:FutureCarbon

Carbon Composite Innovations

WEBINAR: NEW CARBONS, FUTURE APPLICATIONS

Platelet-type carbon nanofibers and their applications

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Material Innovations in Composites

About FutureCarbon: History

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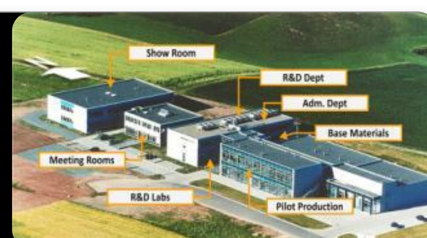
Founder: Dr. Walter Schütz
Foundation: 2002, operational since 2004
Focus: Super-Compounds
Place: Germany, Bayreuth - Upper Franconia
...the German Heart of New Materials



mpe
Mannesmann Pilot Development

vodafone

MANNESMANN

Mobilfunk	Demag Kraus Maffei	Sachs
Eurokom	Rexroth	VDO
Arcor	Dematic	Steel Business

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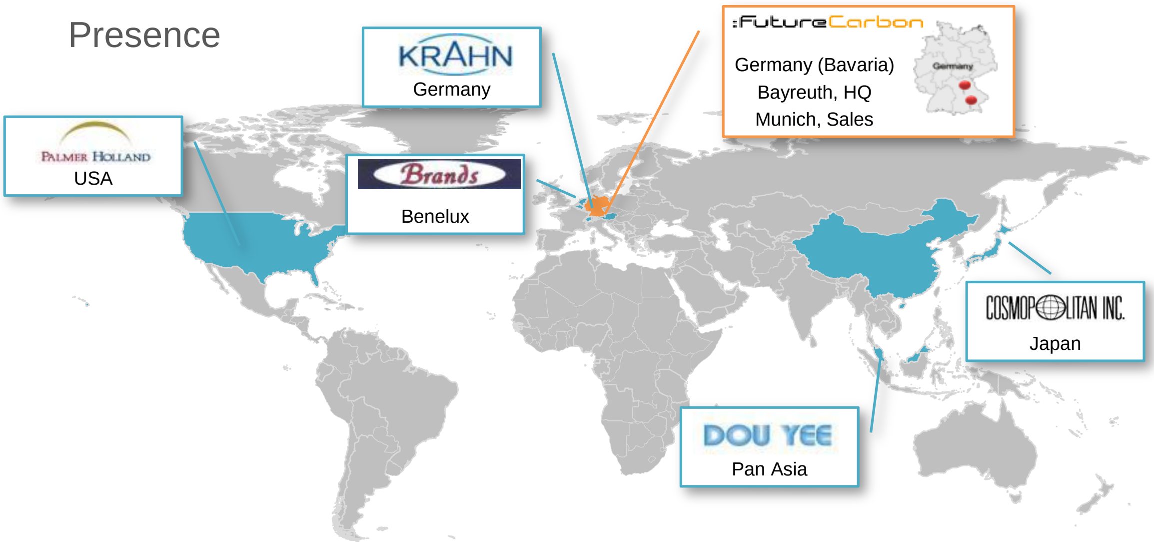
Presence



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Material Base | Value Chain

From raw material to applied product

Material Base
- Carbon Nanomaterials
- Carbon black
- High Tech Graphites

Material Processing
- cleaning
- functionalizing
- homogenizing
- metallization
- delamination/ exfoliation

Semi Finished Product
- Material combination
- App specific resins/coatings
- Aqueous & Solvent formula, e.g.
  - Dispersions
  - Resins
  - Coatings
  - Thermoplastics
  - masterbatches

Finished Product
- Carbo e-Therm
- CarboImpreg
- CarboCond
- CarboDis
- CarboForce
- CarboShield
- Custom Product

Applied Product
- CeT Grid
- CeT Tape

…from **Standard** to **Custom Products** in Mass Volume Scales
✚ Application Services

