EuroNanoForum 2019
June 12-14, 2019, Bucharest, Romania

PILLAR 4 – NANO for EU RE-INDUSTRIALIZATION

Nanomembranes and Hollow Nanoparticles based on Gallium Nitride

Ion Tiginyanu

Academy of Sciences of Moldova
National Center for Materials Study and Testing
Technical University of Moldova

www.ncmst.utm.md
E-mail: tiginyanu@asm.md

Outline

1. Introduction. The importance of GaN
2. GaN hollow nanoparticles and their biomedical applications
3. GaN ultrathin membranes and photonic crystals on their basis
4. GaN microtubes with nanometer-thick walls
5. Flexible three-dimensional hybrid nanoarchitectures
6. Conclusions

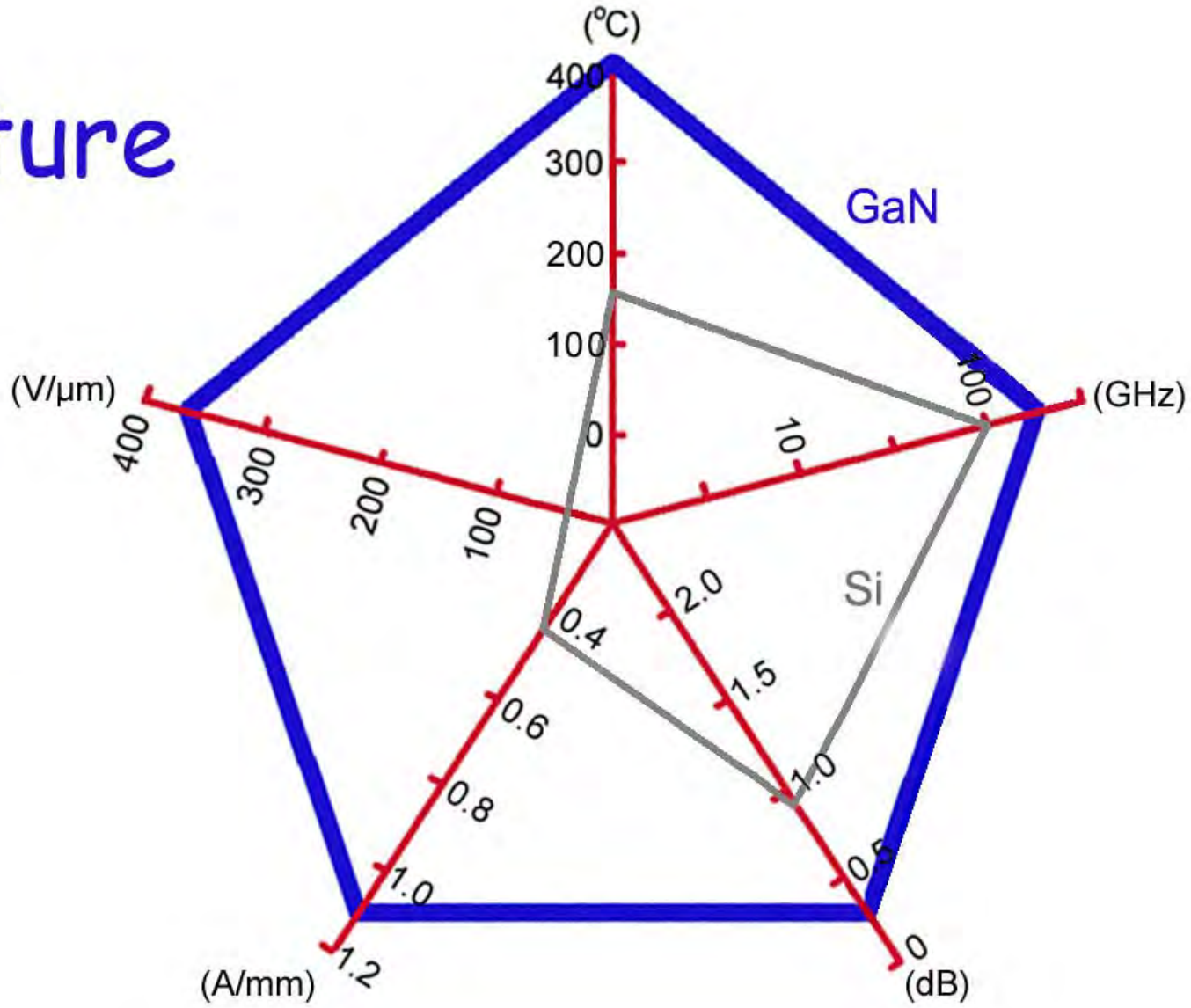
Why GaN is so important?

