

Max-Planck-Institut für Polymerforschung
Max Planck Institute for Polymer Research

Specific Surface Area of 2630 m²/g

High Charge Carrier Mobility

No Bandgap

Layer Thickness of 0.345 nm (1 Atom)

Optical Transparency High Flexibility

High Electric Conductivity

$E = \hbar v_F q$

Elektronen
Löcher

Max-Planck-Institut für Polymerforschung
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How to fabricate graphene ?

a) Exfoliation of graphite

b) Chemical Vapor Deposition

c) Pyrolysis

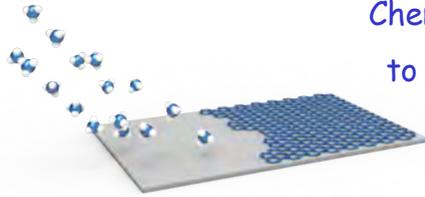
d) Precision Synthesis

Nat. Rev. Chem. 2017, 2

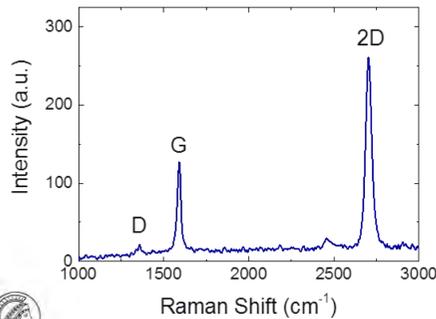
b. CVD Growth of Graphene



Chemical vapor deposition (CVD)
to grow high-quality graphene



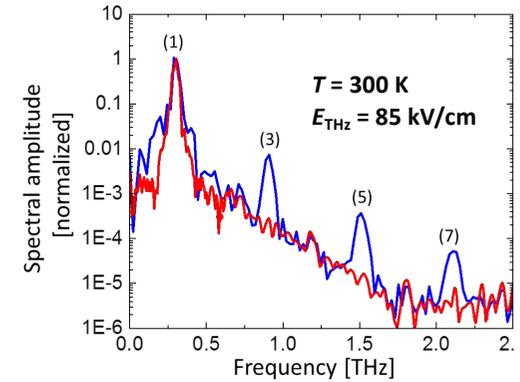
Raman spectrum



THz High Harmonics Generation

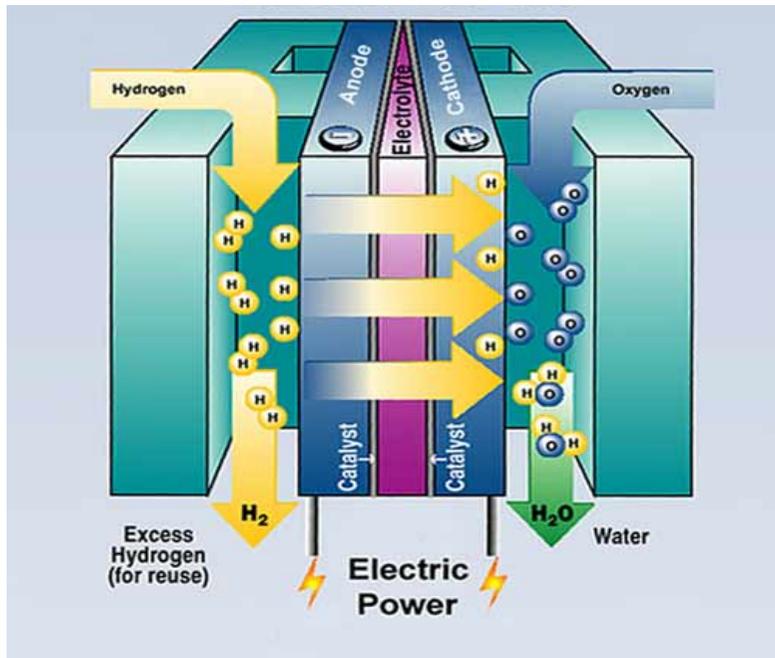


- extremely efficient due to
- thermodynamic response of background electronic population
- extremely high nonlinear coefficients ($\times 10^{18}$!)