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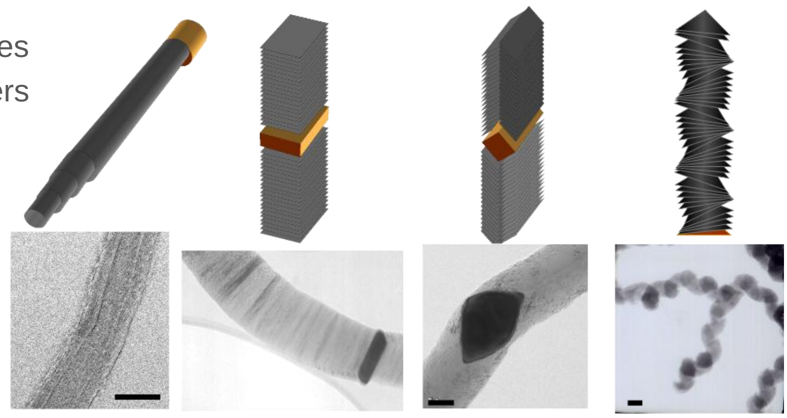
Carbon nanomaterials by FutureCarbon

- Carbon nanotubes
- Carbon nanofibers
  - Platelets
  - Herringbones
  - Screws



CNT CNF-PL CNF-HB CNF-SC

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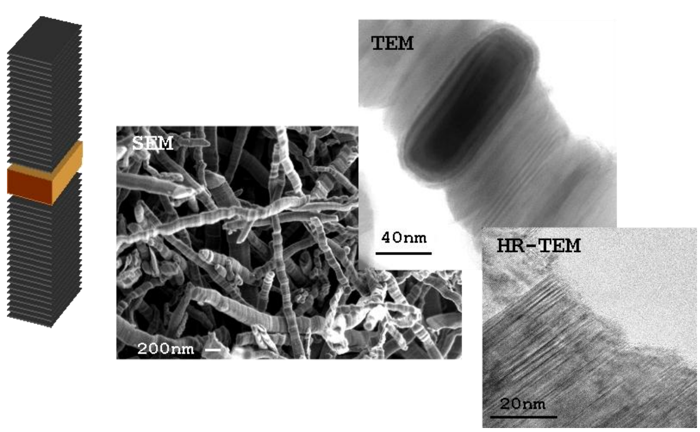
Carbon nanofibers platelet-type (CNF-PL)

- D: 100-250 nm
- L: 0.5-5 µm
- BET: 120m²/g



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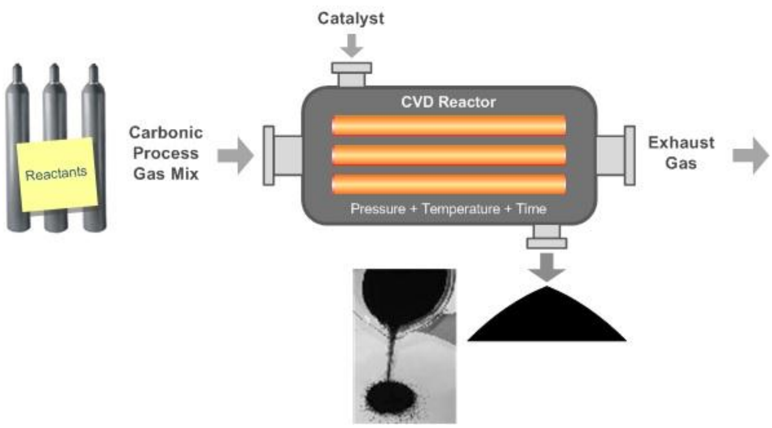
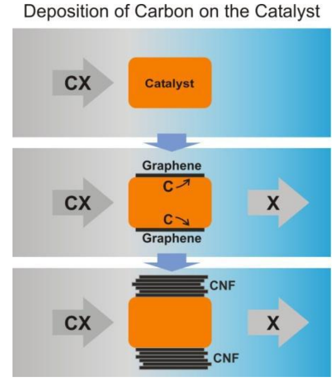
Synthesis

- CCVD process (catalytically assisted chemical vapour deposition)