Advantages of GaN versus Si

Temperature

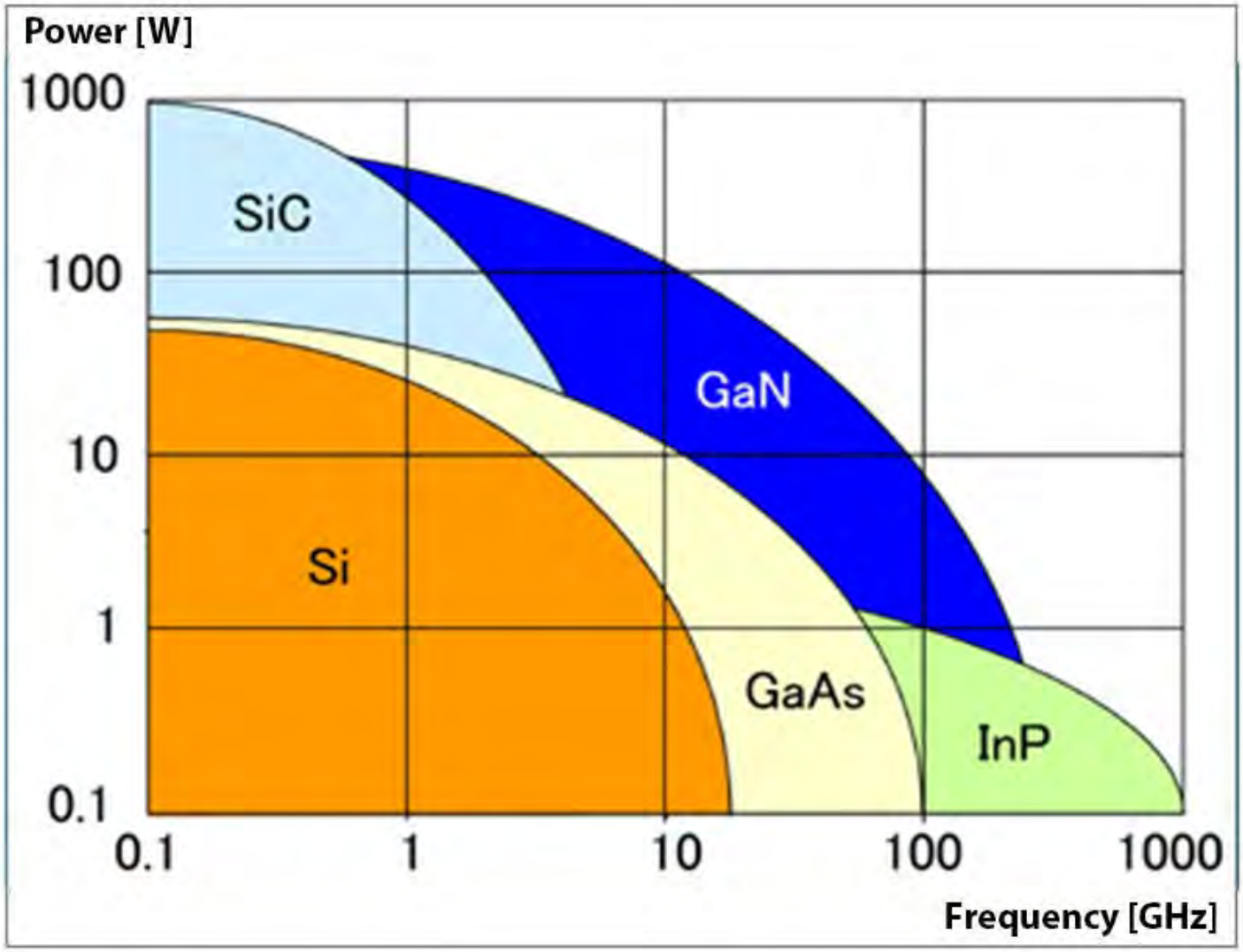
Voltage

Current



http://www.gansystems.com/why_gallium_nitride_new.php

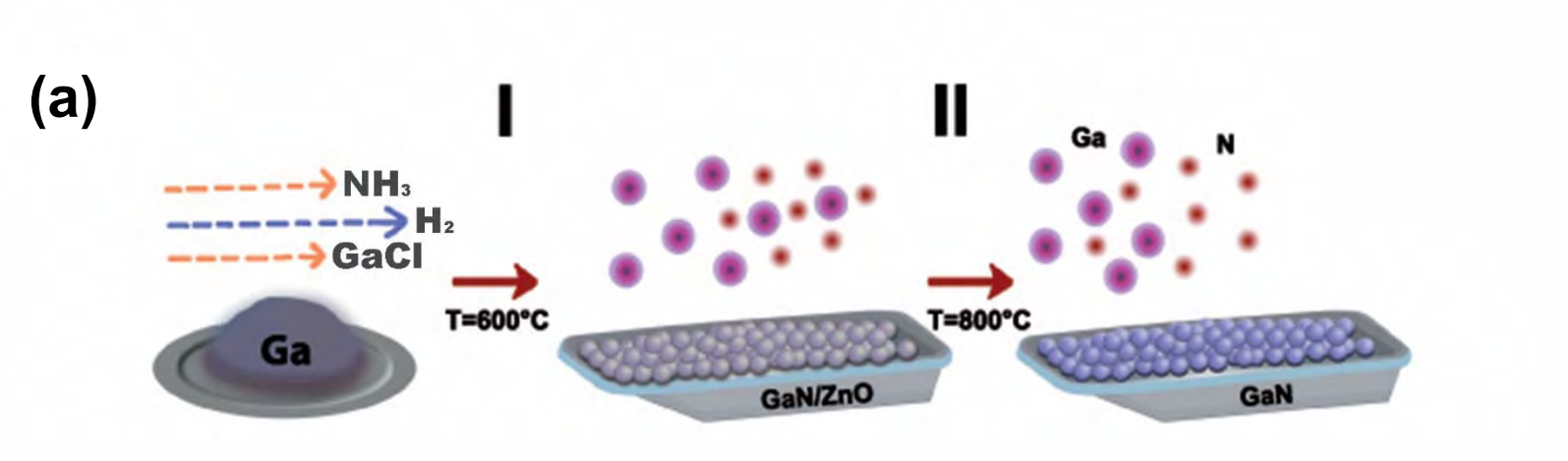
Advantages of Gallium Nitride

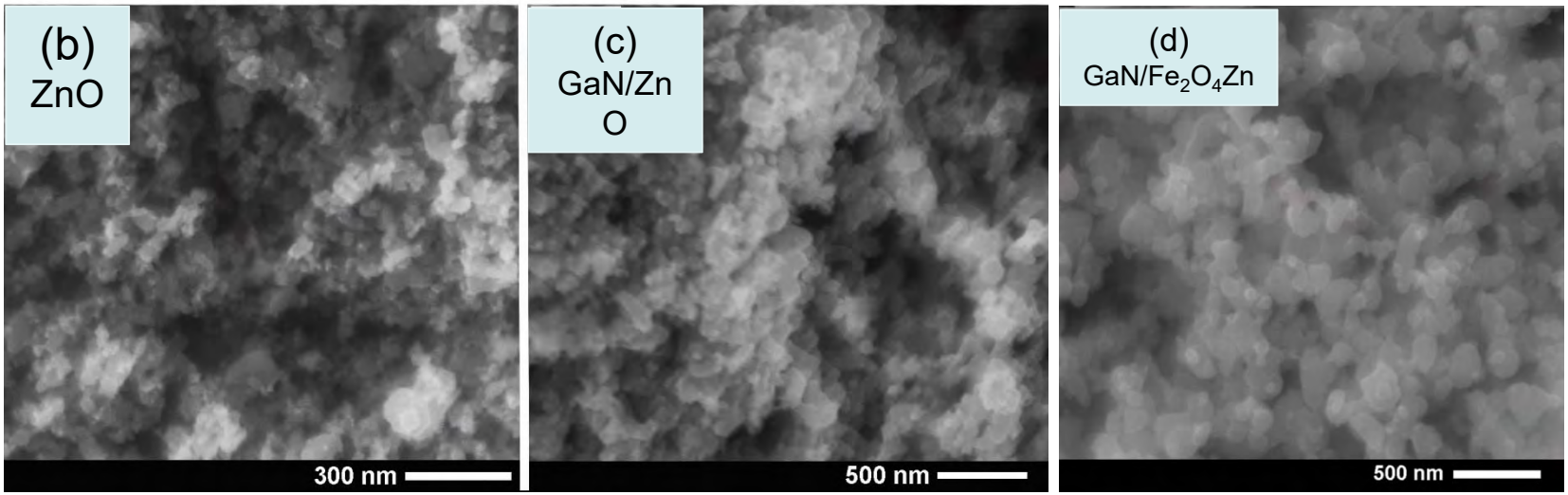


Robert Dwilinski. AMMONO: www.slideserve.com/jane/outstanding-quality-gallium-nitride-gan-enabler-for-new-industries

GaN nanoparticles and their biomedical applications

Synthesis of GaN nanoparticles

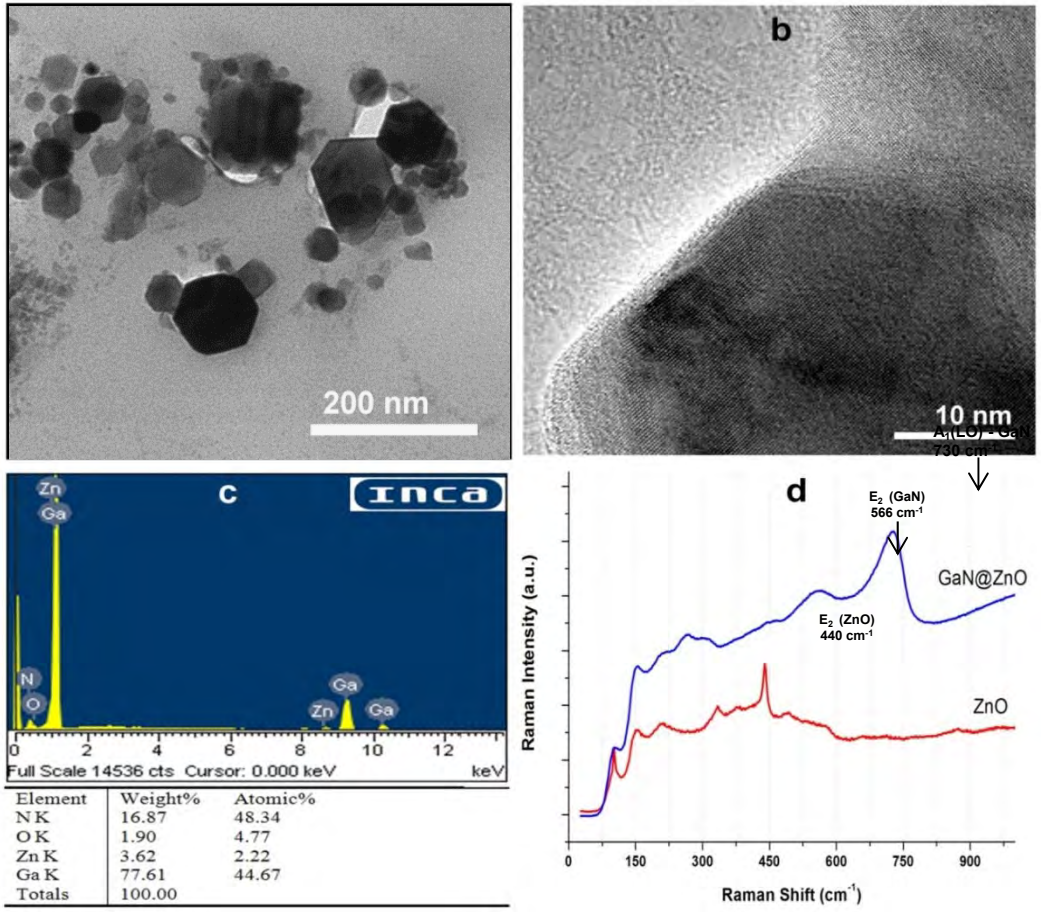




(a) - schematic representation of synthesis process of GaN nanoparticles using ZnO and Fe_2O_4Zn sacrificial layer. SEM pictures presented in (c) and (d) show the morphology of the resulted nanoparticles, which does not differ form the initial ones depicted in (b)

T. Braniste *et al*, *Beilstein J. Nanotechnol. 7*, 1330–1337 (2016).

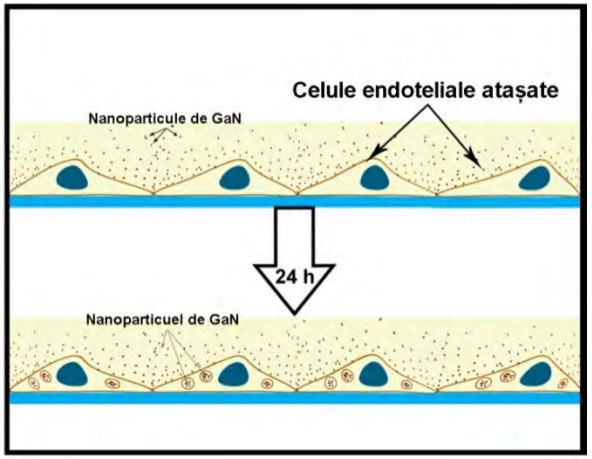
Characterization of GaN nanoparticles synthesized on ZnO



