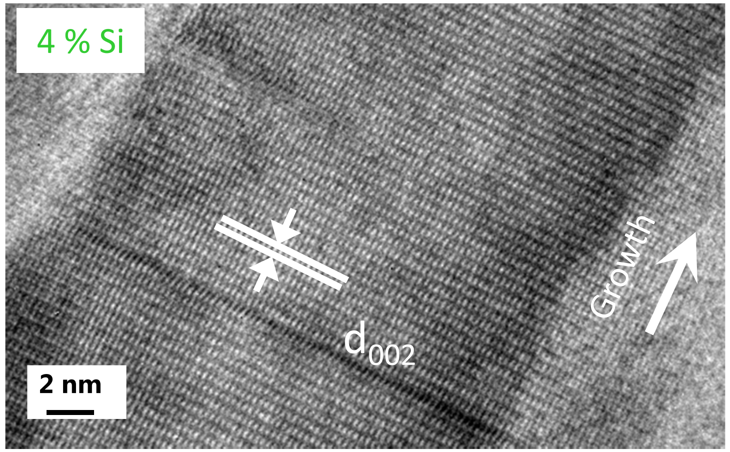
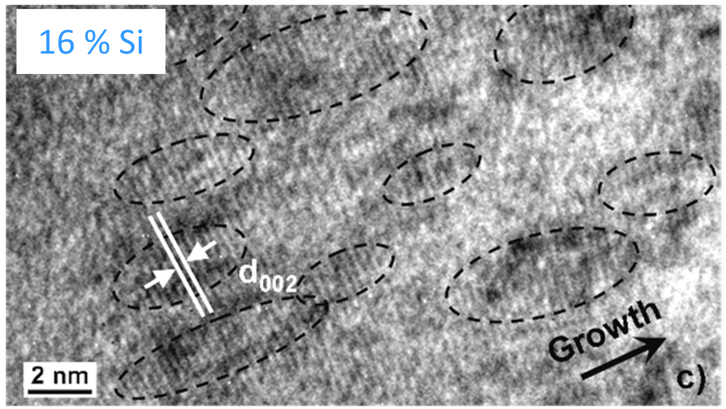
Transparent Hard Coating: $Al_{1-x}Si_xN - Si_3N_4$

