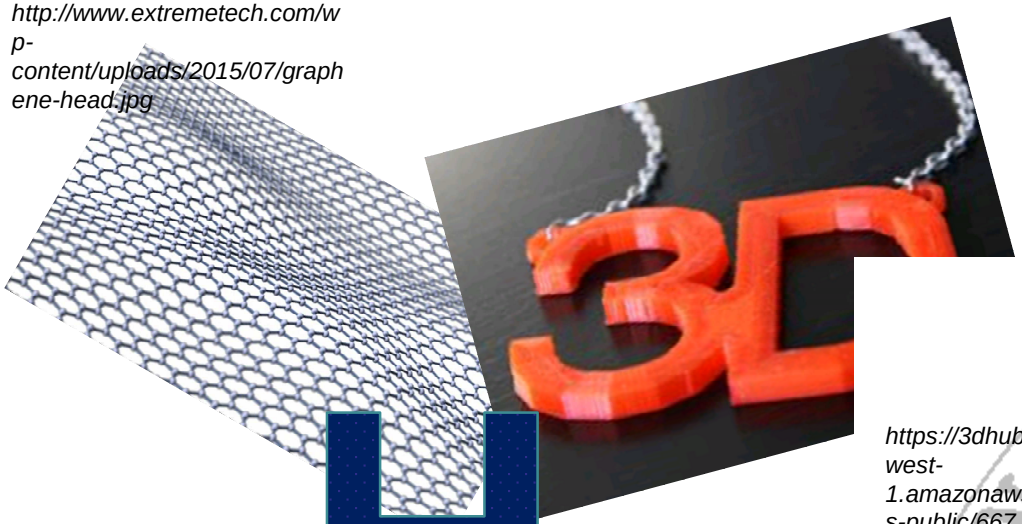
Christian-Albrechts-Universität zu Kiel

# FLAG-ERA Meeting Budapest

*http://www.extremetech.com/wp-content/uploads/2015/07/graphene-head.jpg*




$H_2$

*https://3dhubs.s3-eu-west-1.amazonaws.com/s3fs-public/667.jpg*

Rainer Adelung

Institut for Materials Science -
Chair for Functional Nanomaterials

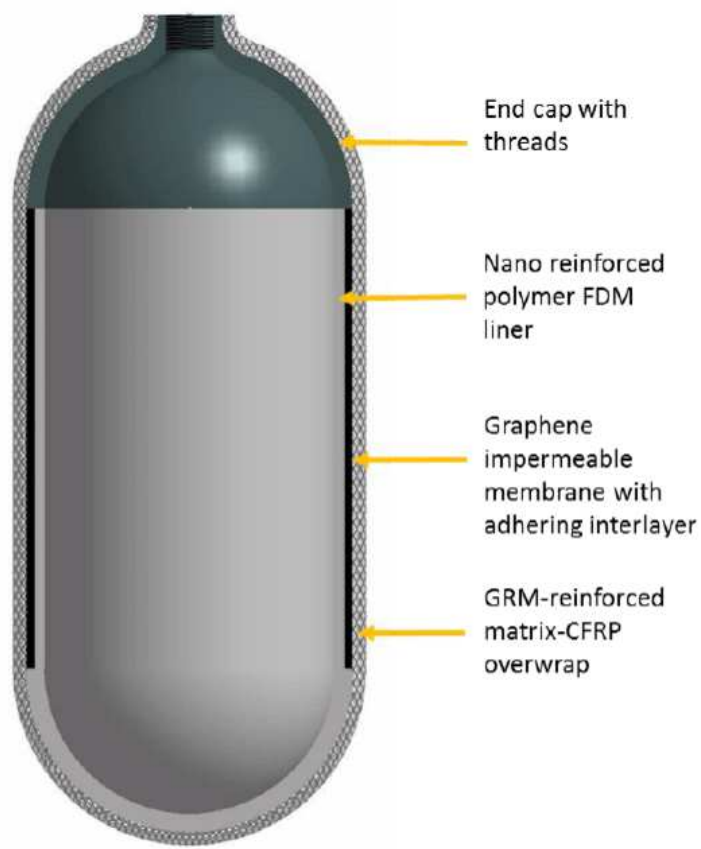
# GRMH2TANK

Christian-Albrechts-Universität zu Kiel

# Aim of the Project

Christian-Albrechts-Universität zu Kiel

- High-performance and lightweight Graphene-CFRP compressed hydrogen storage tank for aerospace applications
- Nanomaterial reinforced 3D printed polymer liner
- Graphene low permeability layer
- Graphene and related Materials reinforced matrix CFRP composite overwrapped layer



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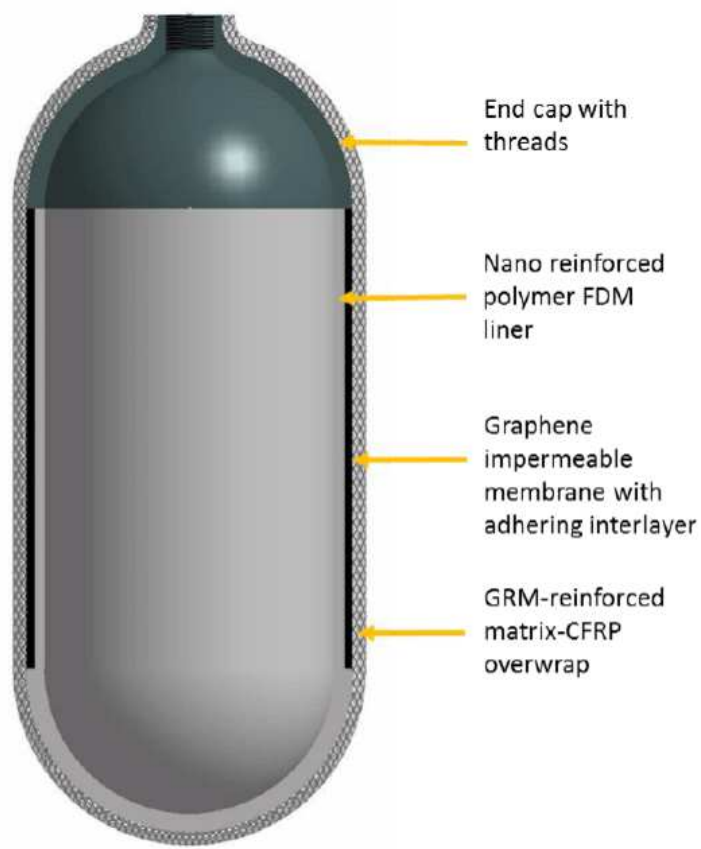