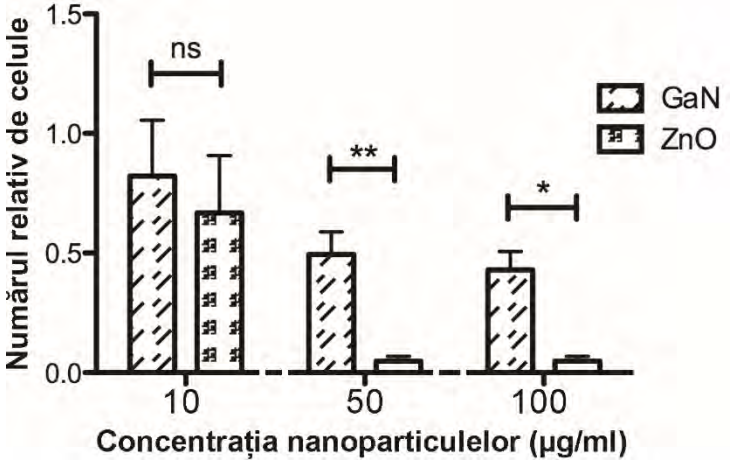
Element	Weight%	Atomic%
N K	16.87	48.34
O K	1.90	4.77
Zn K	3.62	2.22
Ga K	77.61	44.67
Totals	100.00	

TEM pictures of GaN nanoparticles grown on ZnO (a) and HRTEM of a single nanoparticle (b); EDX analysis is presented in (c) and comparative Raman measurements in (d) confirm the GaN growth and ZnO decomposition.

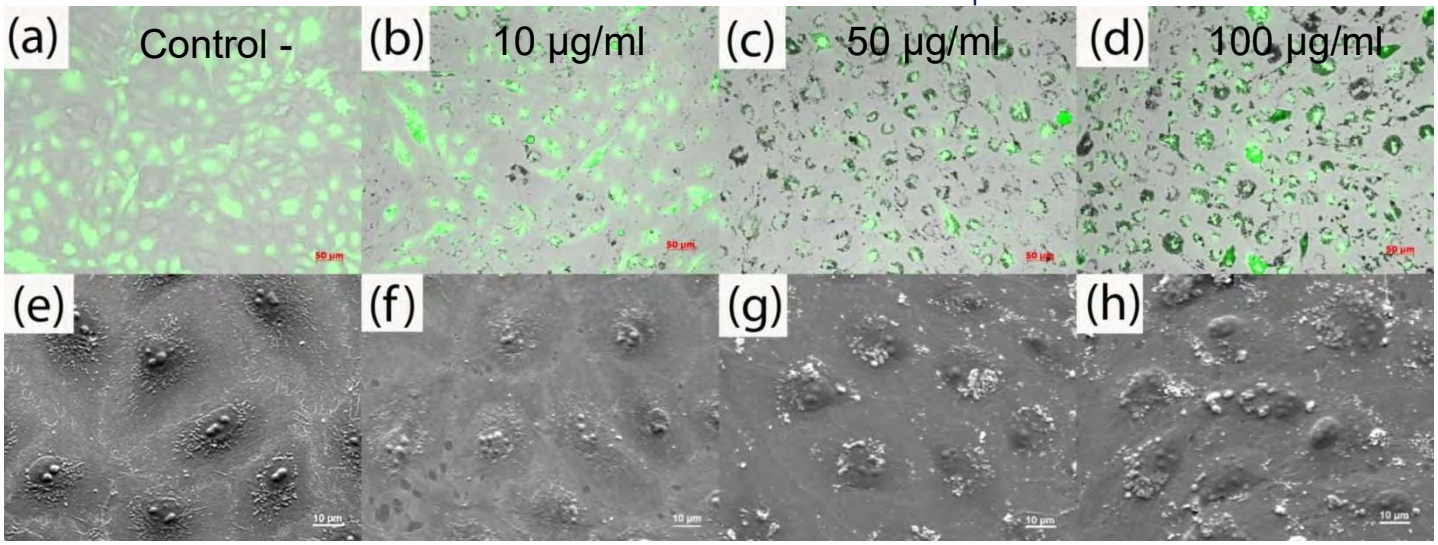
The interaction of free floating nanoparticles and living endothelial cells



Experimental concept



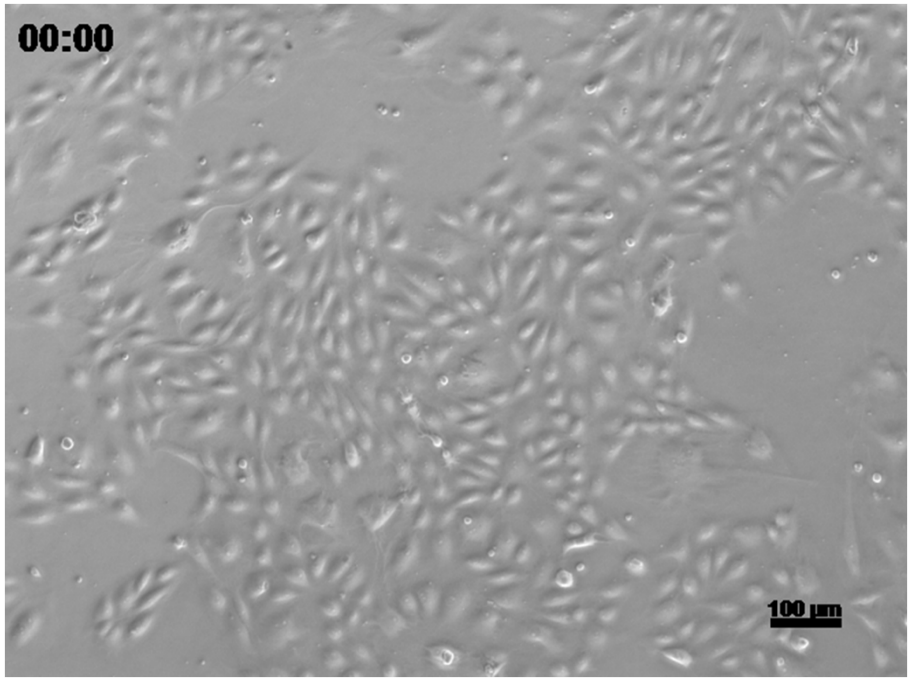
After 3 days of incubation of Endothelial Cells with NPs, we can observe that high concentrations of ZnO NPs are very toxic for cells, while by increasing the concentration of GaN NP cells are slowed down in the development and the nanoparticles are collected around cells.



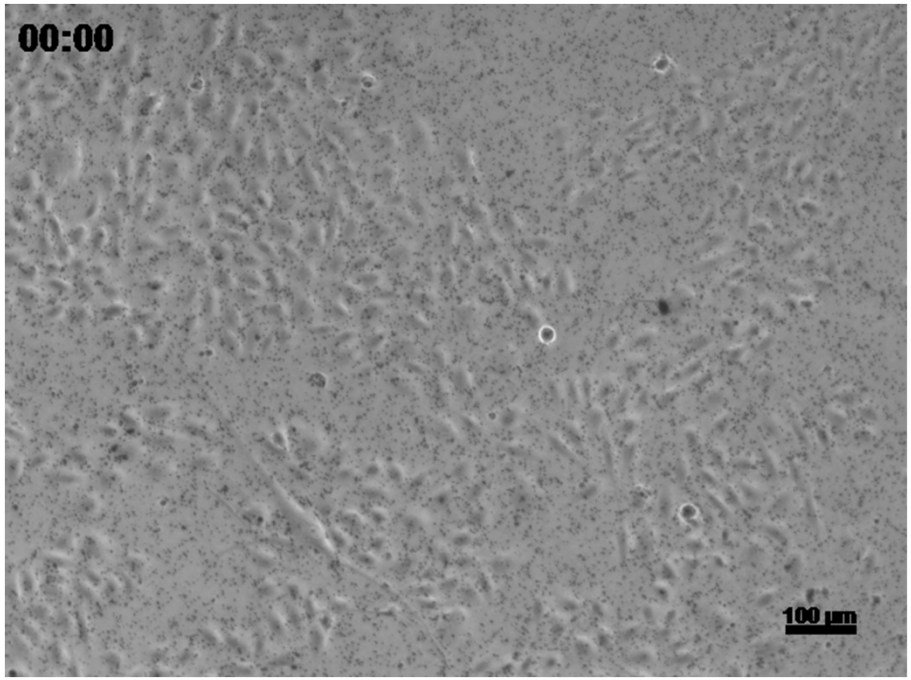
Nanoparticles distribution in endothelial cells culture after three days of cultivation of porcine aorta endothelial cells and GaN NPs. Optical views are presented in pictures (a) – (d) and SEM images are in (e) – (h). The concentration of GaN nanoparticles is 10 µg/ml for (b) and (f), 50 µg/ml for (c) and (g), and 100 µg/ml for (d) and (h). Images (a) and (e) represent the positive control of cells in EGM2

Uptake of GaN nanoparticles by endothelial cells

Endothelial cells in the control group



Endothelial cells incubated with GaN nanoparticuels (50 µg/ml).