Deposition of Carbon on the Catalyst



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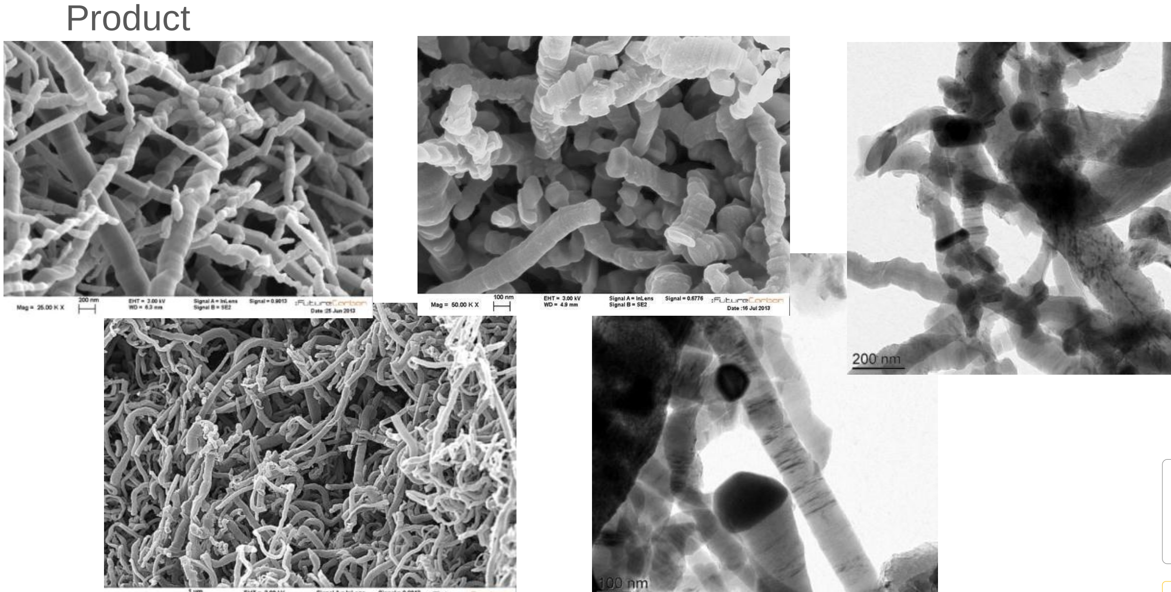
Product



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Properties

- Stabilizing surface structure for small particles
- Particularly high oxidation stability
- Hydrothermal stability
- Electrical conductivity
- Further processing possible:
  - Purification
  - Functionalization
  - Annealing
  - …

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Applications

- Additive for electrical conductivity
  - Dispersed in resin
- Catalyst for PEM fuel cells
  - Metallization of CNF-PL
- Catalyst for production of hydrogen from wet biomass
  - Hydrothermal stability
- Graphene production
  - Exfoliation of graphene layers from CNF-PL

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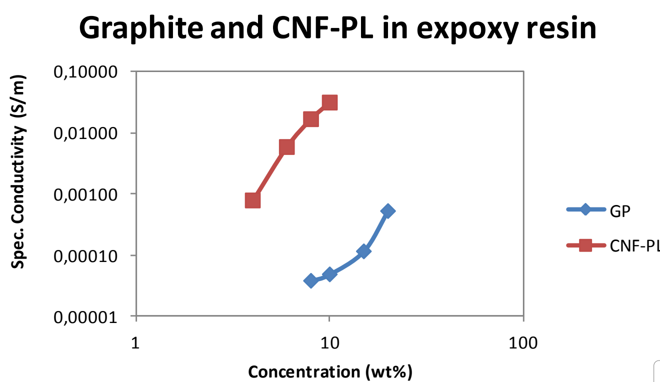
CNF-PL as additive for electrical conductivity

- Dispersion in epoxy resin
- Measurement of electrical conductivity after curing
- Comparison of CNF-PL with graphite
- CNF-PL result in higher electrical conductivity than graphite