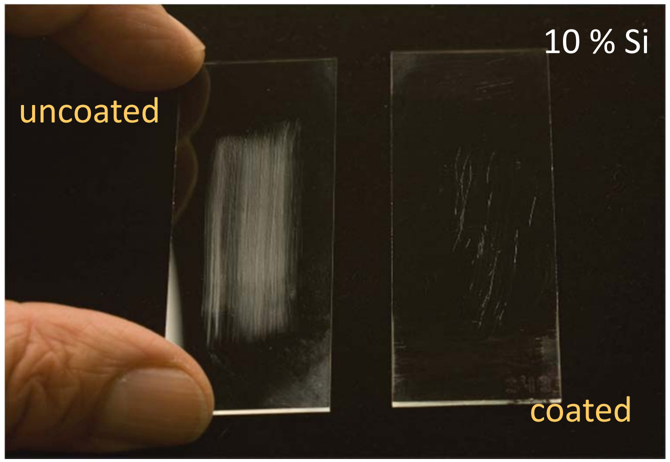




HRTEM of $Al_{1-x}Si_xN$ crystallites in Al-Si-N



Scratching with SiC paper



Joining: Melting Point Depression

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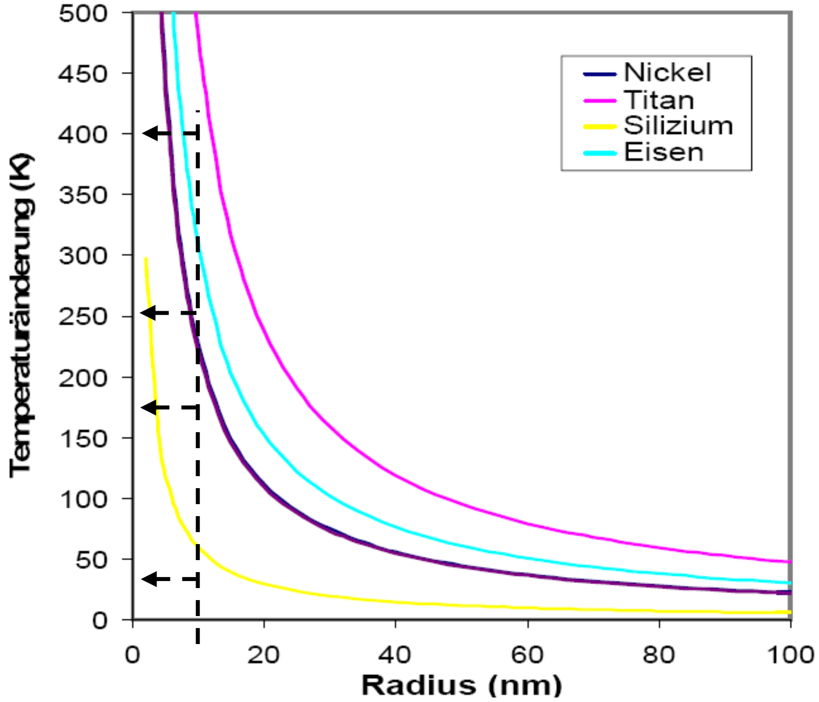
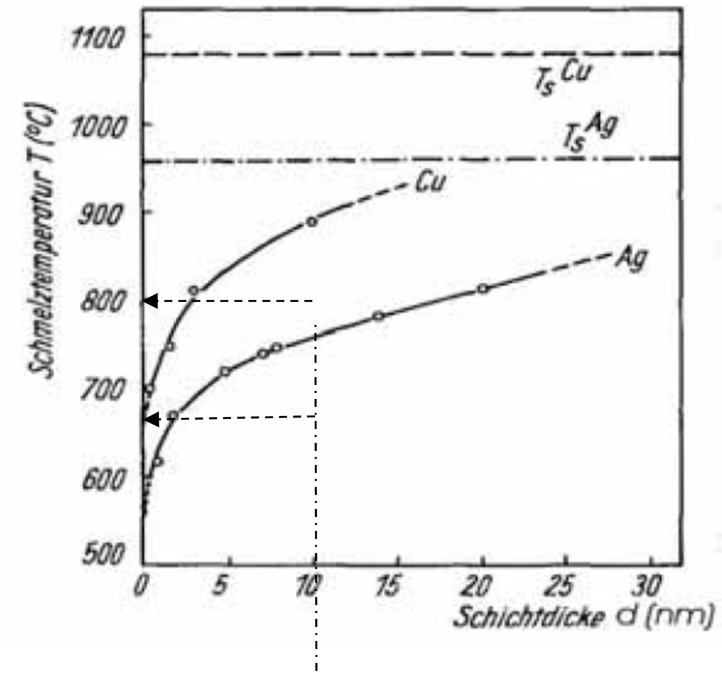




$$\Delta T = (T_S - T) = \frac{2\sigma \cdot T_S}{\rho \cdot L \cdot r} \sim \frac{1}{r}$$

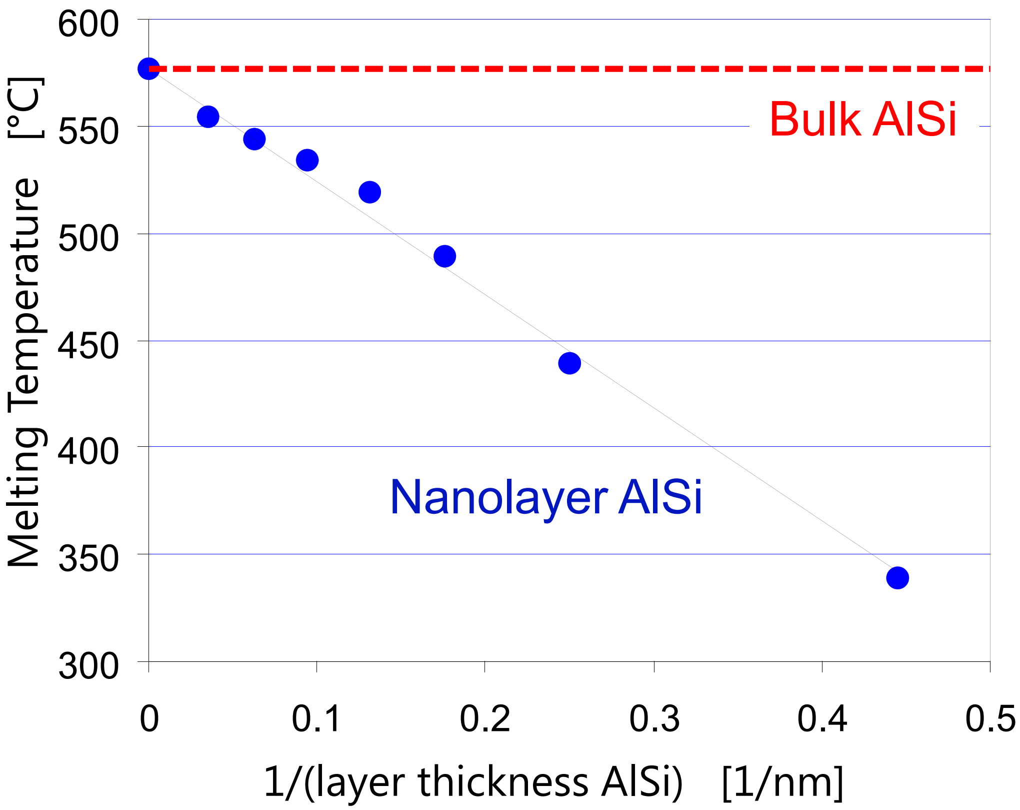
$$T_S(d) = T_S \cdot e^{-\frac{\sigma v}{L d}}$$