**Lightweight yet highly insulated tank for pressurized hydrogen gas**

# Scientific Background & Key Challenges

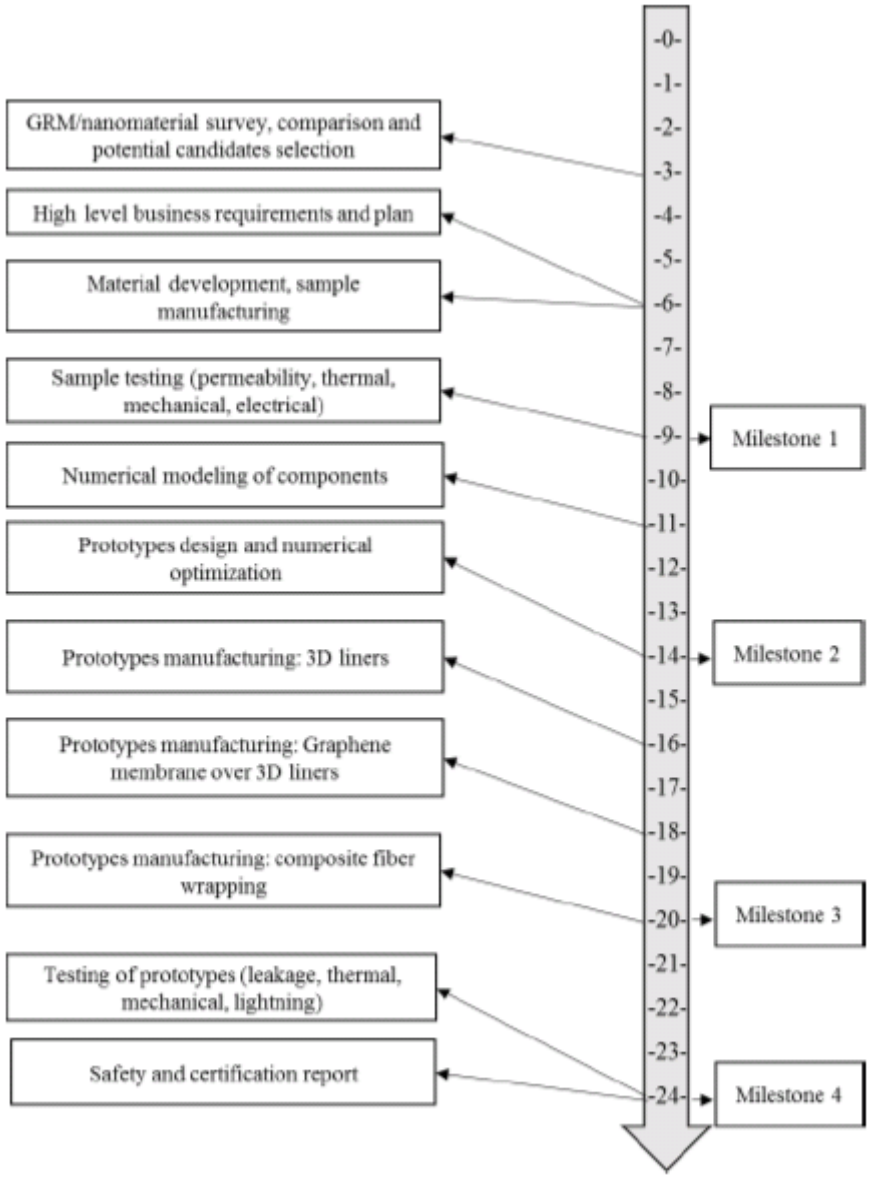
Christian-Albrechts-Universität zu Kiel

- Low Hydrogen Permeability
  - Design of a Graphene membrane as a gas barrier
- High Pressure
  - Nanomaterial filled polymer composites for 3D printed liner and overwrap
- Extreme Conditions (Aircraft)
  - Pressure ($\Delta p = 0.7$ bar) and temperature ($\Delta T = 110$ °C) changes
- Low weight
- High electrical conductivity (against lightning strikes)

# Work Plan

Christian-Albrechts-Universität zu Kiel

- WP1 Design and numerical analysis
  - Gelxyz, BTU
- WP2 Nanomaterial reinforced 3D printed liner manufacturing
  - U. Kiel, Leibniz
- WP3 Production of hydrogen proofed GRM membrane
  - Leibniz, U. Kiel
- WP4 GRM reinforced composite manufacturing
  - Leibniz, U. Kiel
- WP5 Samples and prototyping testing
  - Onera, BTU