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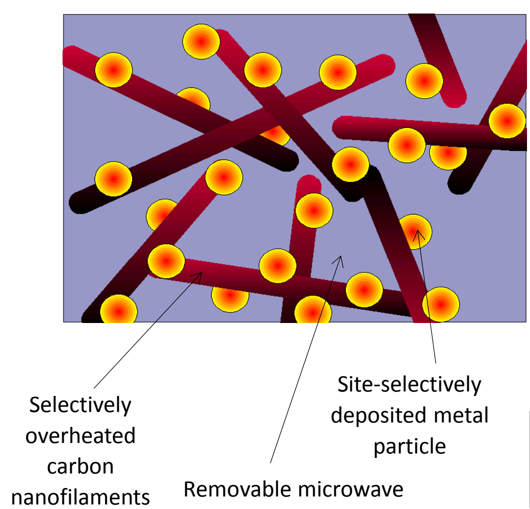
Metallized CNF-PL as catalyst for PEM fuel cells

- Deposition of nano metal particles on CNF-PL
- Metallization process: Colloid microwave processing
- Possible for:
  - Pt, Ru, Pd
  - Cu, Ag, Fe, Co, Ni
- Platelet shape prevents further growth of metal particles



Developed in collaboration with LS Werkstoffverarbeitung, Univ. Bayreuth

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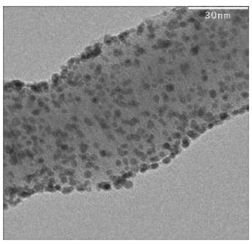
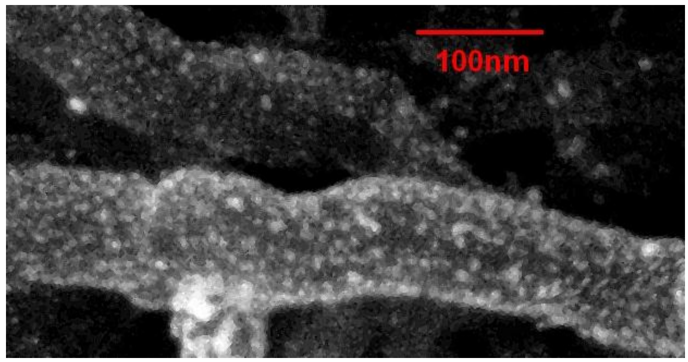
Metallized CNF-PL

- Nano Pt on CNF-PL support
  - TEM (left)
  - SEM (right)





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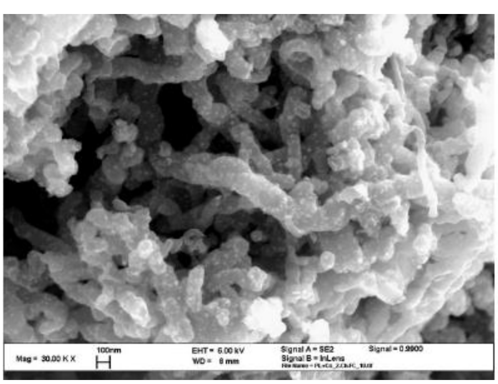
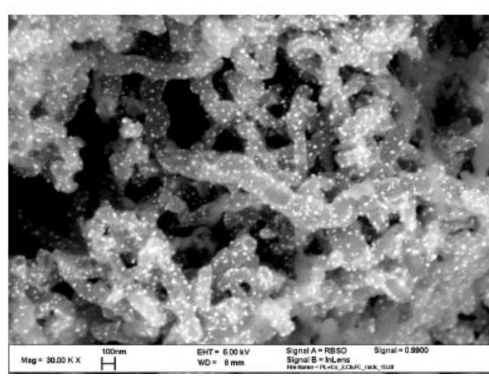
Metallized CNF-PL

- Here: 12 wt% Co on CNF-PL





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CNF-PL as catalyst for sustainable fuel production

- Catalyst for hydrogen production from wet biomass
- Current research project “SusFuelCat”
- Goals:
  - Production of almost carbon monoxide free hydrogen
  - Highly active catalyst with high selectivity towards hydrogen
  - Validated long-term stability of catalyst
  - Lowering costs of catalyst
- Hydrothermal stability is important