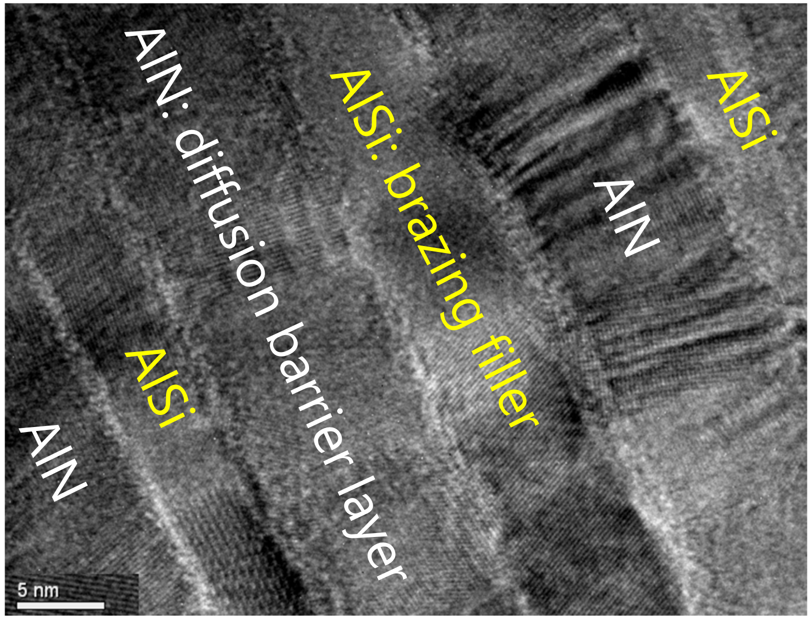
Discovered in 1954 by M. Takagi
Source: Wilden, DVS Forschungsseminar, 2006

T_S: bulk melting temperature
σ : solid-liquid interface energy
L : bulk heat of fusion
ρ : density of particles
r: particle radius