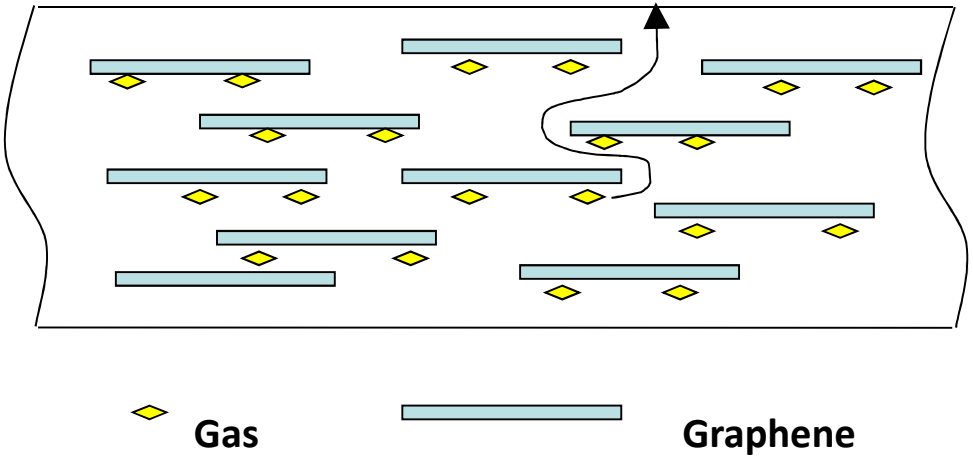


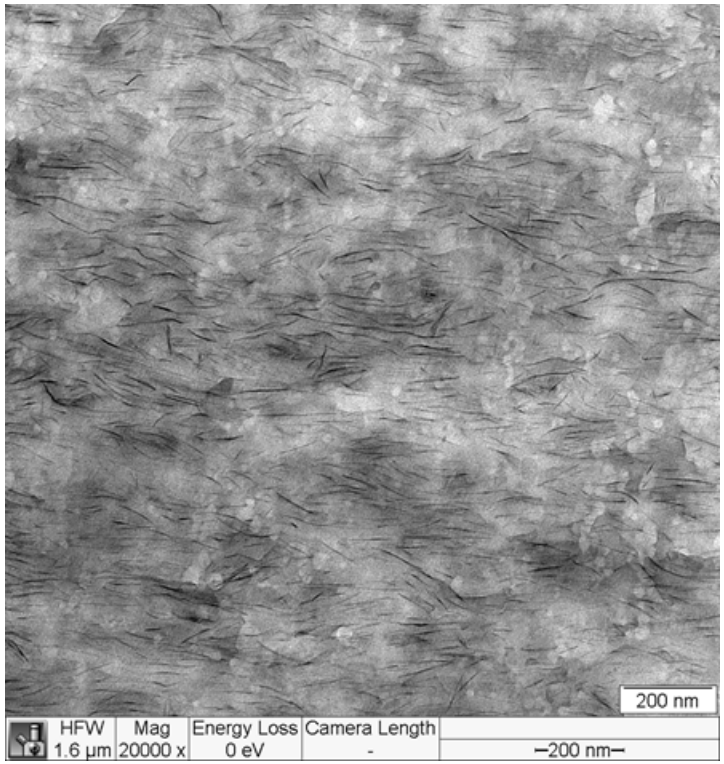
# Project Consortium

Christian-Albrechts-Universität zu Kiel

- **Leibniz Institute für Polymerforschung (IPF)**
  - Expertise in nanoparticle reinforced polymer compounding and extrusion
  - Development of Graphene composite membrane as hydrogen diffusion barrier

Leibniz-Institut
für Polymerforschung
Dresden e.V.



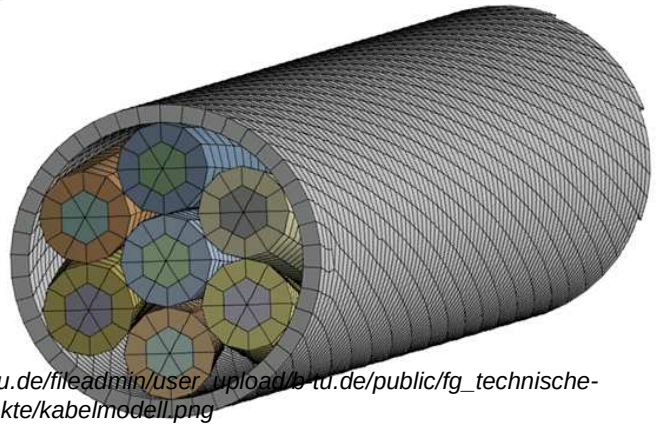

8 % Montmorillonit in Polyamid 6

# Project Consortium

Christian-Albrechts-Universität zu Kiel

- **Brandenburg University of Technology Cottbus-Senftenberg (BTU)**
- Key competence is the analysis of complex systems and boundary conditions and the development of mechanical model systems
- Numerical simulation and analysis of nanoreinforced 3D printed liner and GRM overwrap

b-tu Brandenburgische Technische Universität Cottbus - Senftenberg



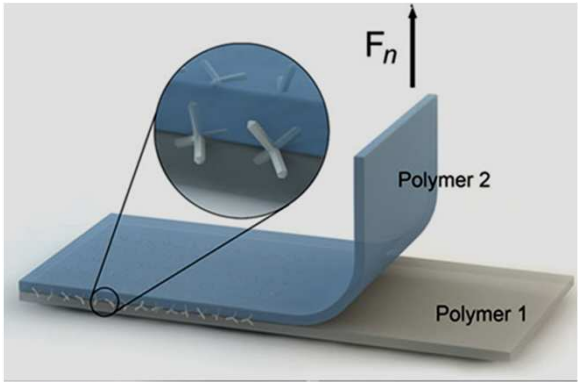
*https://www.b-tu.de/fileadmin/user_upload/b-tu.de/public/fg_technische-mechanik/projekte/kabelmodell.png*

http://*static.hs-lausitz.de/www/typo3temp/pics/CIMG4335_2_fb10f1078b.jpg*

# Project Consortium

Christian-Albrechts-Universität zu Kiel

- **Kiel University (CAU)**
- Expertise in functional nanocomposites, containing carbon nanostructures or metal oxide fillers like ZnO
- Manufacturing of nanoparticle reinforced tank liner using a fused deposition modeling process (3D printing)