with D. Turchinovich

Nature 2018, available online



<http://www.metalprices.com/>

THz High Harmonics Generation



Conductive formulations and inks

- Printable electronics, E-textiles, coatings

Composite materials

- Antistatics, mechanical reinforcement

Energy storage materials

- Batteries, capacitors

Catalysis

- Support materials, photocatalysis

Transparent electrodes

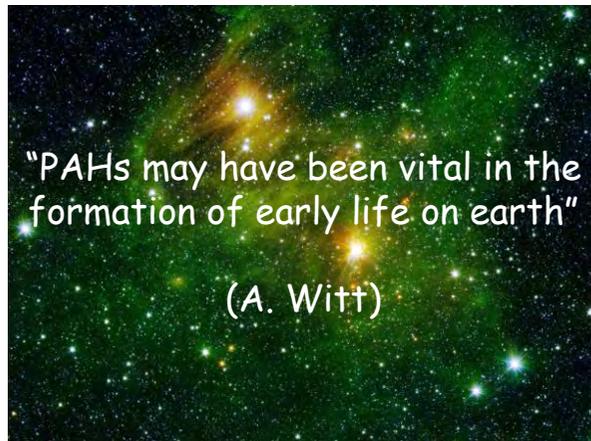
- Photovoltaics, displays

Carbon semiconductors

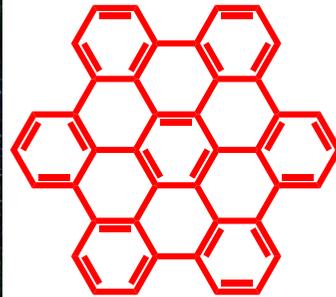
- Transistors, spintronics



2. Nanographenes



Source:www.wikipedia.org

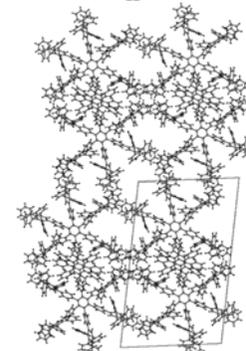
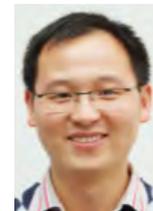
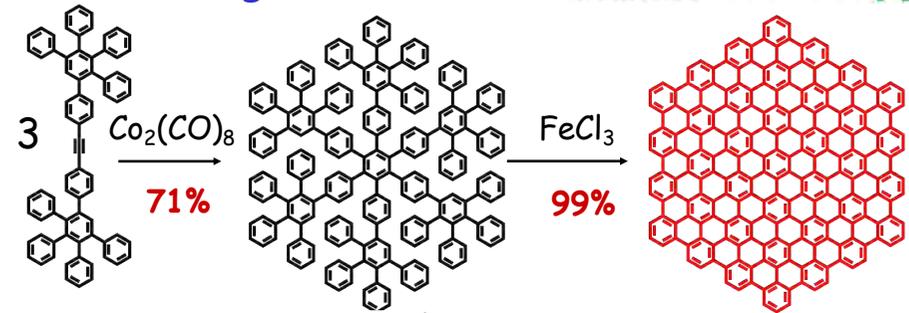


"Superbenzene"

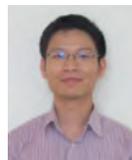
Angew. Chem. Int. Ed.
1995, 34, 1609

(PAHs found in interstellar space, comets and meteorites)

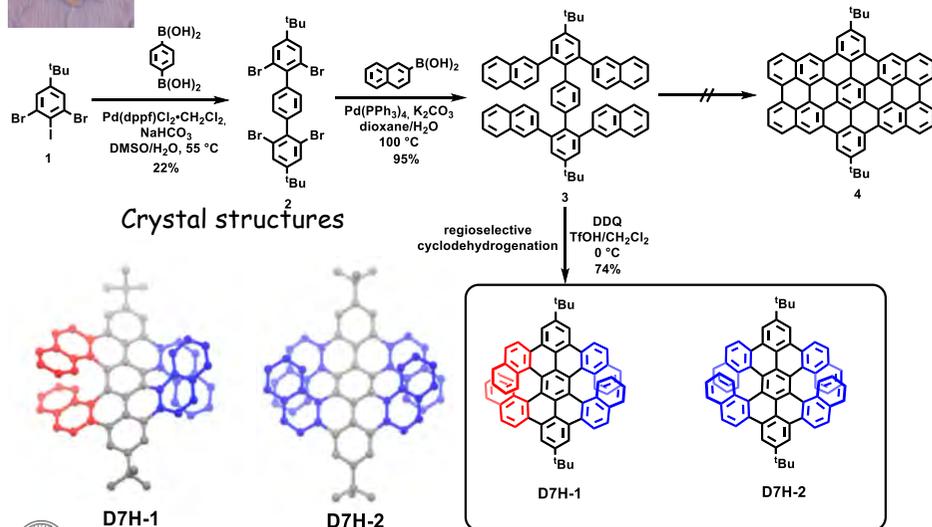
Molecular lego with benzene



Nature Materials 2009, 8, 421
Adv. Polym. Sci. 2013, 262, 61



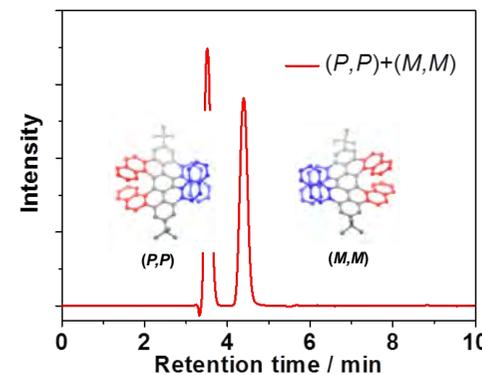
b. Chirality: the case of double[7]carbohelicene