Nano-Brazing Fillers for Joining of Al-Alloys

Melting temperature of AlSi in AlN/AlSi nano-multilayers





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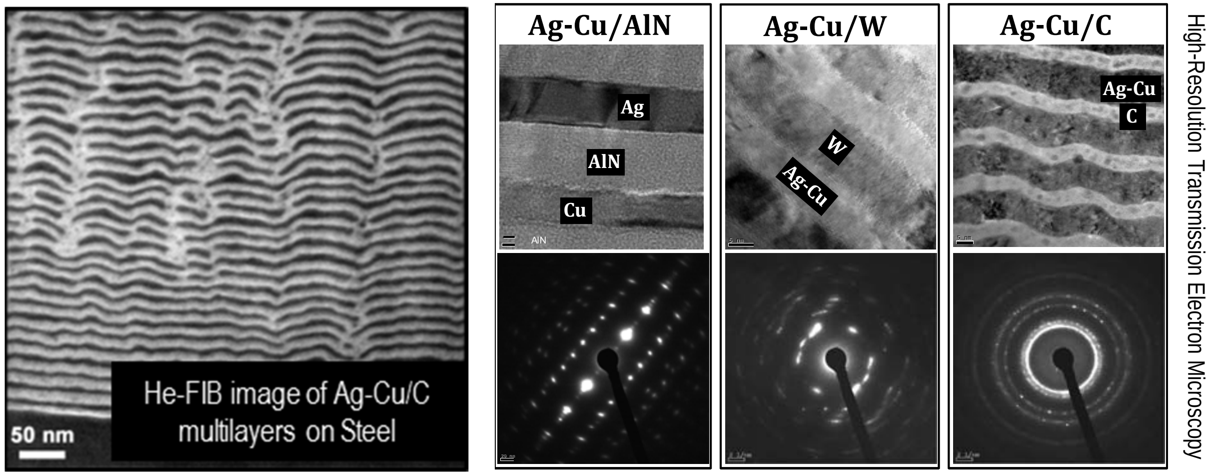
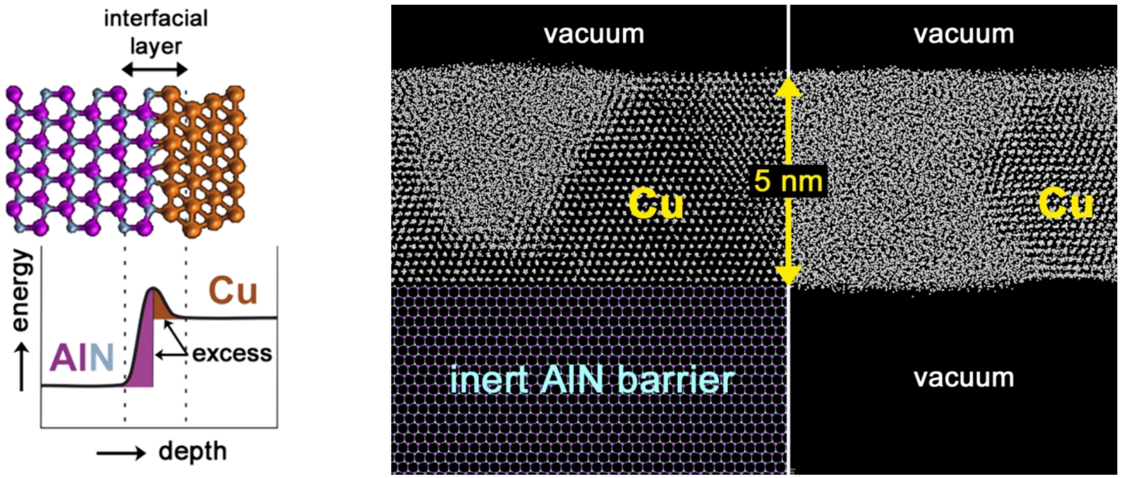
Nano-Brazing Fillers

Theoretical predictions vs. experimental verifications



Microstructural investigations by cross-sectional He-Focussed-Ion-Beam (FIB) imaging and HR-TEM



DFT and thermodynamic predictions of local interface structures and energetics

Multi-scale atomistic simulations (combining DFT, Molecular Dynamics, Monte Carlo , Molecular Statics) of pre-melting of free-standing and interface-bounded Cu films at 1200 K (bulk melting @1358 K).

Transparent Conductive Electrodes

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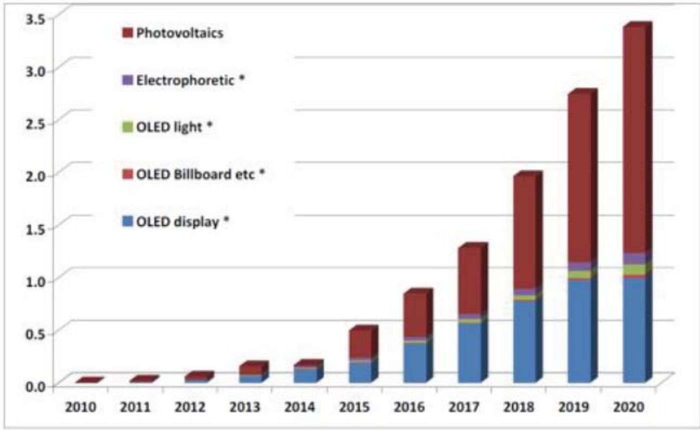
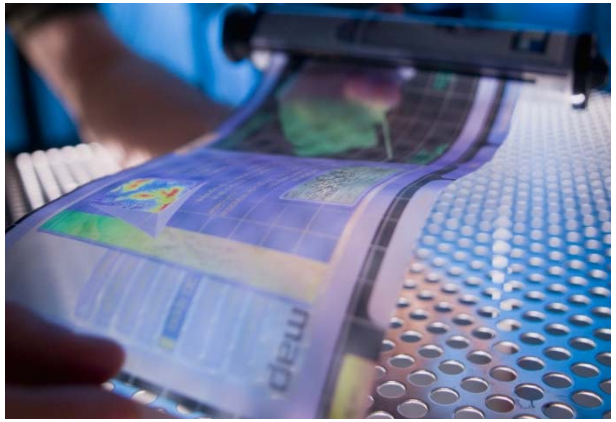
Applications of transparent conductive oxides (TCOs)