*Jin, X., Strueben, J., Heepe, L., Kovalev, A., Mishra, Y. K., Adelung, R., Gorb, S. N. and Staubitz, A. (2012), Joining the Un-Joinable: Adhesion Between Low Surface Energy Polymers Using Tetrapodal ZnO Linkers. Adv. Mater., 24: 5676–5680. doi:10.1002/adma.201201780*

*Mecklenburg, M., Schuchardt, A., Mishra, Y. K., Kaps, S., Adelung, R., Lotnyk, A., Kienle, L. and Schulte, K. (2012), Aerographite: Ultra Lightweight, Flexible Nanowall, Carbon Microtube Material with Outstanding Mechanical Performance. Adv. Mater., 24: 3486–3490. doi:10.1002/adma.201200491*

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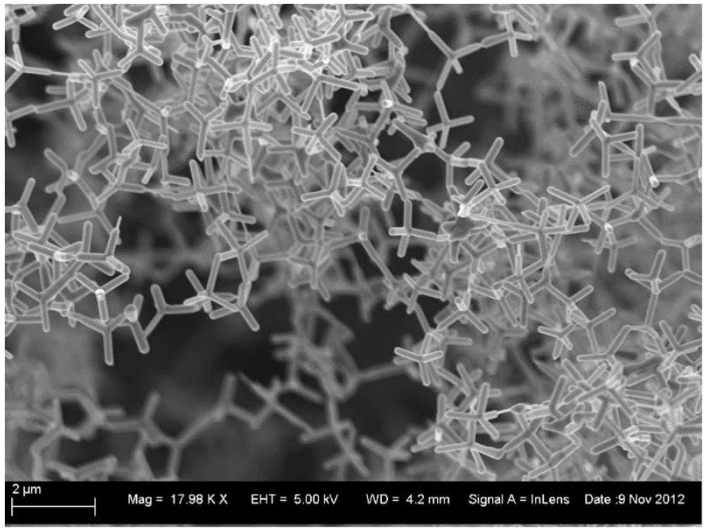


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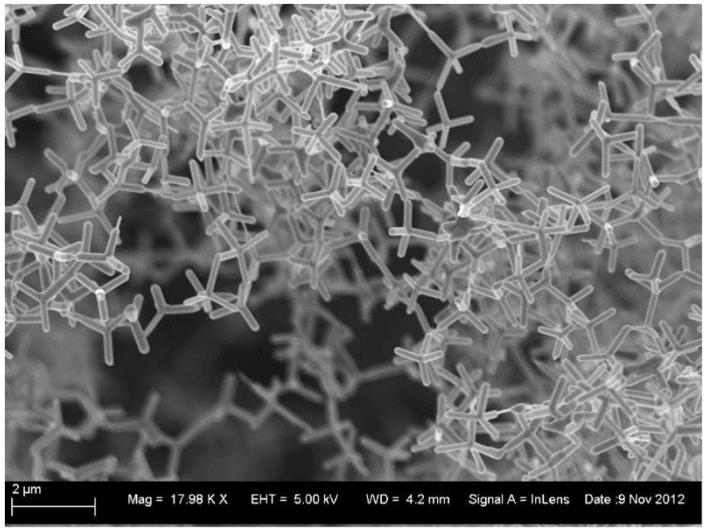


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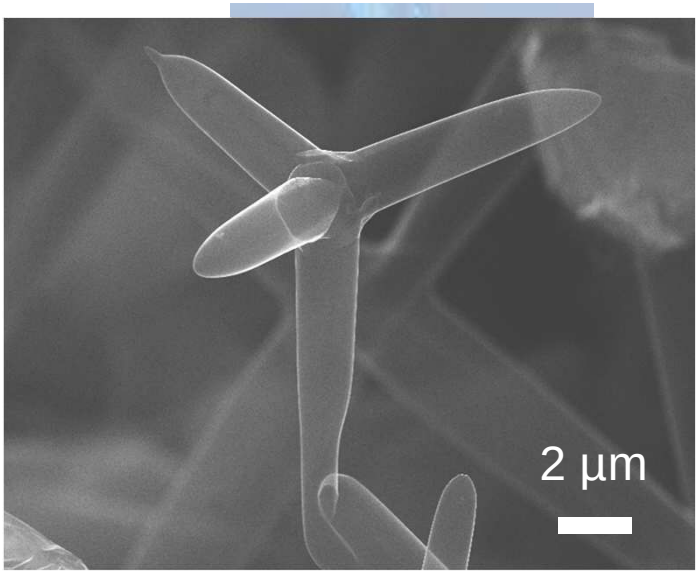