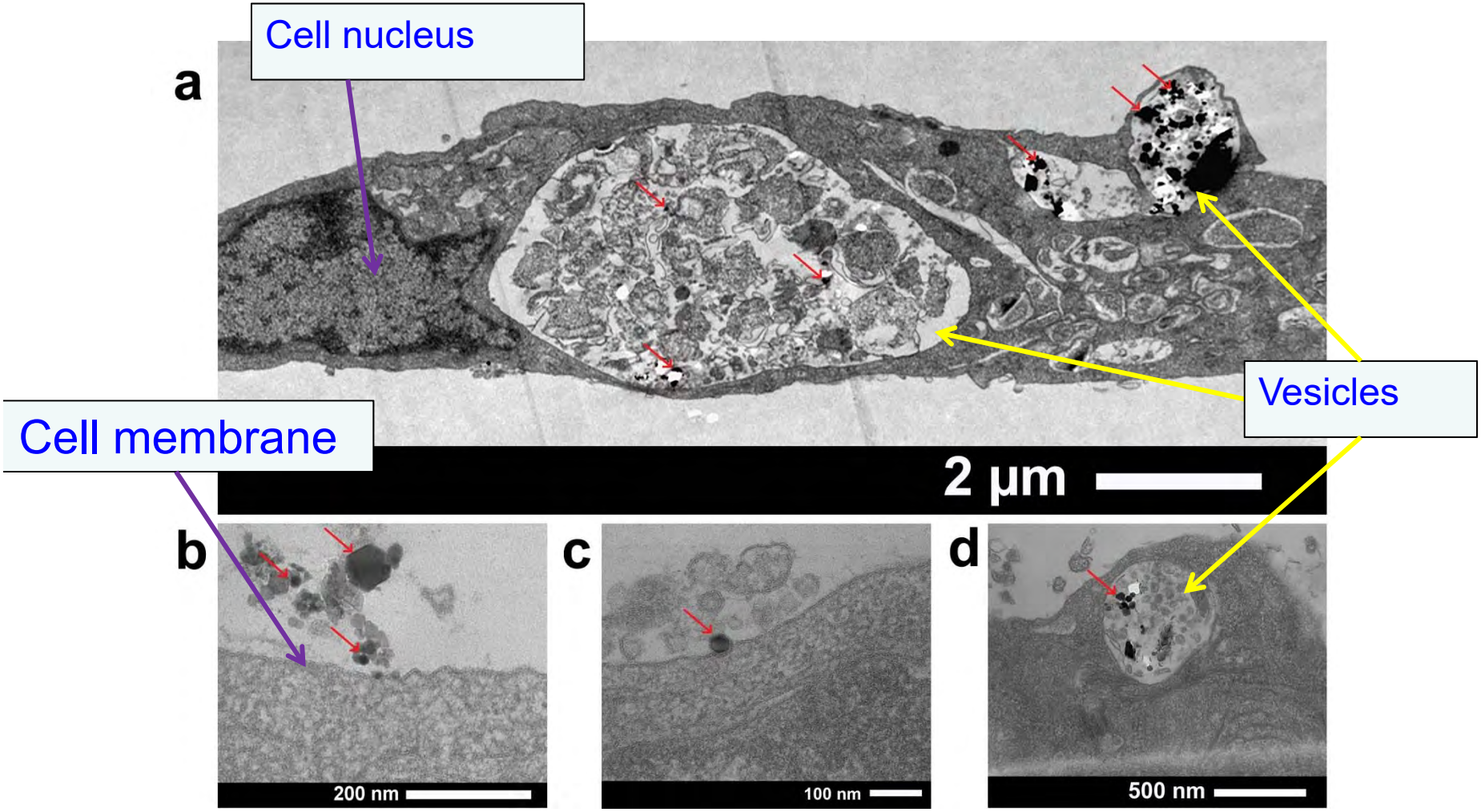


The cells were found to collect the nanoparticles surrounding them, nevertheless the mobility and the proliferation activity of endothelial cells are not affected by the presence of GaN nanoparticles in the medium.

Note: The investigations were performed for 20 h, one picture being shot every 10 min.

T. Braniste *et al*, *Beilstein J. Nanotechnol. 7,* 1330–1337 (2016).

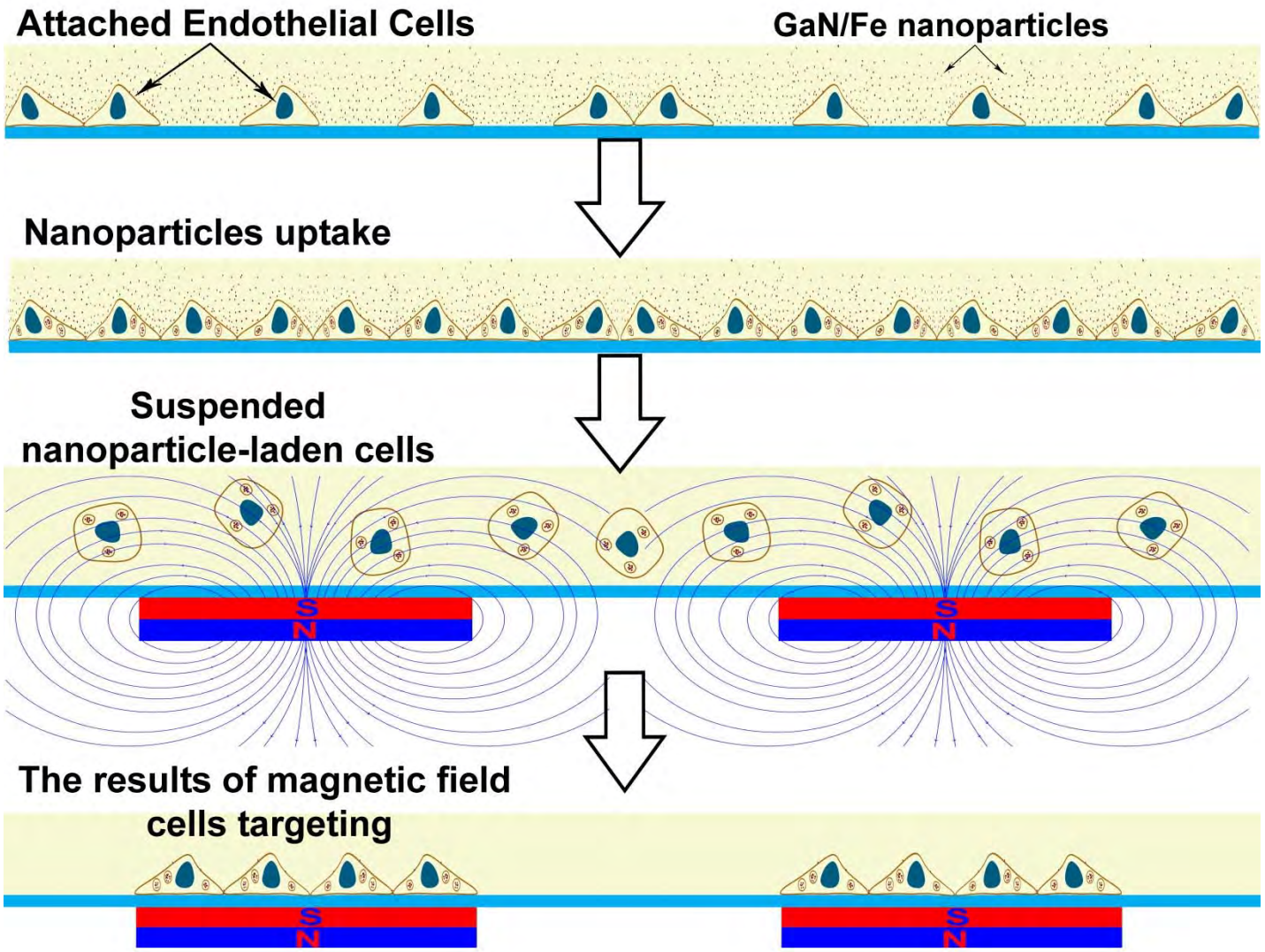
Uptake of nanoparticles by endothelial cells and localization in vesicles determined by TEM investigations