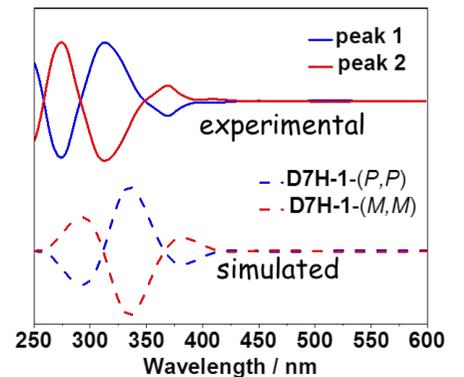
Angew. Chem. Int. Ed. 2017, 56, 3374

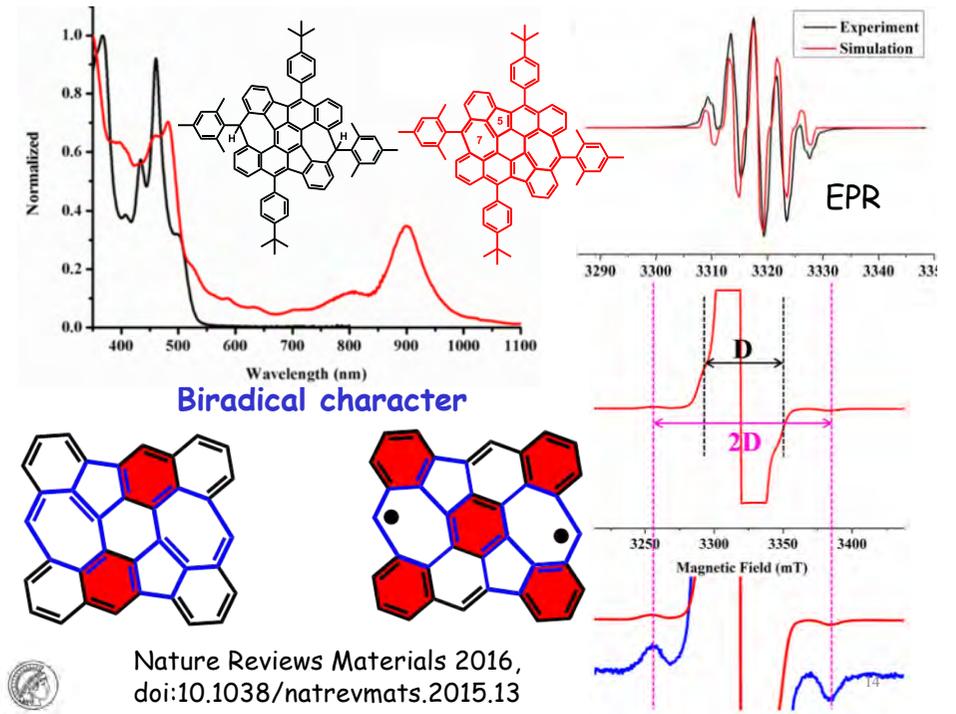
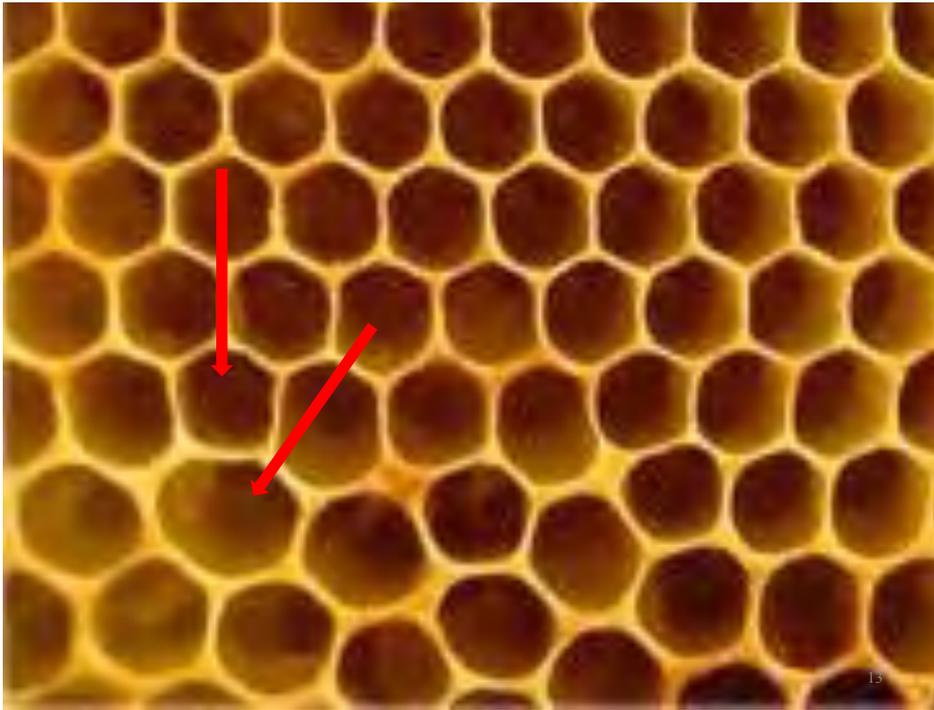
Chiroptical Properties