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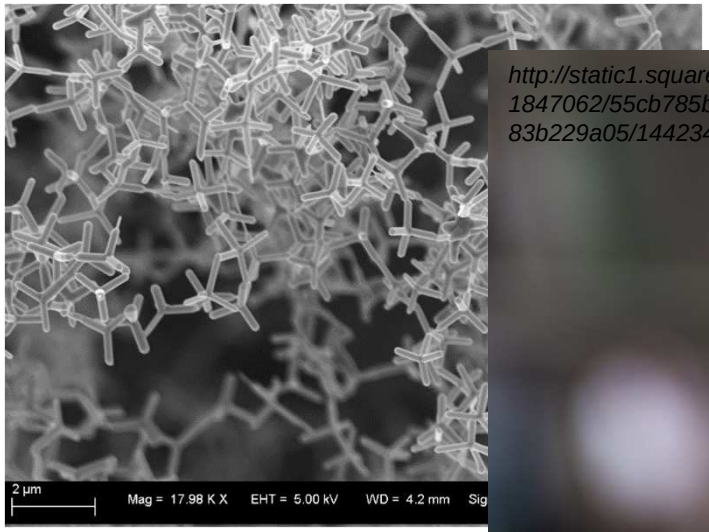


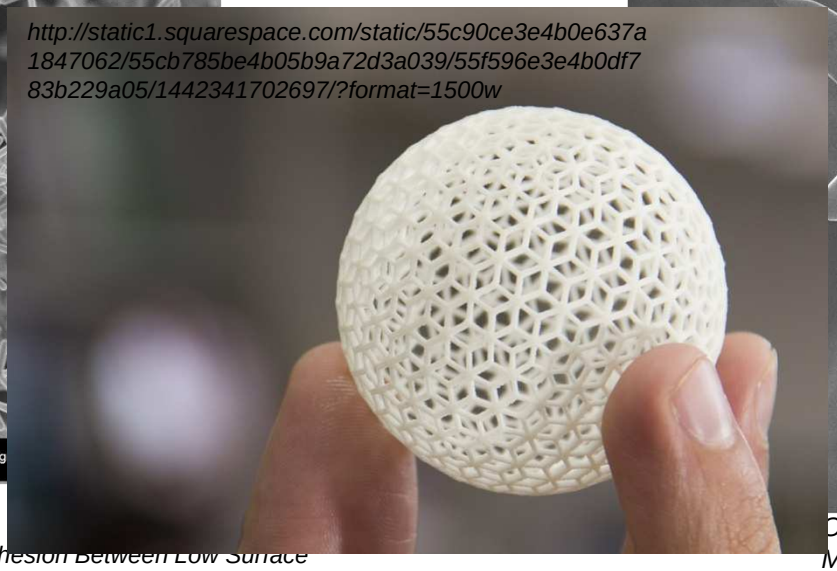

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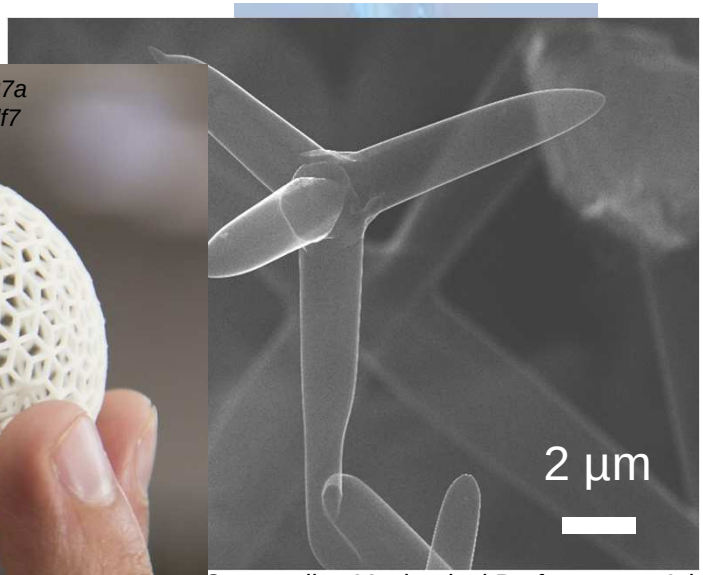


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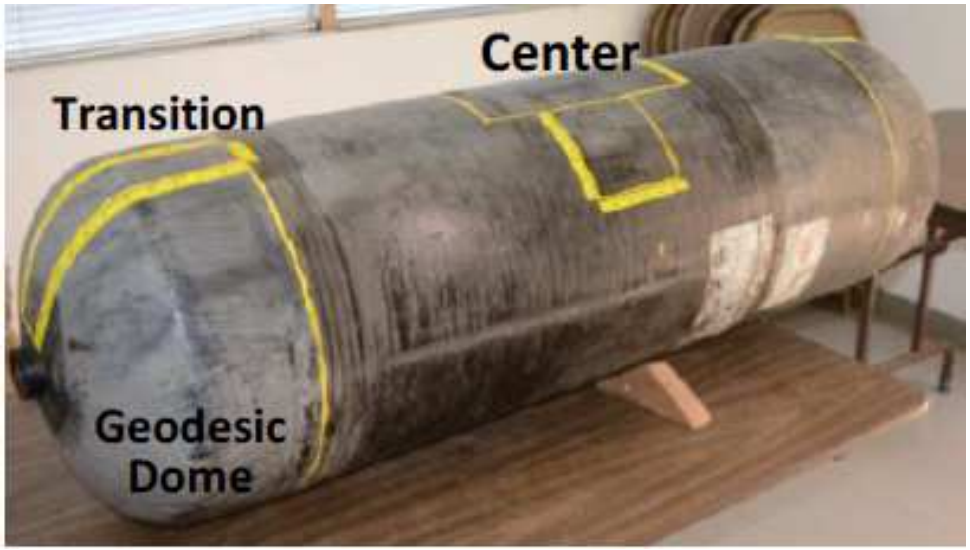
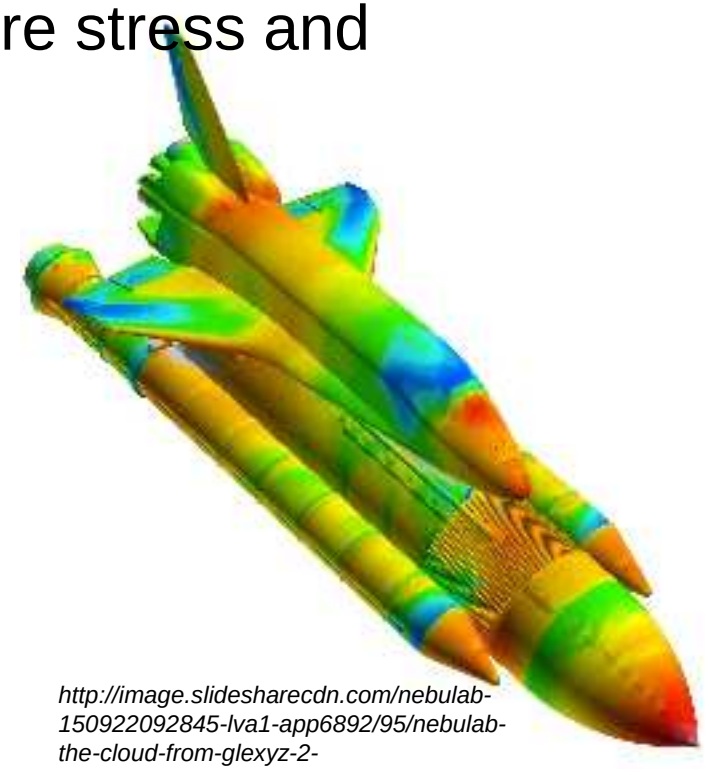
# Project Consortium