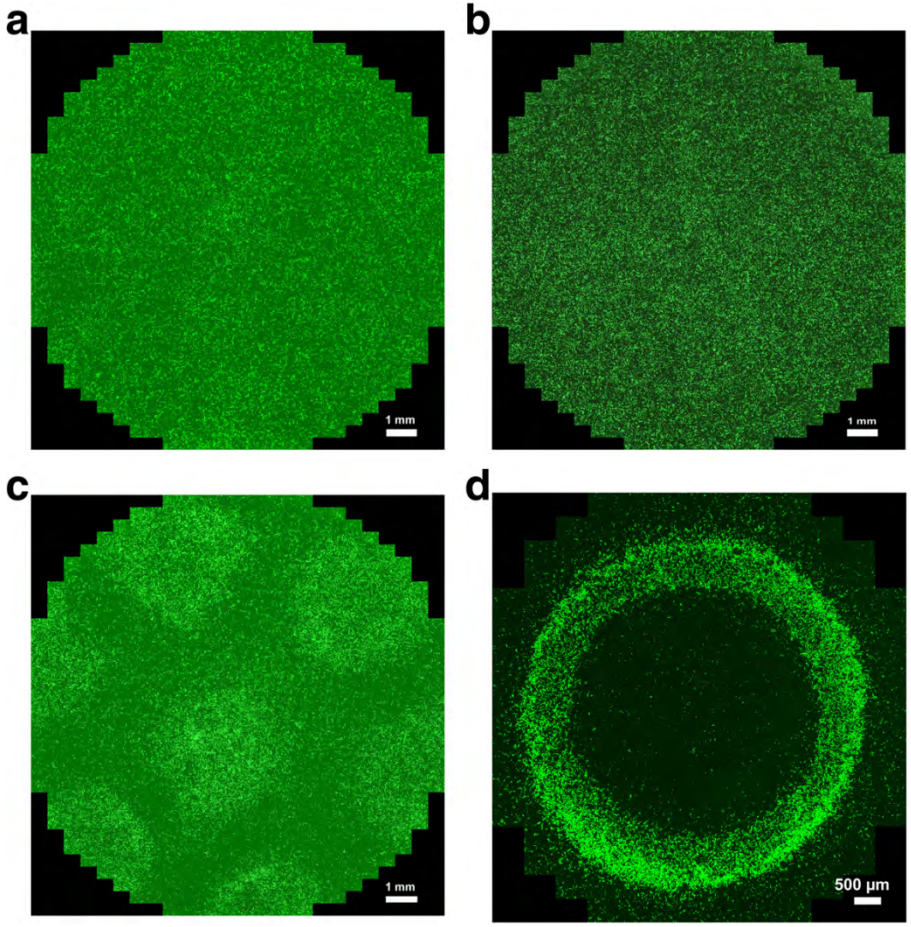
TEM pictures taken from a endothelial cell incubated with GaN/Fe nanoparticles.

T. Braniste *et al*, *Nanoscale Research Letters 12*, 486 (2017).

Magnetic guiding of endothelial cells targeted with nanoparticles



Magnetic guiding of endothelial cells targeted with nanoparticles



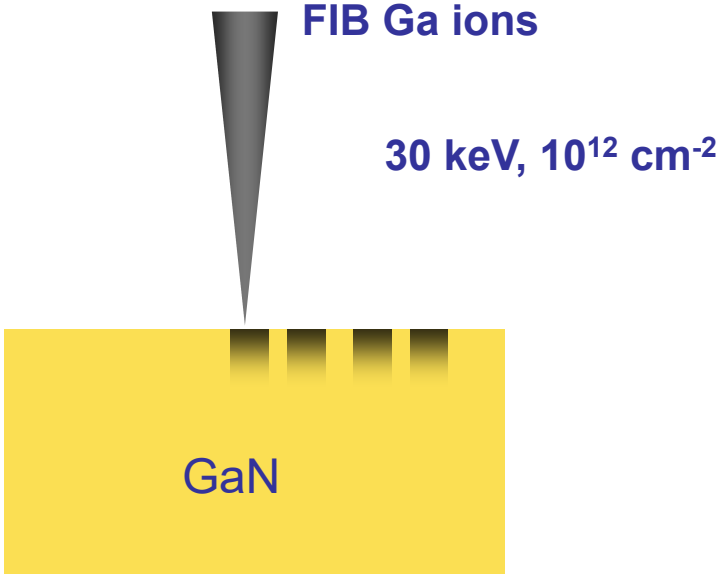
Fluorescence pictures of endothelial cells targeted with GaN/Fe nanoparticles and incubated in control groups (a,b) and in magnetic field gradients (c,d) and. After few hours of incubation a non-uniform distribution of cells exposed to magnetic field could be notified, while cells targeted with nanoparticles and incubated in normal conditions (without magnetic field) are distributed uniformly on the surface of culture plate.

T. Braniste *et al*, *Nanoscale Research Letters 12,* 486 (2017).

GaN ultrathin membranes

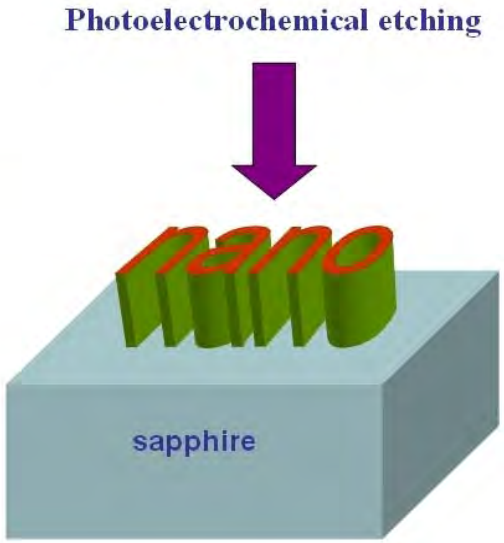
Surface Charge Lithography

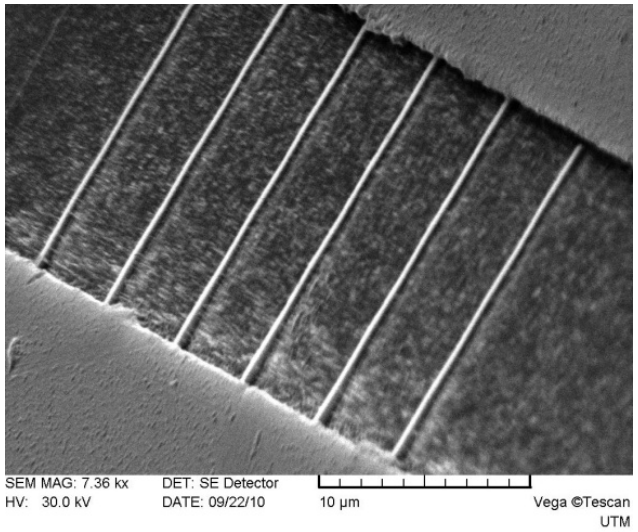
Direct Writing of Negative Charge
+
Photoelectrochemical Etching