Optical resolution by
Chiral HPLC



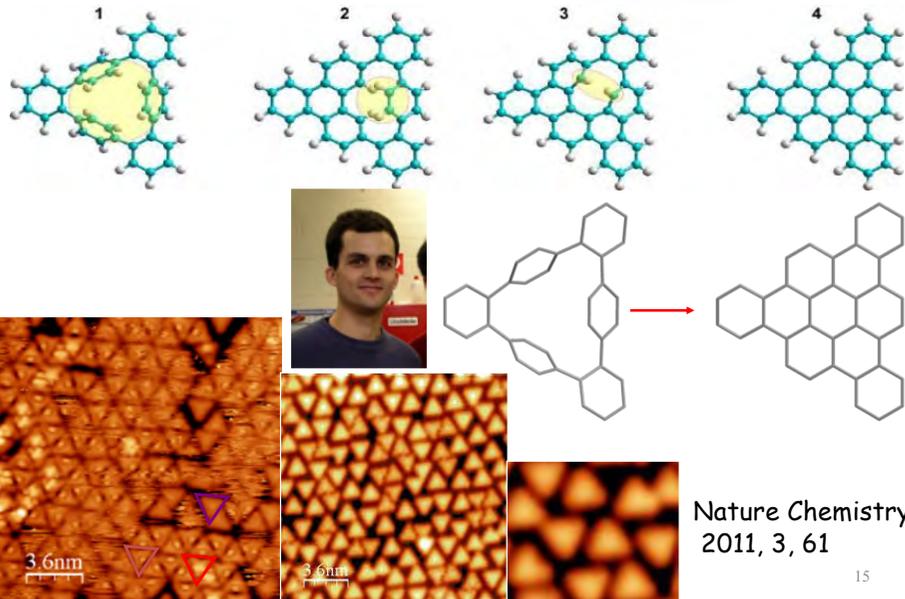
CD spectra



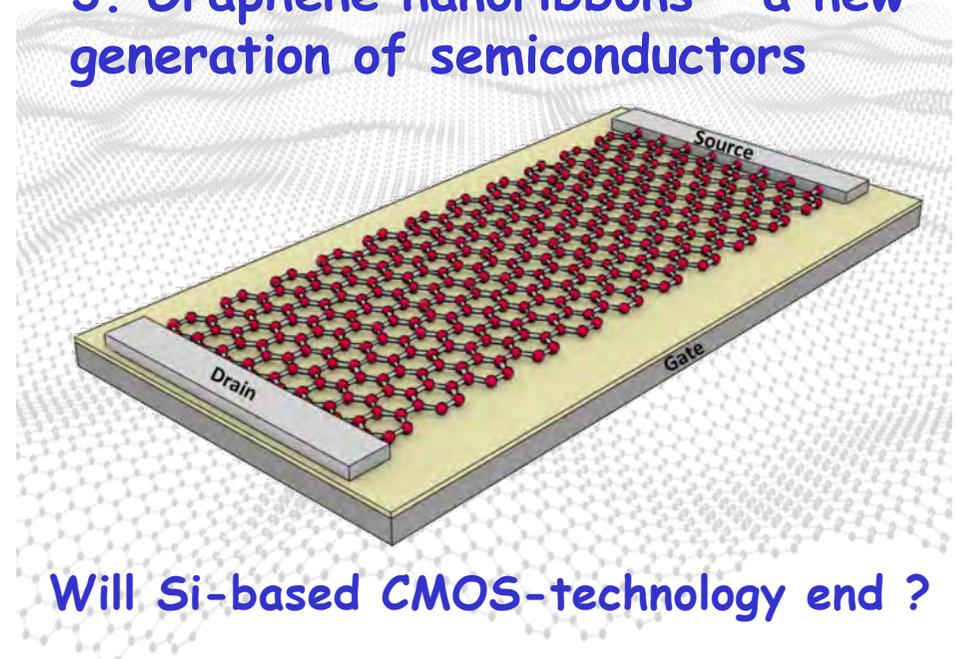


d. Surface chemistry - under in-situ STM control

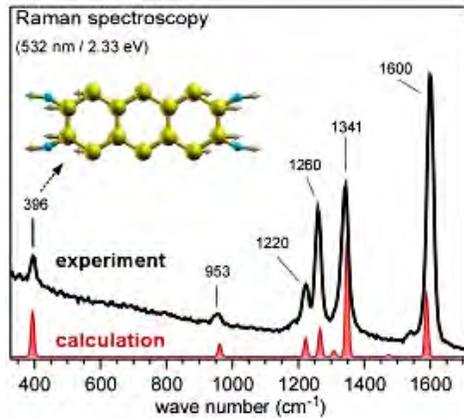
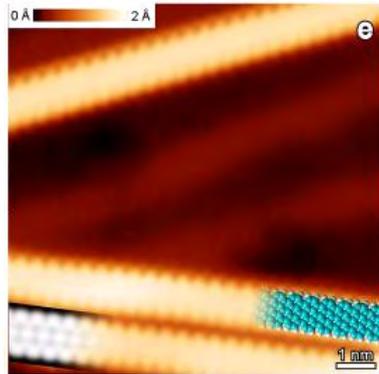
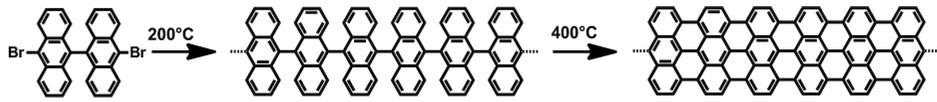
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3. Graphene nanoribbons - a new generation of semiconductors