Source: IDTechEX

New applications: High flexible electronics (Prototypes of flexible computers (2013))

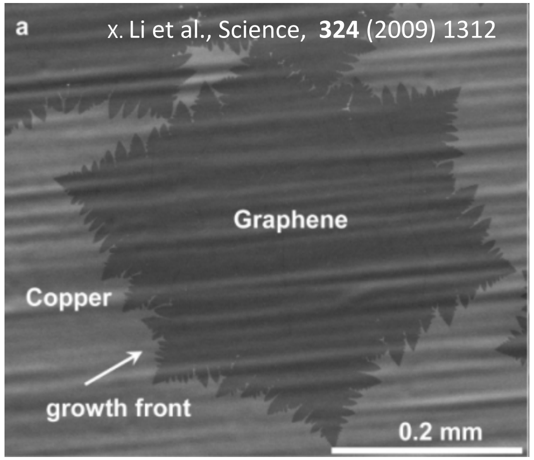


….. requires a replacement of TCOs. → Graphene is an excellent candidate!

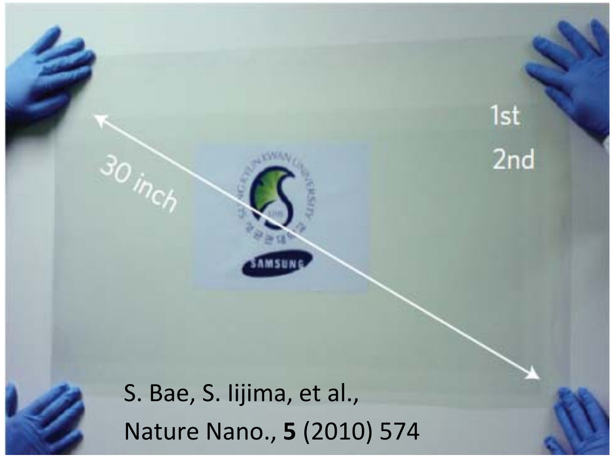
Graphene Synthesis

A Rapid Development

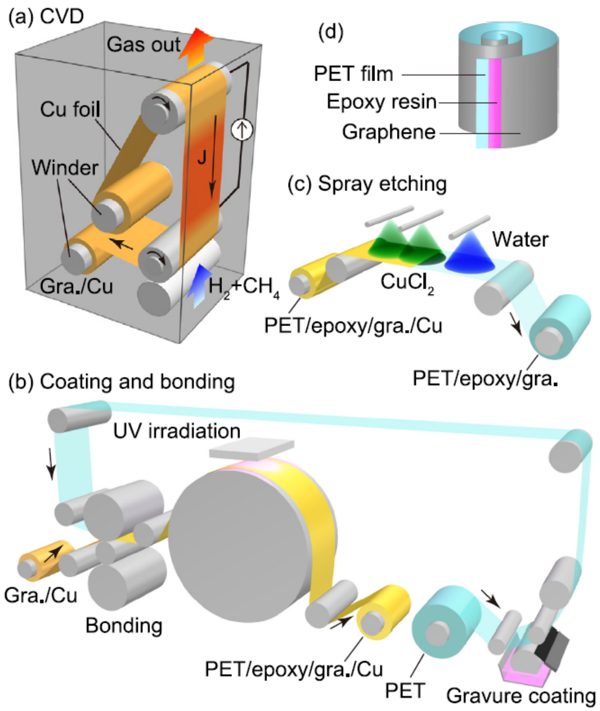
K. Novoselov, A. Geim et al., Science, **306** (2004) 666