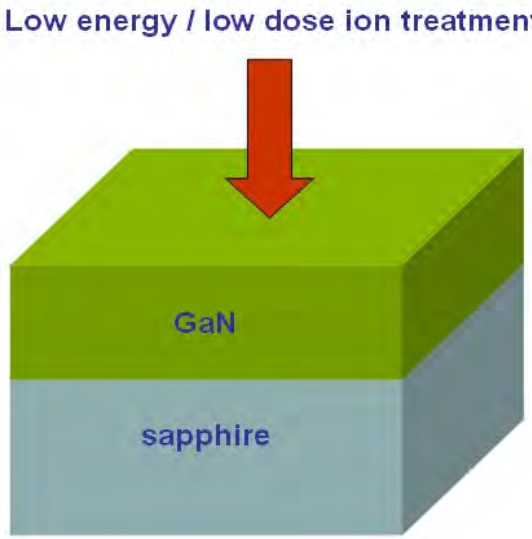
Gold Medal, Pittsburgh

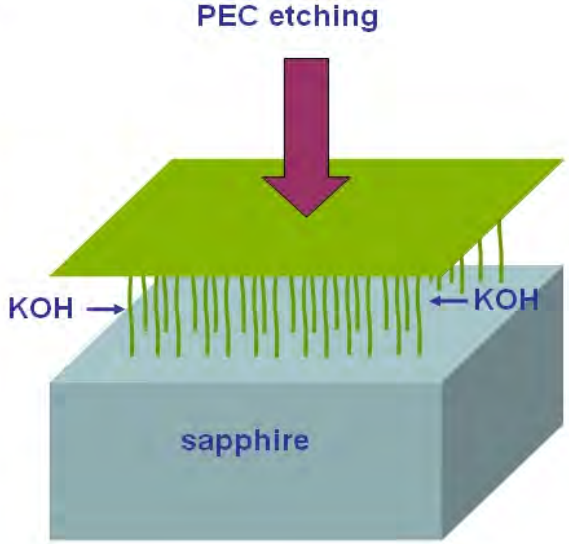
GaN nanostructures

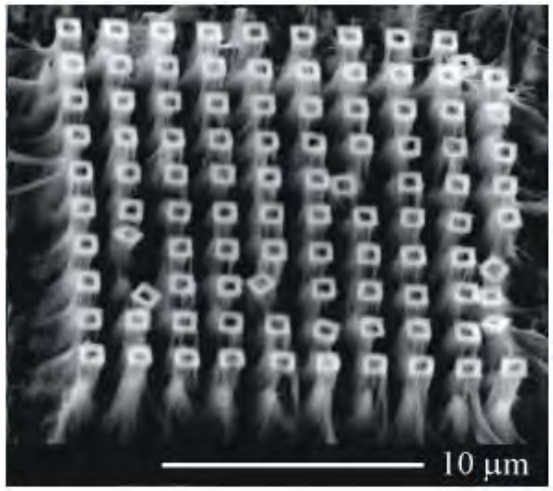


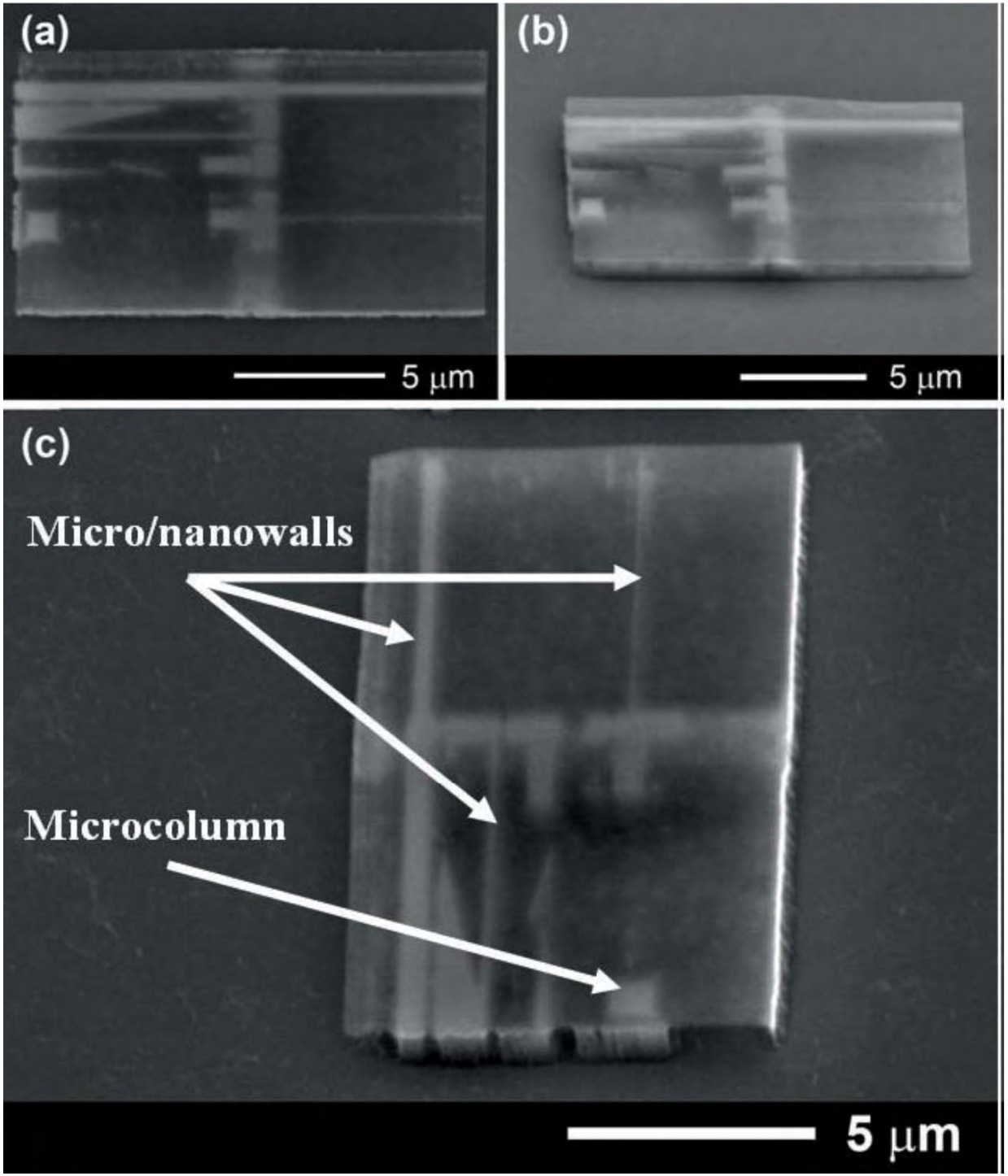


GaN ultrathin membranes









Design and maskless fabrication of suspended membranes

NanotechWeb.org

LATEST NEWS ARTICLES

- Surface writing produces designer nanostructures
- Nanomachines could benefit from superlubricity
- Graphene capsule helps image nanocrystal growth
- Heterostructures make better solar cells
- Polymer helps separate CNT mix

RELATED STORIES

- Nano-roof reveals dislocations (Jan 2011)
- Temperature orders TiO2 nanotubes (Apr 2010)
- Salty water puts metal nanotubes in order (Jun 2008)
- Gallium nitride nanopyramids resist radiation (May 2007)

RELATED LINKS

- Ion Tiginyanu

RESTRICTED LINKS

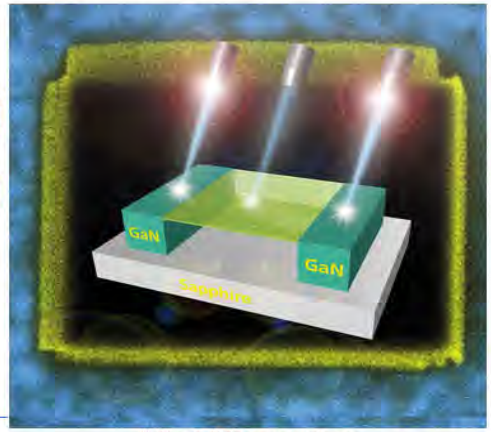
- *Physica Status Solidi - Rapid Research Letters* DOI: 10.1002/pssr.201206020

TECHNOLOGY UPDATE

Apr 12, 2012

Surface writing produces designer nanostructures

A new way to fabricate 3D nanostructures from gallium nitride using a focused ion beam (FIB) has been developed by researchers in Moldova, Australia, Germany and France. The technique, which involves directly writing a negative charge on the surface of GaN with the FIB and then photoelectrochemically etching the sample, allows ultrathin membranes and supporting nanocolumns to be fashioned in a controlled way. GaN is a large-bandgap semiconductor widely used in electronics applications such as high-temperature, high-power electronics and optoelectronics for light-emitting diodes and lasers. The material is also piezoelectric, so bridge-like GaN membranes might even find use in applications like nanoelectromechanical systems (NEMS).



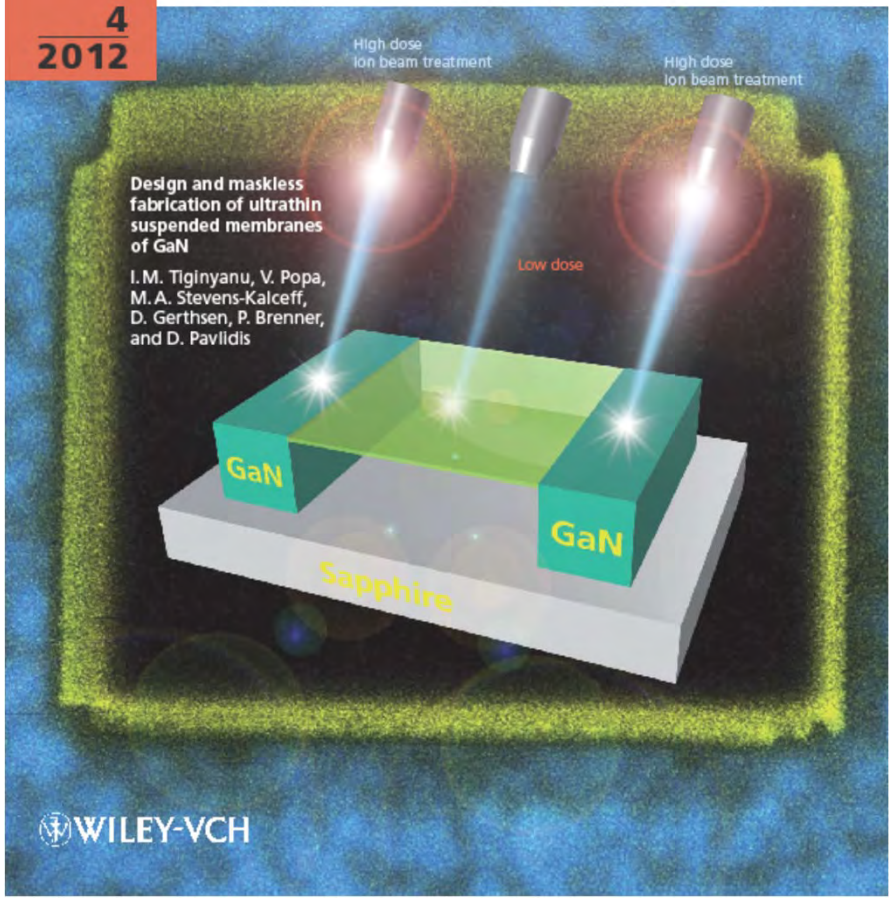
Making GaN 3D nanostructures

Ion Tiginyanu and colleagues of the Moldova Academy of Sciences and Technical University of Moldova recently put forward a new way to make nanometre-thin membranes of gallium nitride hanging over a network of GaN threading-dislocation "whiskers" that act as a support. Their fabrication technique was based on etching away highly crystalline material from the GaN bulk epilayers, leaving behind only the negatively charged dislocation networks and a thin surface film to which the dislocations remain attached.