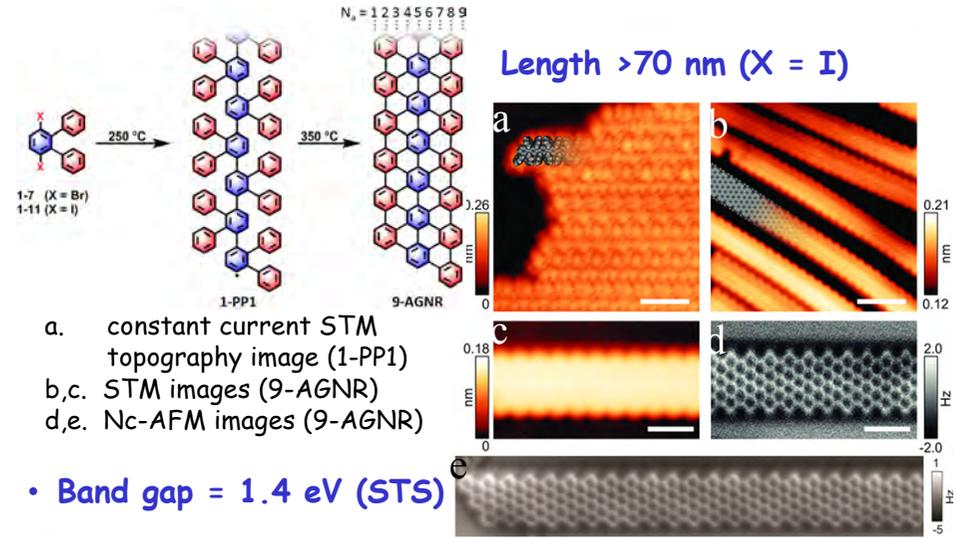


Straight graphene nanoribbons with atomic precision: 7-AGNR



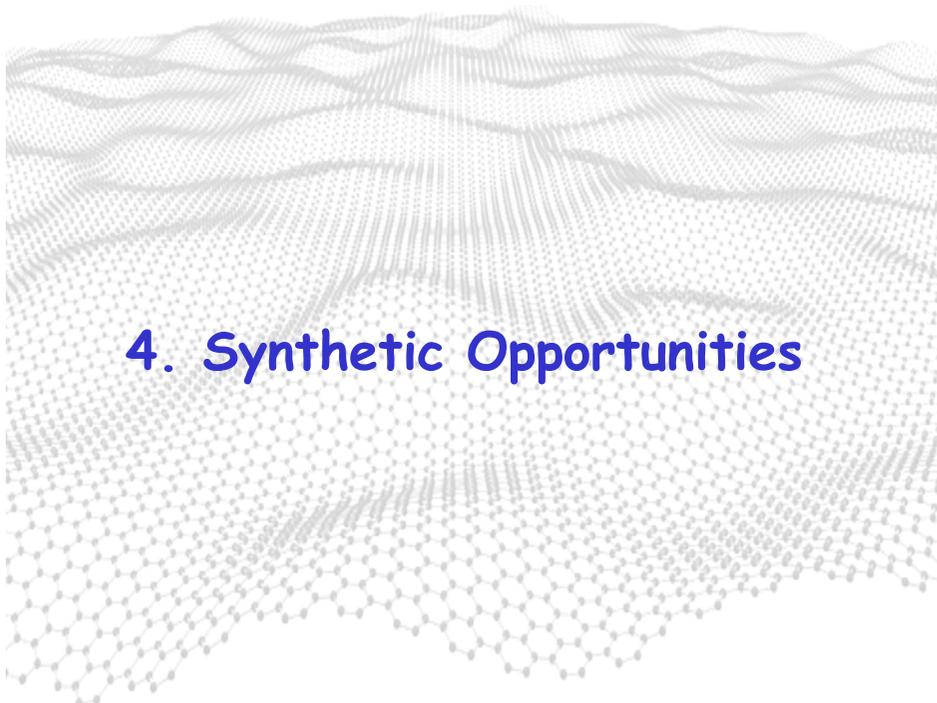
Nature 2010, 466, 470

9-Atom wide armchair-GNR (9-AGNR)



