Carbon Nanomembranes –

A New Class of Material for Disruptive Applications

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CNM Technologies GmbH

Company Details

Details: Founded in 2011; Start of operational activities in 2012
CNM Technologies holds all patents relevant to carbon nanomembranes.

Activities: Production, sales, and development of new applications of CNMs.

Founding Partners and Shareholders:

- **Dr. Albert Schnieders**: managing director, founder, physicist, former general manager of Tascon USA and application scientist at ION-TOF USA, companies specializing in surface science (NY, USA)

- **Prof. Armin Gölzäuser**: founder, scientific advisor, inventor of CNMs, head of the research group “Physics of supramolecular systems and surfaces” at Bielefeld University with approx. 10 scientists, and first class laboratory and R&D facilities (HIM, XPS, STM, ...)

- **Jörg Vandreier**: founder, management consultant, former CFO of SAP Systems Integration AG, itelligence AG, and IDS Scheer AG

- **Gründerfonds Bielefeld-Ostwestfalen, managed by eCAPITAL entrepreneurial Partners AG, Münster**: invested since May 2014

Funded by the European Union
Carbon Nanomembranes (CNMs)

A New and Unique Class of Material

CNMs are molecular thin, i.e. 1 nm, man-made polymeric membranes.

Household plastic wrap covering a salad bowl

Area covered: 50 x 50 cm²
Film thickness: 10,000 nm

Free-standing CNM

Area covered: 50 x 50 μm²
Film thickness: 1 nm

Reduction of all dimensions by a factor of 10,000

Exemplary Properties

- Controllable chemical functionalization, porosity etc.
- Versatile and scalable manufacturing (from CMOS-compatible integration to large area membranes)
- CNMs are complementary to graphene, but can be transformed into graphene.

CNMs – a modular construction system for functional (biomimetic) nanomembranes
A pristine monolayer of CNM is highly permeable for water and nearly impermeable for any gases larger than He.

CNMs can be easily chemically functionalized.

Perforation can be intrinsically achieved during fabrication.

CNMs are elastic and follow the morphology of a substrate.

CNMs are electrically insulating.

CNMs can be transformed into graphene.

A pristine monolayer of graphene is a perfect barrier for gases.

Graphene cannot be easily functionalized and loses its properties during the process.

Perforation has to be performed retroactively (e.g. via UV/ozone etching or ion bombardment).

Graphene is more brittle.

Graphene has a unique electronic structure.

Graphene cannot be transformed into CNMs.
Carbon Nanomembranes (CNMs)

A Platform Technology with a Huge Variety of Applications

Membranes
- Filtration
- Separation
- Protective coatings
- Barrier layers

Medicine
- Diagnostics, lab-on-a-chip *
- Dialysis
- Tissue engineering
- Next generation sequencing **

Nanotechnology
- TEM- and SPR-sample holder
- Nano tribology
- Nano fluidics
- Nano electromechanical systems (NEMS)

Electronics
- Sensor technology
- Semiconductor manufacturing
- Flexible electronics
- Displays

Energy
- Capacitors
- Batteries
- Fuel cells
- Electrolysis

* Current focus  ** promising research results and/or interest from market
Application: Water Filtration

CNMs - Separation for the Future

- purification of contaminated water (heavy metals, drugs, …)
- concentration of watery solutions (e.g. food industry, wastewater treatment)
- energy-efficient sea water desalination
- atmospheric water generation

CNM as Highly Water-Permeable and Selective Membrane

**Problem:** Polymeric membranes (state-of-the-art as water filtration tools) often suffer from poor separation performances and their operation requires high pressure.

**Solution:**
- Water permeance several orders higher than other membranes
- High selectivity (only water and Helium are transported)
Scaling of Fabrication

Several options of already existing technologies are available for scaling of the three fabrication steps.

Preindustrial fabrication based on batch-production (to be implemented in the coming year)
- Capacity: a few 10,000 m²/year
- Size: 30 x 30 cm² (or other)
- Price: a few 10 €/m²

Concept for high volume manufacturing based on roll-to-roll process
- Size: variable
- Needs development on machine side

Concept for manufacturing based on organic vapour phase deposition (OVPD)-process
- Size: 300 x 300 mm² or 300 mm Ø
- Machine for SAM-Production and Crosslinking “available”

* US 8,377,243 B2, EP 2 144 711 B1
CNM-Based Hybridmembranes

Free-Standing CNMs Supported by Porous Polymer

Test of “large-area” membrane (approx. 2 cm²) for forward osmosis (FO) applications
Application Example: Bio-Sensors

CNMs for Functional Immobilization of Oligonucleotides

- point-of-care diagnostics
- chemical and biological sensors
- next generation sequencing

CNM as Functionalization Layer for Oligonucleotide Immobilisation

**Problem**

- Oligonucleotides can adopt complex 3D-structures, which can bind a target with high affinity and specificity (e.g. aptamers)
- Immobilization of oligonucleotides on a surface often leads to loss of their structure
  \[\Rightarrow\] without structure: no target recognition

**Solution: Use of CNMs**

- Easy and fast immobilization of oligonucleotides via click-chemistry
- Immobilized aptamers maintain their 3D-structure and therefore their specific target binding properties
- Interaction of bound targets with surface-sensitive sensors possible due to 1 nm thickness of CNM
Further Applications

Potential is not Exhausted

Energy Storage

CNM as ultrathin Carbon-based dielectricum
- Component for energy storage:
  - Energiewende
  - E-Mobility
- Flexible Electronics
- Wearables

CNM as Surface-Electrolyte-Interface-Layer
- Next generation battery technology

“Nanomicrophone”

CNM as oscillating membrane allows smallest design

Pellicle for EUV-Lithography

Problem
- no satisfying pellicles available, since no material is transparent
- particles of even some nm size cause defects on wafer

Solution: Standard CNM as EUV-pellicle meets many specifications of manufacturer

Sample Support for TEM

Advantages CNM
- lowest background signal
- homogeneously thin
- chemical functionalization possible

Single atom resolution
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