ISSN 1862-6254
Phys. Status Solidi RRL
6 - No. 4 April
A37–A50, 145–186
(2012)

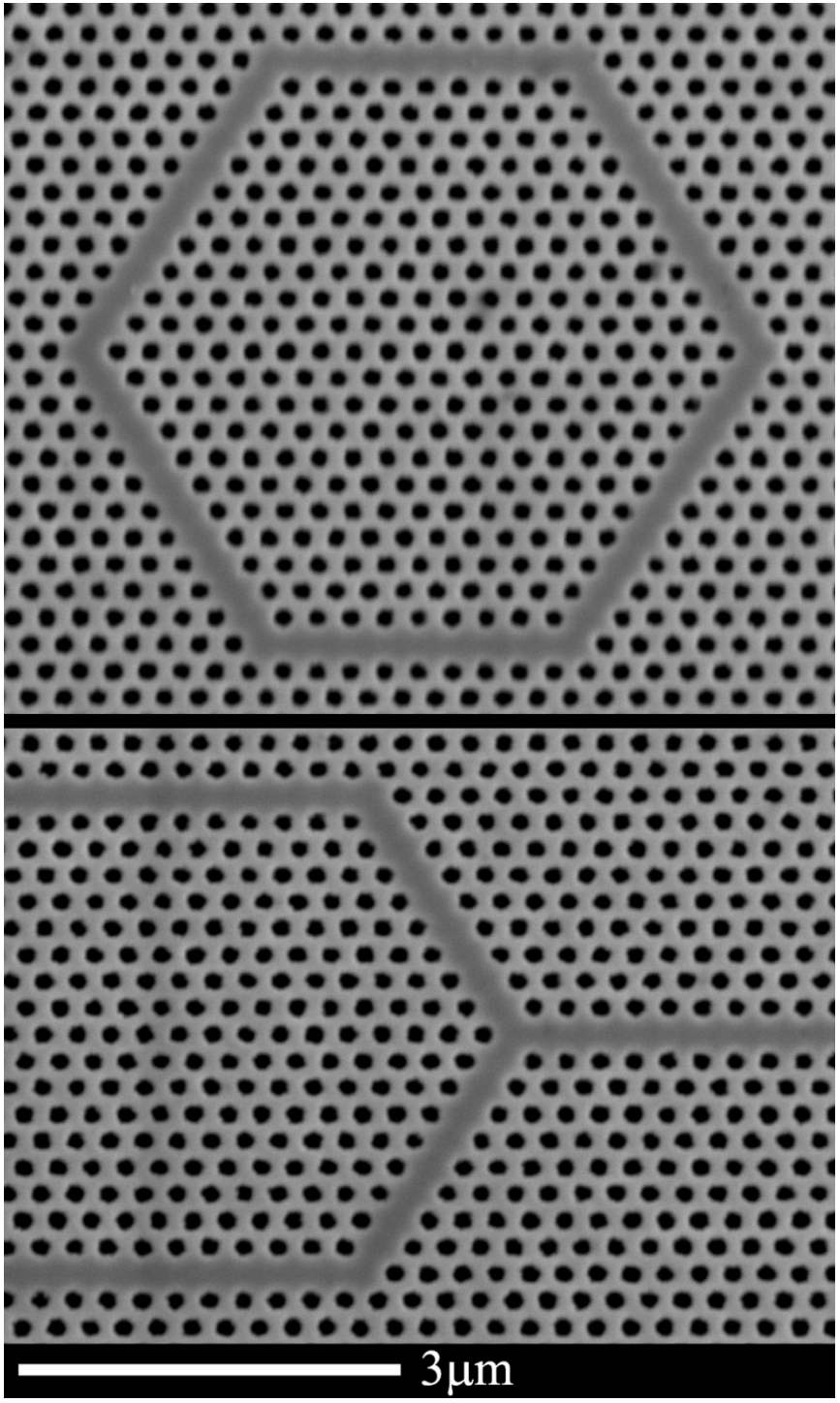
physica status solidi pss rrl
www.pss-rapid.com
rapid research letters