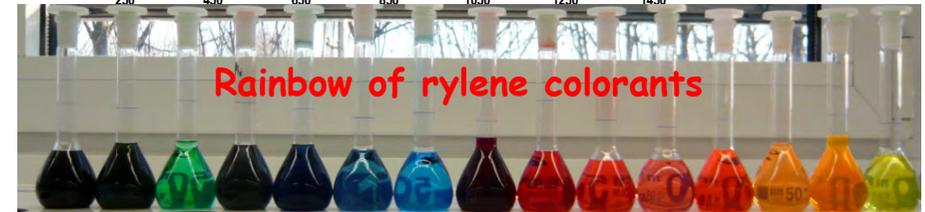
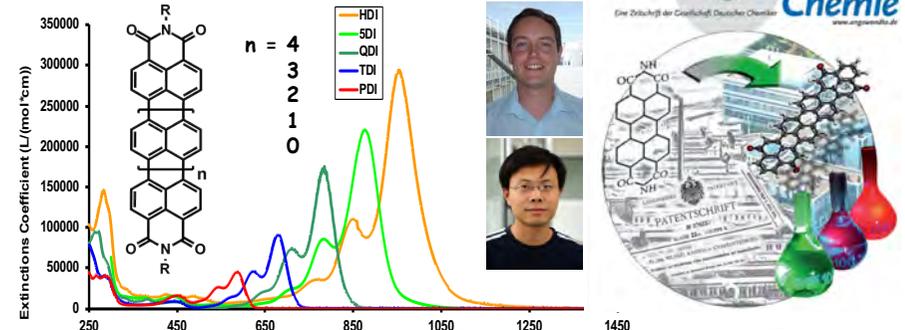
- a. constant current STM topography image (1-PP1)
 - b,c. STM images (9-AGNR)
 - d,e. Nc-AFM images (9-AGNR)
- Band gap = 1.4 eV (STS)

ACS Nano 2017, 11, 1380

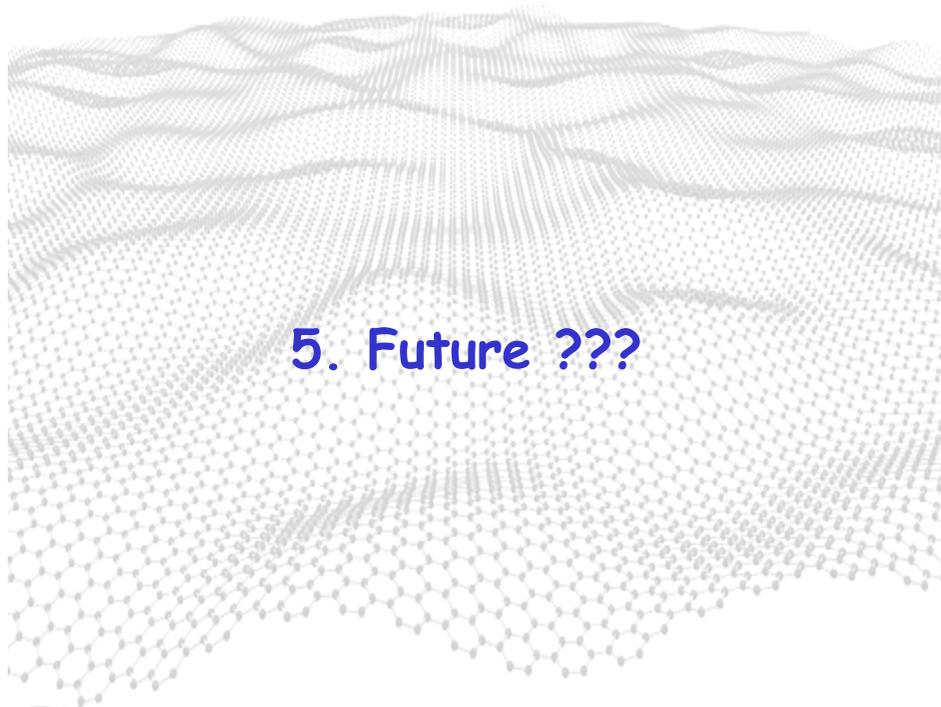


4. Synthetic Opportunities

a. From colorants to GNRs



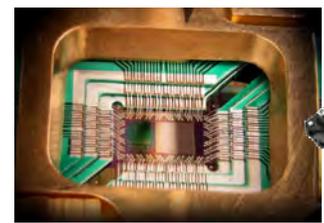
Nature 2010, 446, 905 (v. Hulst) Nature Photonics 2009,3, 654 (Moerner)
Nature Nanotechnology 2014, 9, 131 (Hofkens); ibid. 9, 183 (Basche)
Angew. Chem. Int. Ed. 2015, 54, 2285;



Electronics in the 21st century

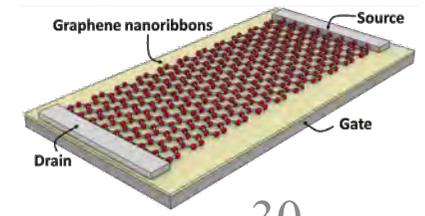
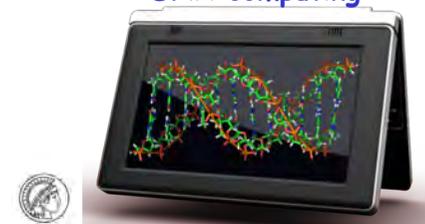


smaller faster denser
 quantum computing spintronics artificial neural networks

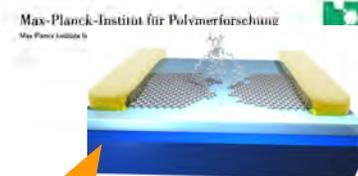


DNA computing

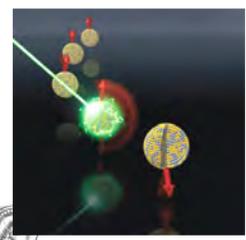
single-molecule electronics



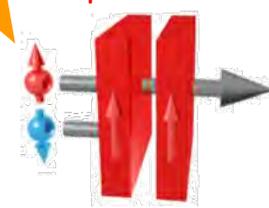
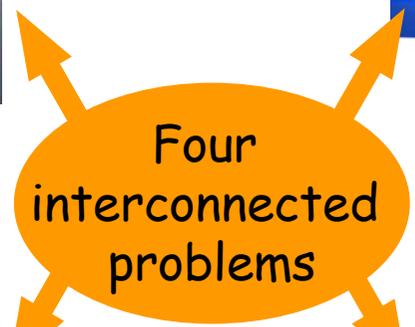
Quantum computing