SusFuelCat

www.susfuelcat.eu

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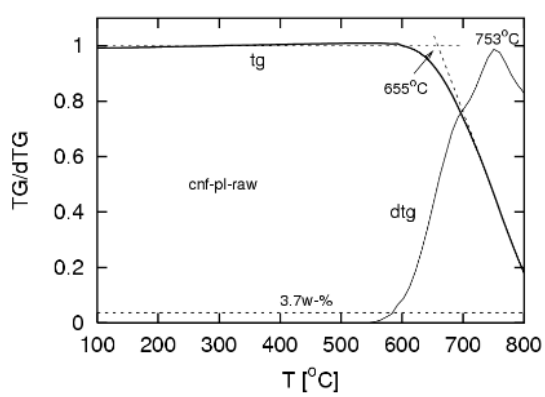
CNF-PL as catalyst for sustainable fuel production

- Test of hydrothermal stability via TGA
- CNF-PL is stable at 650°C in N_2/H_2O atmosphere



SusFuelCat

www.susfuelcat.eu

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Graphene production from CNF-PL

- Exfoliation of graphene sheets from CNF-PL
  - Mechanical exfoliation
  - Via intercalation
  - Via supercritical CO_2
- Research project “UNCOS”
  - Attempts to exfoliate graphene from CNF-PL
  - Research still ongoing

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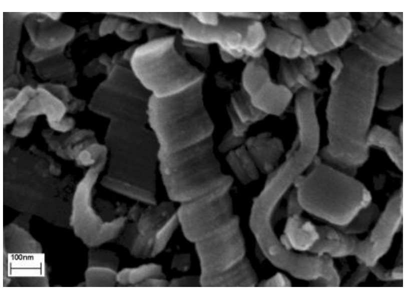
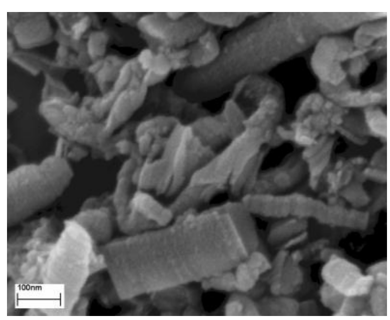
Mechanical exfoliation

- Grinding, milling, shear mixing…
- Shear mixing of CNF-PL dispersions
- Reduction in length down to 100-200 nm



Before shear mixing



After shear mixing

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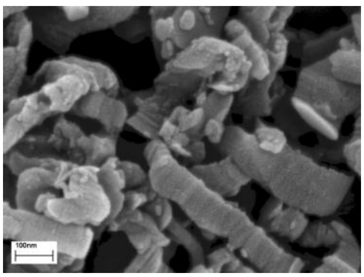
Mechanical exfoliation combined with intercalation

- Route A: Functionalization of CNF-PL with –NH_2 groups
- Route B: Oxidation of CNF-PL via Hummer's method
- Shear mixing of CNF-PL dispersions
- No difference compared to non-functionalized CNF-PL for route A



NH_2-functionalized CNF-PL after shear mixing

?

Route B still in progress

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Graphene exfoliation via supercritical CO_2

- Exfoliation of graphene from graphite via supercritical CO_2
- Independently reported in literature:
  - Pu et al., Materials Letters 2009, 63, 1987-1989
  - Zheng et al., RSC Adv. 2012, 2, 10632-10638
  - C. Wattanaprayoon 2011, Master Thesis, Michigan Technological University, http://digitalcommons.mtu.edu/etds/8