x. Li et al., Science, **324** (2009) 1312



S. Bae, S. Iijima, et al., Nature Nano., **5** (2010) 574



T. Kobayashi et al., Appl. Phys. Lett., **102** (2013) 023112

Graphene for Electronic Applications

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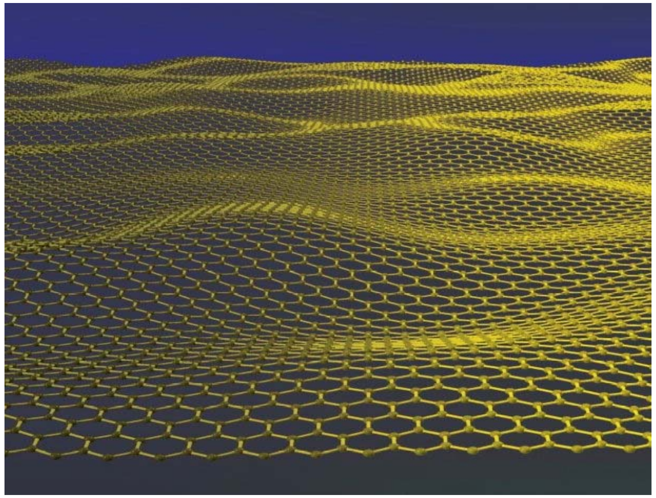
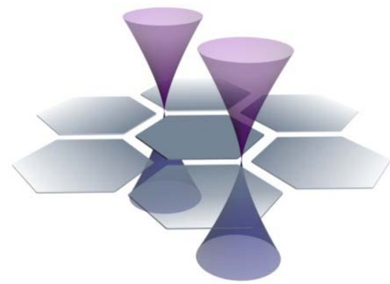
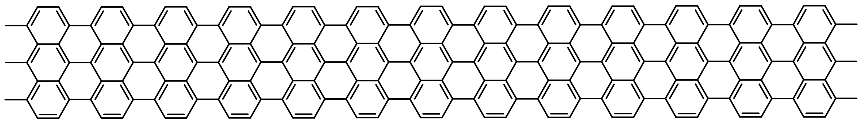


- Thermal conductivity:
  - Graphene ~ 5000 $Wm^{-1}K^{-1}$
  - Silicon ~ 150 $Wm^{-1}K^{-1}$
- Electron mobility:
  - Graphene < 200'000 $cm^2V^{-1}s^{-1}$
  - Silicon 1400 $cm^2V^{-1}s^{-1}$

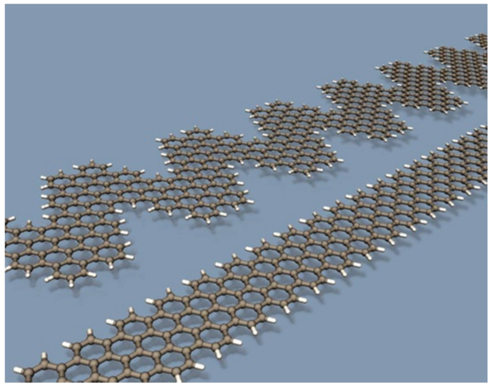


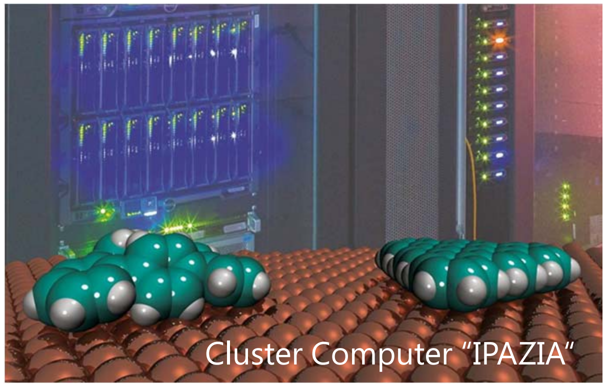
Problem:
Graphene is a semi-metal and not a semi-conductor!!