Christian-Albrechts-Universität zu Kiel

- **GLEXYZ**
- Expertise in product simulation, manufacturing processes and electronics for e.g. aerospace applications
- Simulation task, such as multi-scale progressive failure analysis relative to burst, fatique, creep, rupture stress and leakage/permeation



*http://image.slidesharecdn.com/nebulab-150922092845-lva1-app6892/95/nebulab-the-cloud-from-glexyz-2-638.jpg?cb=1442914271*

# Project Consortium

Christian-Albrechts-Universität zu Kiel

ONERA
THE FRENCH AEROSPACE LAB

- **Onera**
- Expertise in aerospace applications
- Experimental analysis of lightning effects and thermal-mechanical tests

*http://www.anciensonera.fr/sites/default/files/Modane_Avrieux_400x286.jpg*

*http://i.dailymail.co.uk/i/pix/2011/02/05/article-0-0D0BCB0B000005DC-434_1024x615_large.jpg*

# Progress and Perspectives

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- Evaluation of different thermoplastic polymers as matrix material for graphene membrane
  - Variation in graphene content
  - Morphology investigations
  - Evaluation of permeability

- Compounding of nanoparticle reinforced liner material
  - Different filler materials e.g. tetrapodal ZnO
  - Adhesion of  3D printed liner and graphene membrane

# Organization of the interactions with the Flagship Core Project

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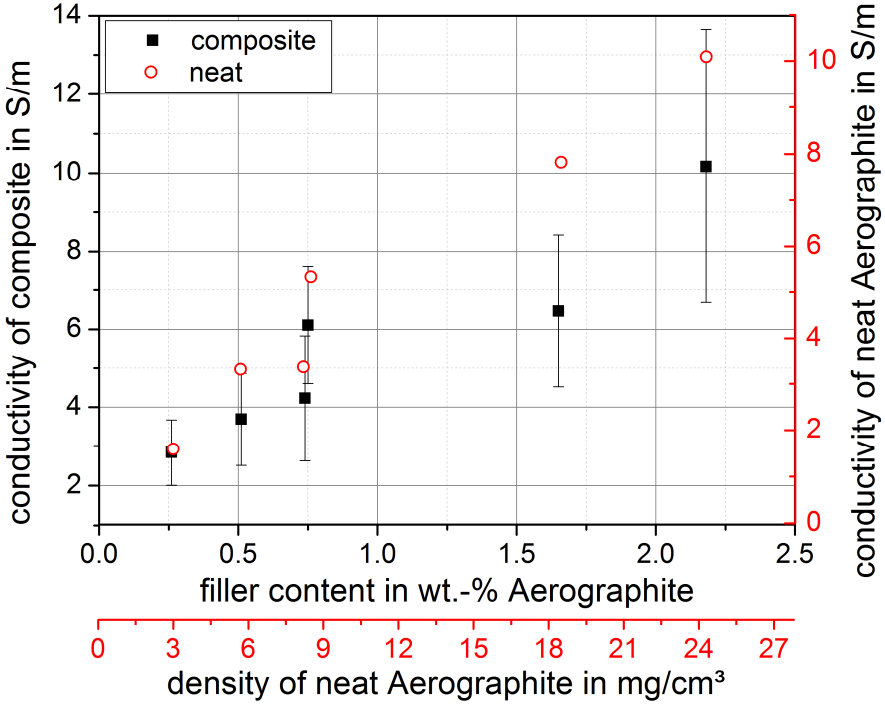
FUNCTIONAL FOAMS AND COATINGS

GRAPHENE FLAGSHIP

- WP 10 now WP 13
  e.g. with TUHH Schulte/Fielder


**Preliminary results on electrical heating of Aerographite composites:**

U = 15 V

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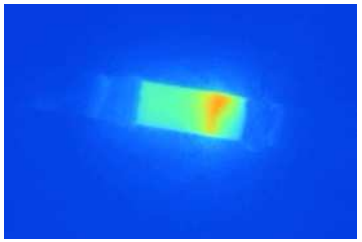