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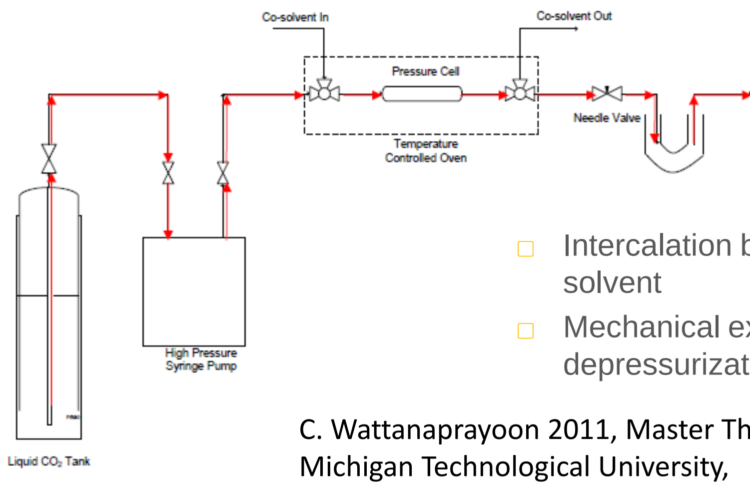
Graphene exfoliation via supercritical CO_2



- Intercalation by $scCO_2$ with co-solvent
- Mechanical exfoliation by rapid depressurization in $scCO_2$

C. Wattanaprayoon 2011, Master Thesis, Michigan Technological University, http://digitalcommons.mtu.edu/etds/8

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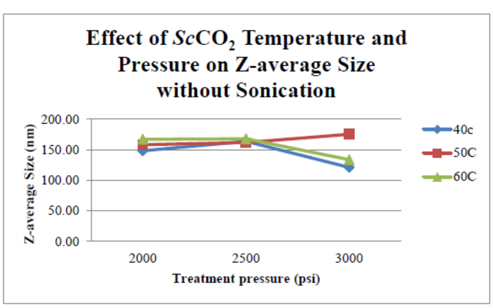
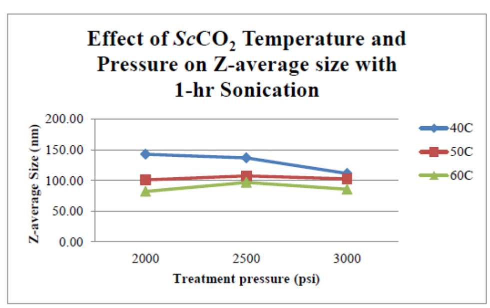
Graphene exfoliation via supercritical CO_2





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- Successful exfoliation of graphite to few-layer graphene in literature
- UNCOS project: Similar setup for CNF-PL -> **?** (work ongoing)

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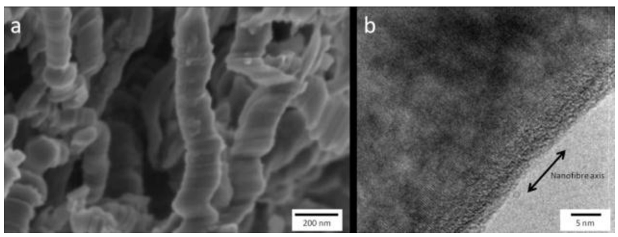
Graphene exfoliation via intercalation in solution

- Successful route by Milner et al. with FutureCarbon's CNF-PL
  - J. Am. Chem. Soc. 2012, 134, 8302-8305
- Intercalation of CNF-PL with potassium-ammonia solution
- Dissolution in THF yields negatively charged graphene



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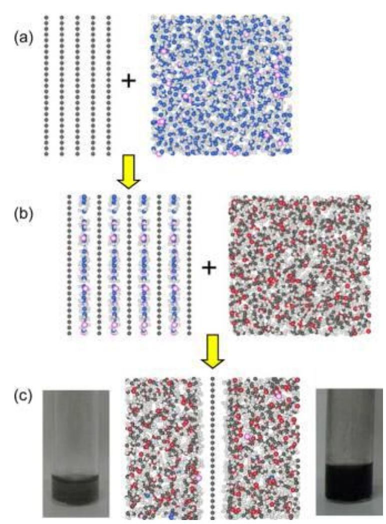
Graphene exfoliation via intercalation in solution

- Example: 0.01 wt % solution (left)
- Example: 0.1 wt % solution (right)
- Analysis by small angle neutron scattering
- Result:
  >95 vol % of single-layer graphene sheets obtained in solution!



Milner et al., J. Am. Chem. Soc. 2012, 134, 8302-8305

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Acknowledgements

THANK YOU!

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