Single-spin sensing



Spin control

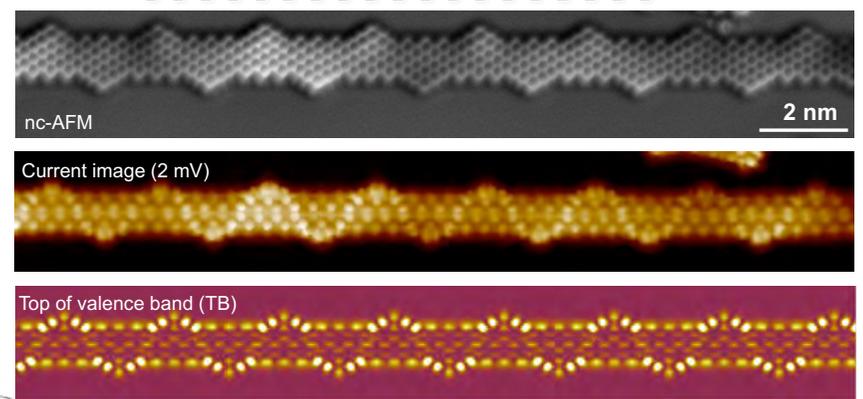
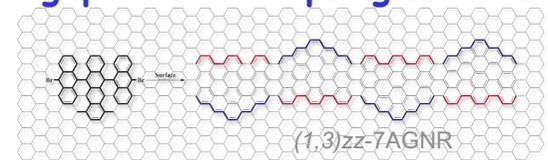


Molecular spintronics

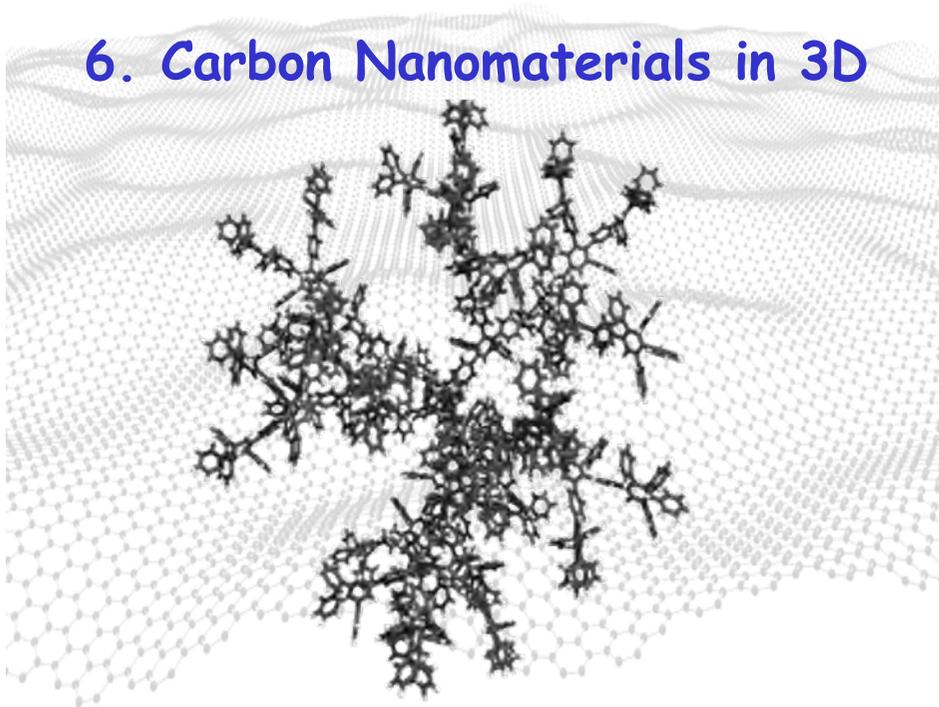
Zigzag-Extended 7-AGNRs with Low Bandgap: toward topological insulators



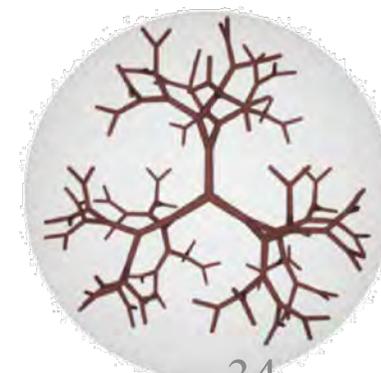
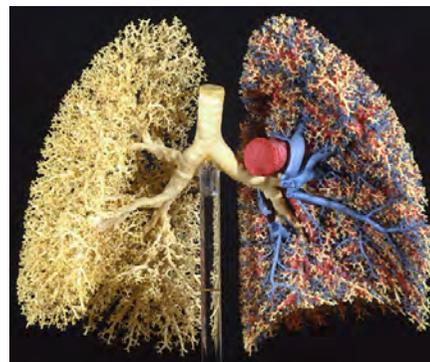
EMPA
Materials Science & Tech