(3p+1) *N*=7: E_G = 1. 6 – 3.8 eV

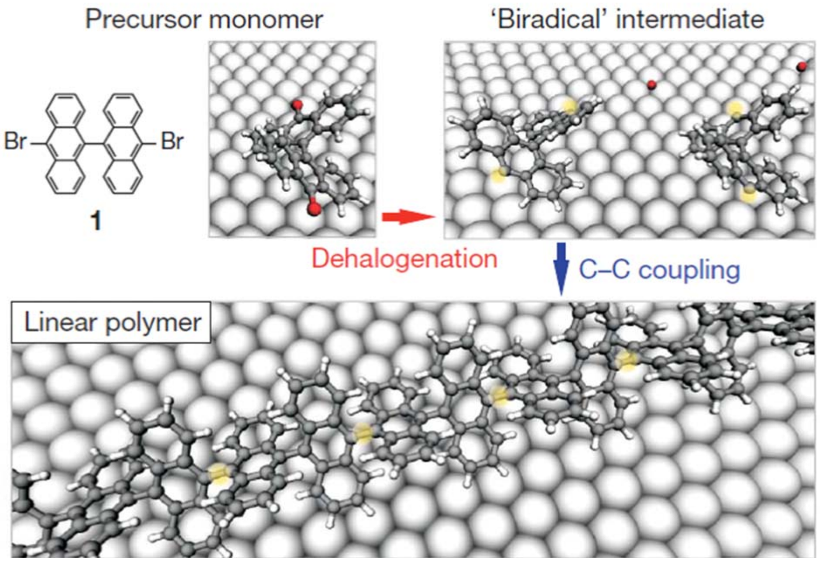
Theoretical prediction: Graphene Nanoribbons (GNR) are semiconductors!