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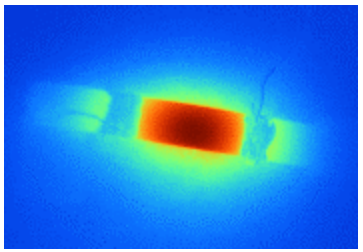

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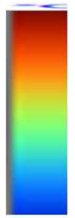


*From Graphene Flagship Meeting April 2016 / TUHH Fiedler/schulte*

# Flagship Flagship Interaction?

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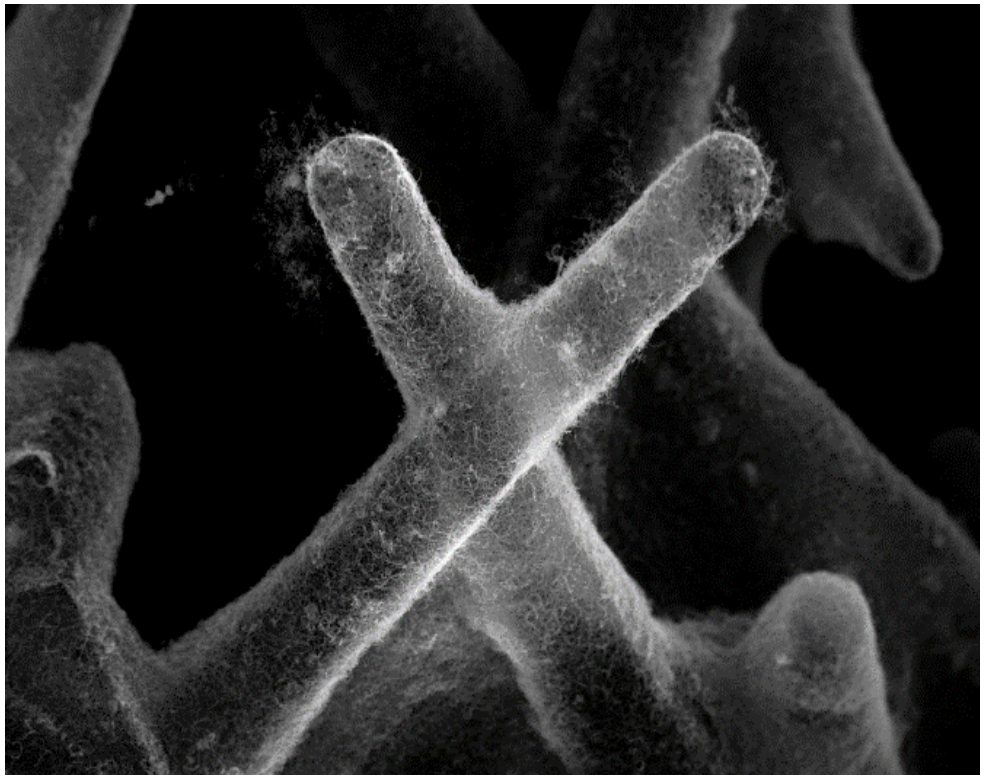
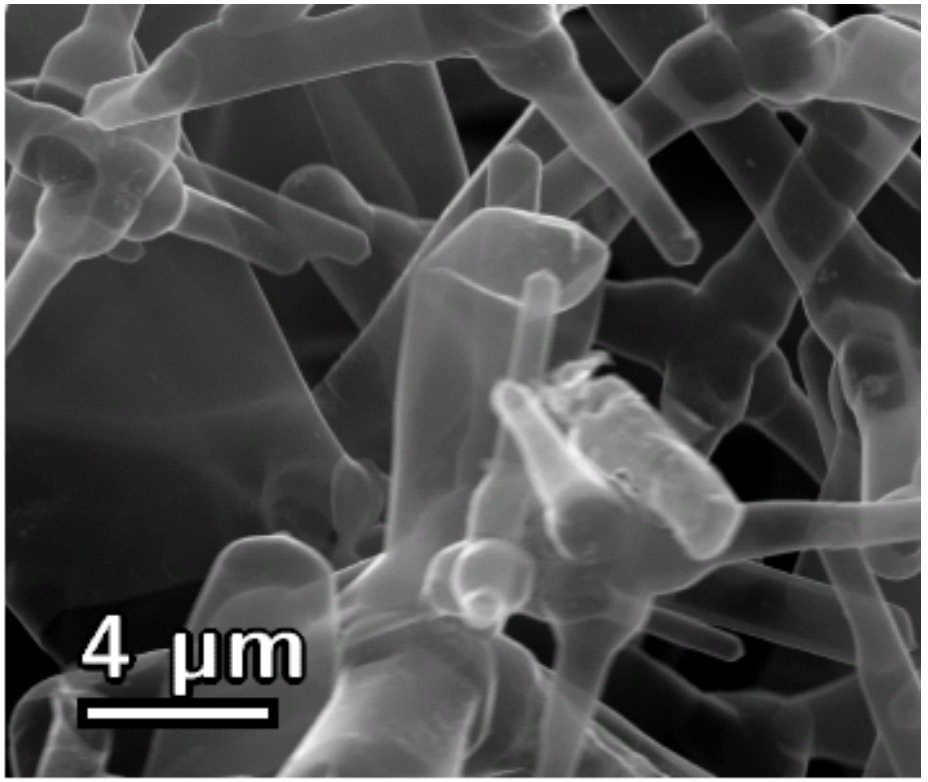
FUNCTIONAL FOAMS AND COATINGS