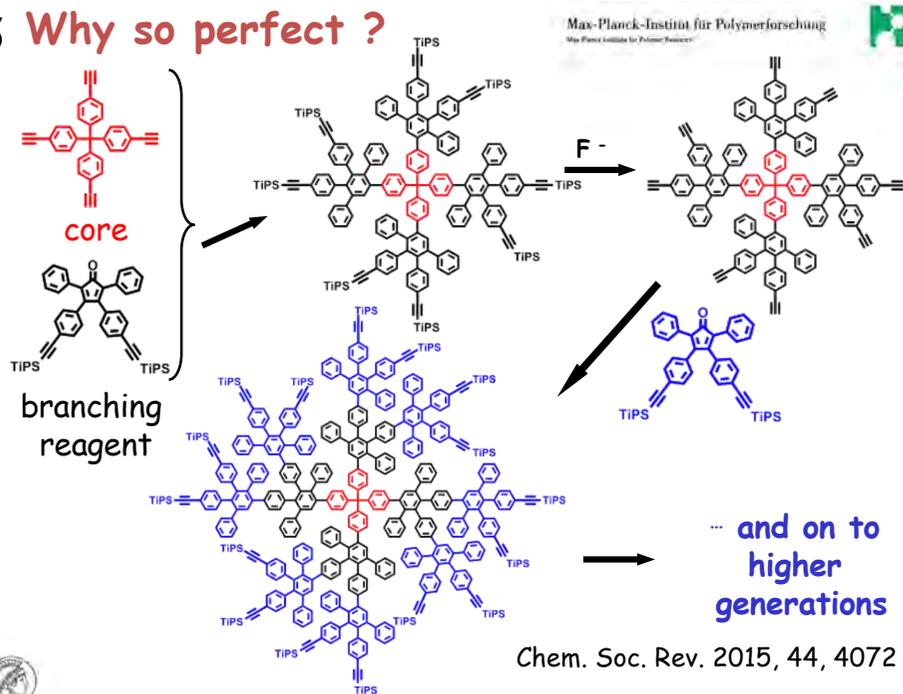
6. Carbon Nanomaterials in 3D



Dendritic structures



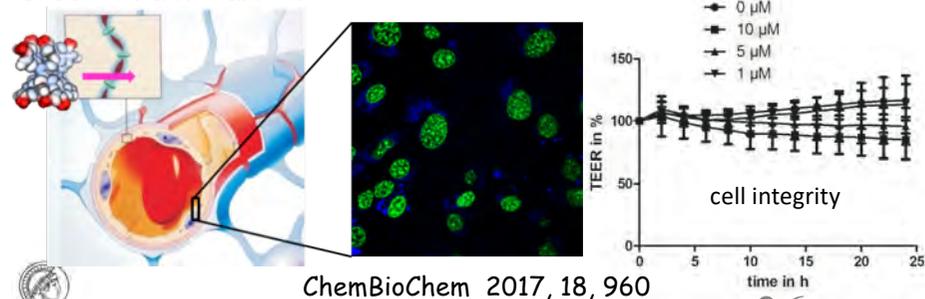
5 Why so perfect ?



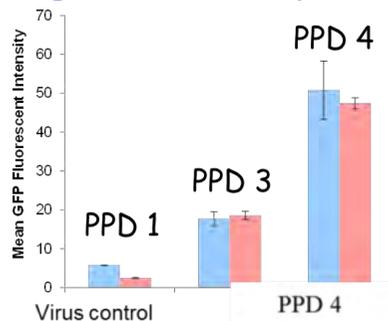
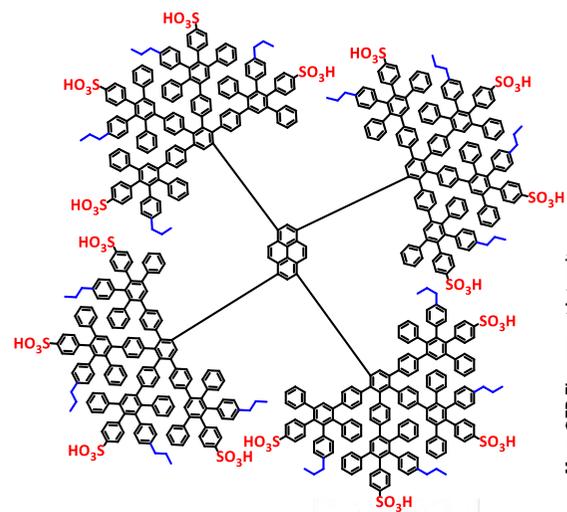
Passing the blood brain barrier



Blood brain barrier



Enhancing adenovirus-mediated gene delivery



Chem. Soc. Rev. 2015, 44, 4072