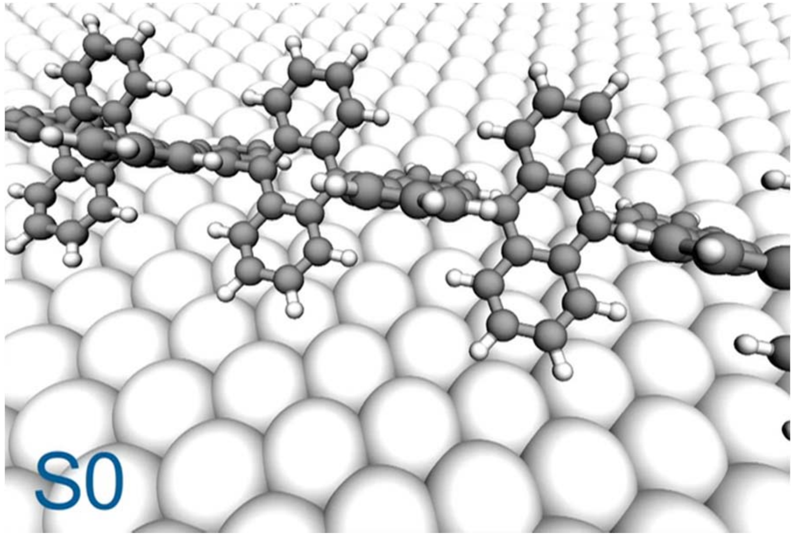


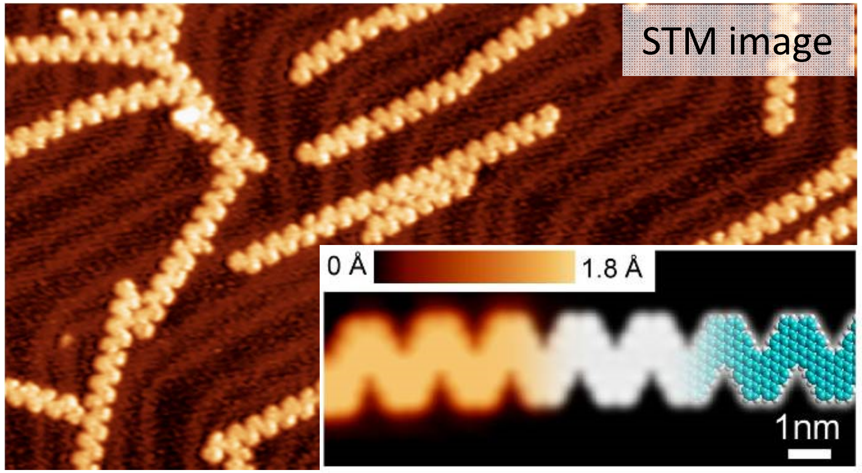


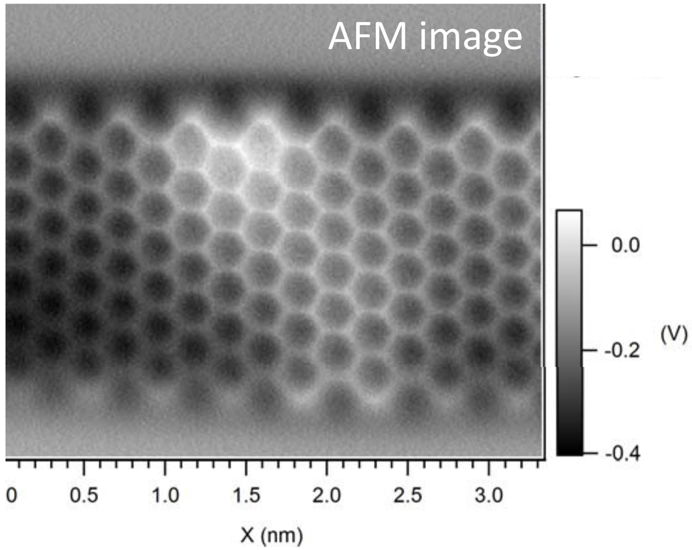
Graphene Nanoribbons

Bottom-Up Synthesis







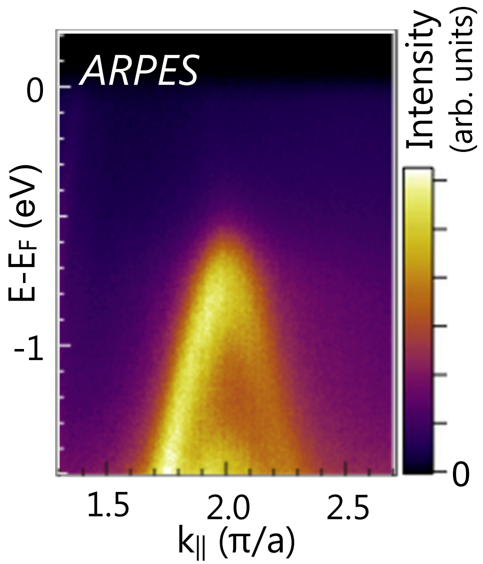


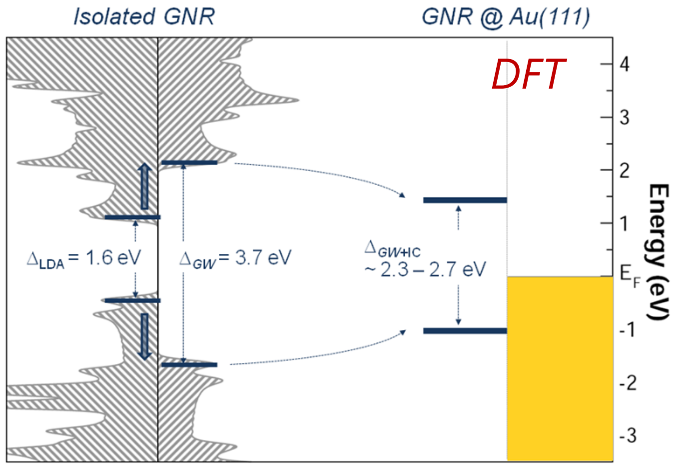
Empa / Pierangelo Gröning

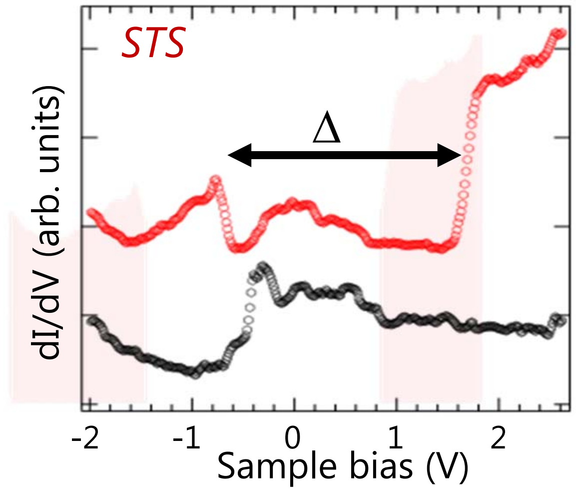
"Nano-Structured Thin Films & Coatings"

Graphene Nanoribbons

- STS: band gap Δ =2.3 eV [on Au(111)]
- ARPES: $m^* = 0.21\ m_0$; *max.* band slope: $8.2{\cdot}10^5$ m/s
- DFT: image charge correction of ~1.4 eV







Publications:

- Chem. Comm., 6919 (2009)
- JACS, **132,** 16669 (2010)
- Nature, **466**, 470 (2010)
- Nature Chem., **3**, 61 (2011)
- ACS Nano, **6**, 2020 (2012)
- ACS Nano, **6**, 6930 (2012)

..... the Material for Future Electronics!


Thank you
for your
kind Attention