FOR 2093: Memristive Devices for Neural Systems

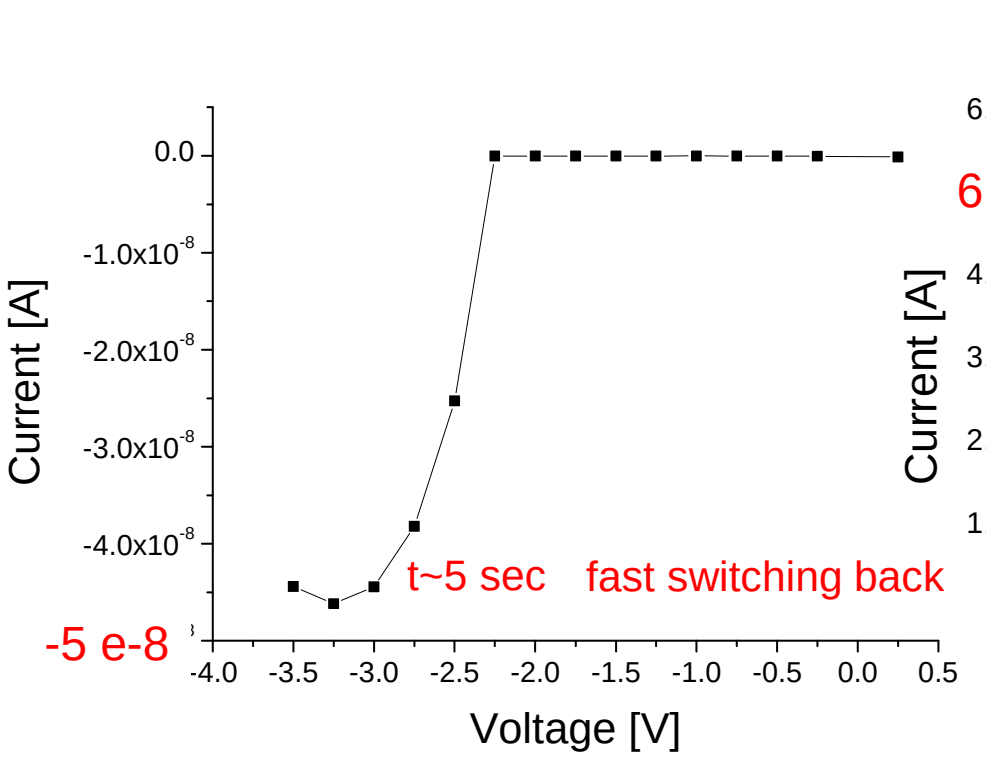
Human Brain Project

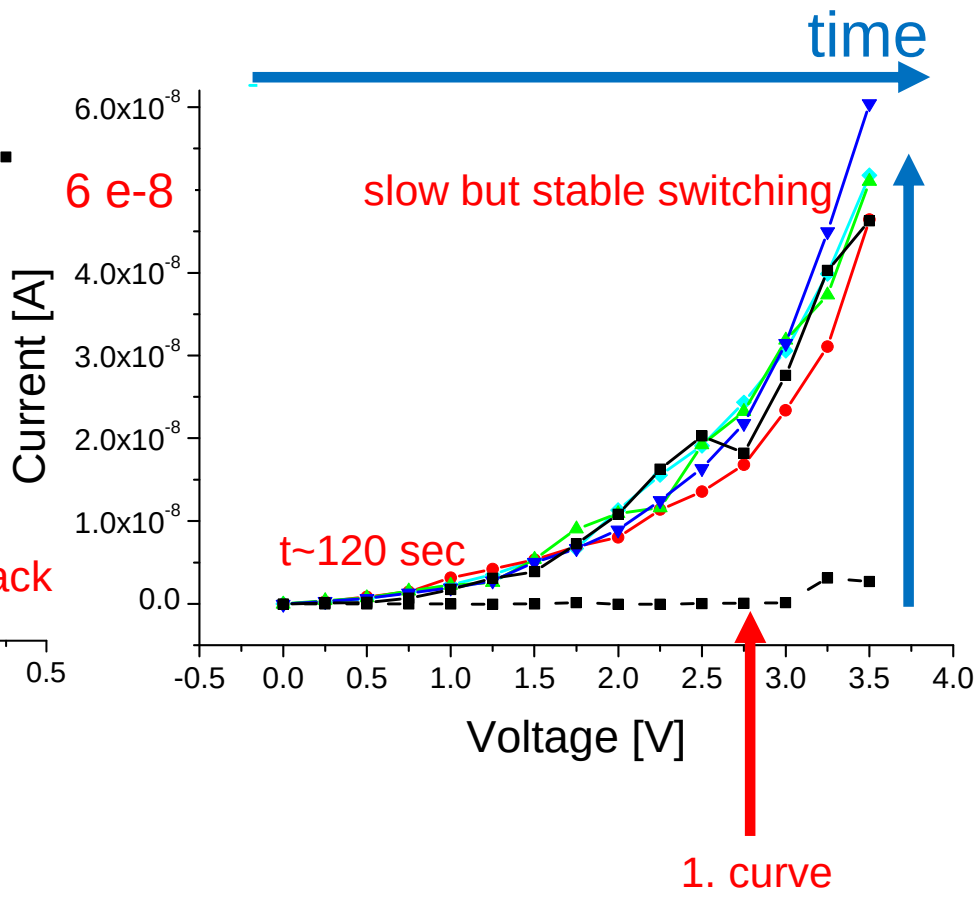
GRAPHENE FLAGSHIP





# Typical behavior for mechanically weak networks: "relay" like



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