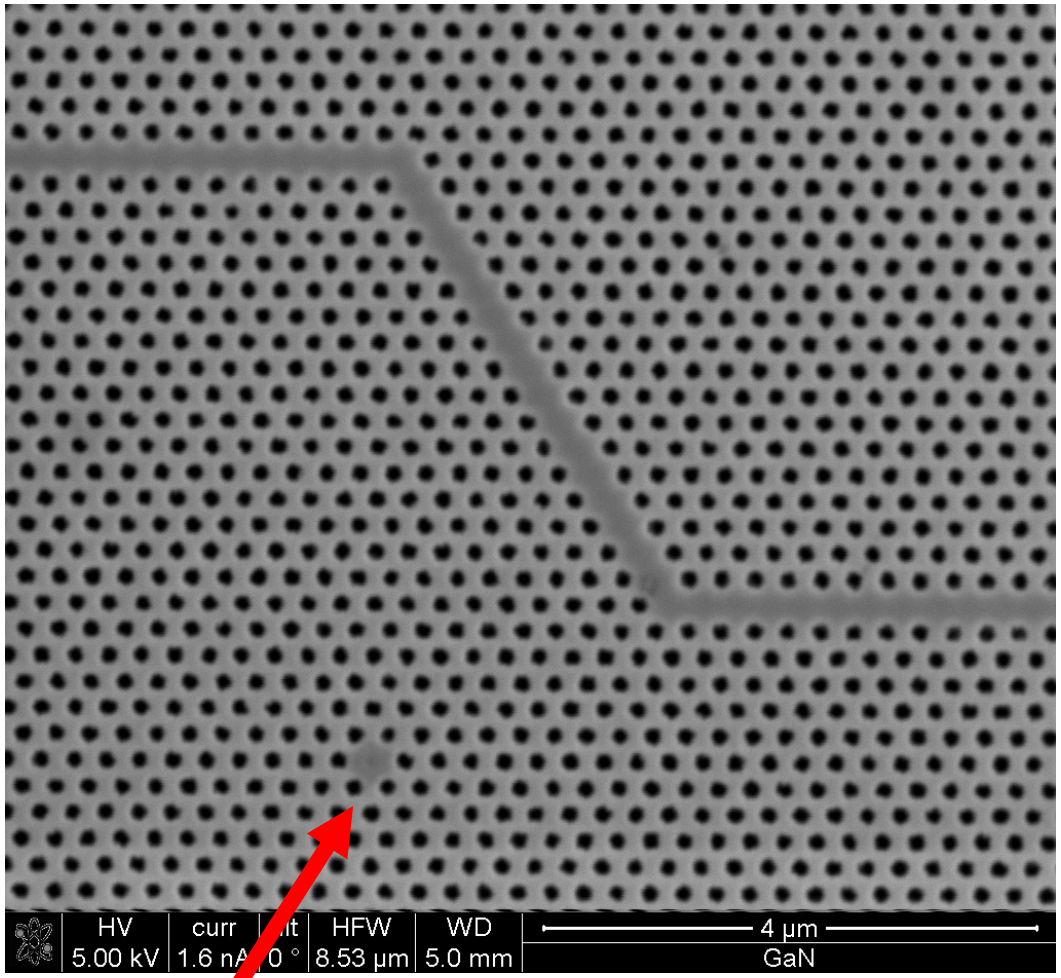
4
2012



***Physica Status Solidi – RRL*, Vol. 6, no 4, pp. 148-150 (2012).**

GaN ultrathin photonic crystals

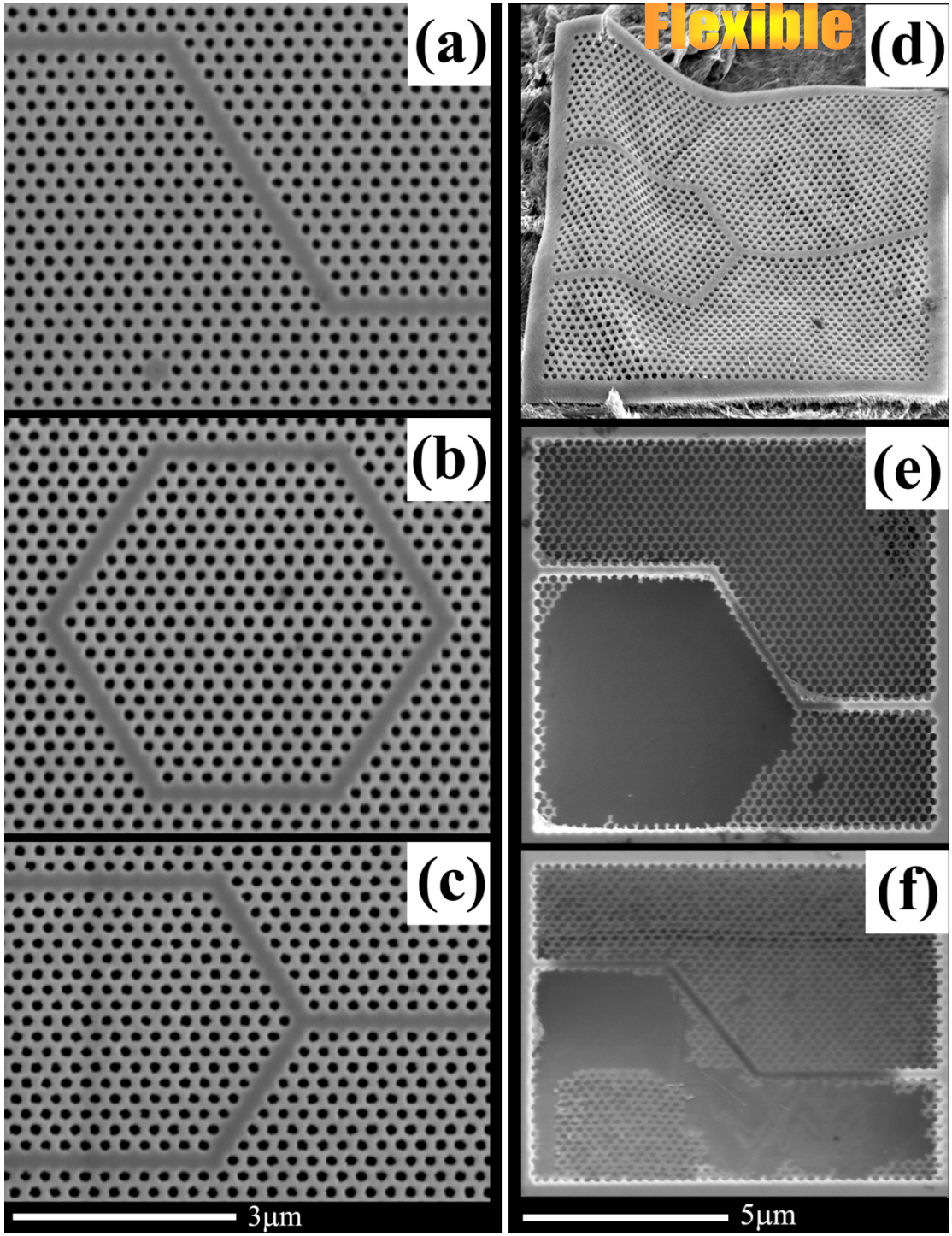




Absence of one hole

GaN-based Flexible Photonic Structures

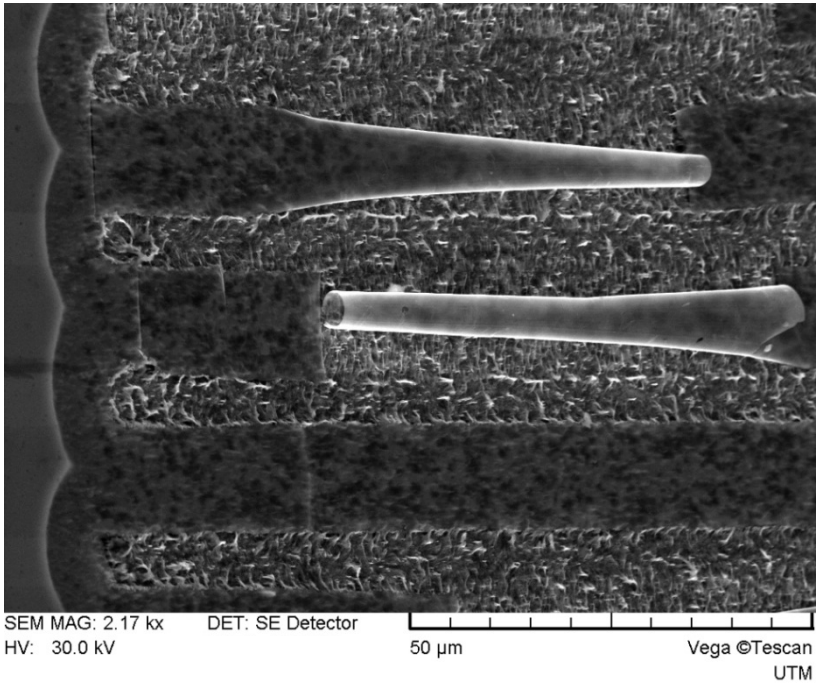
15-nm thick

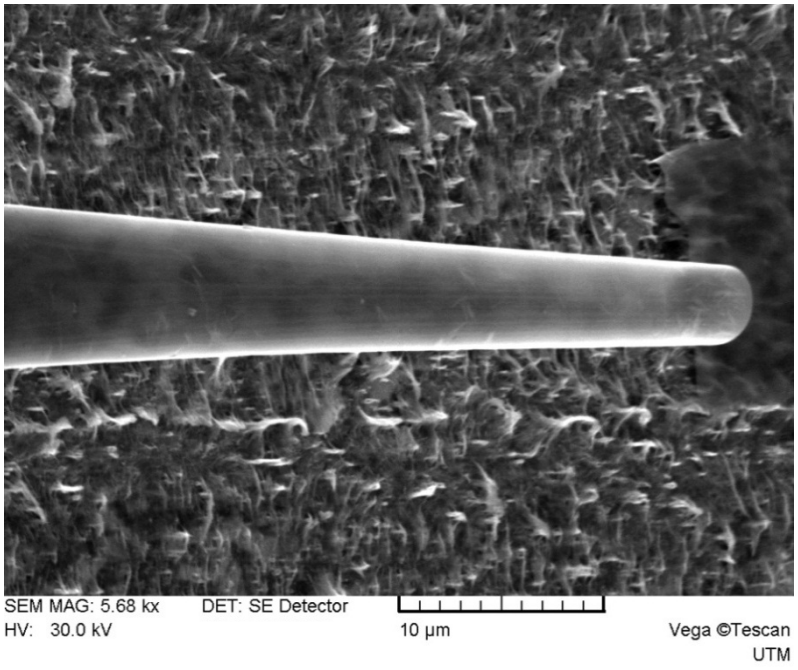


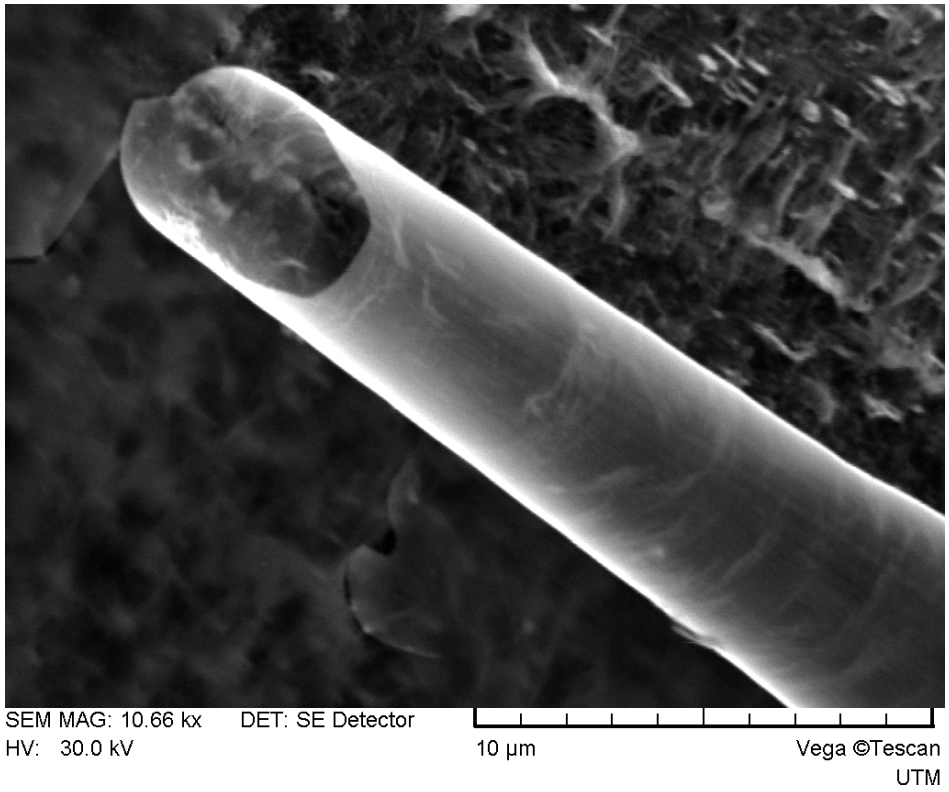
Journal of Nanoelectronics and Optoelectronics, Vol. 9, no 2, pp. 271-275 (2014).

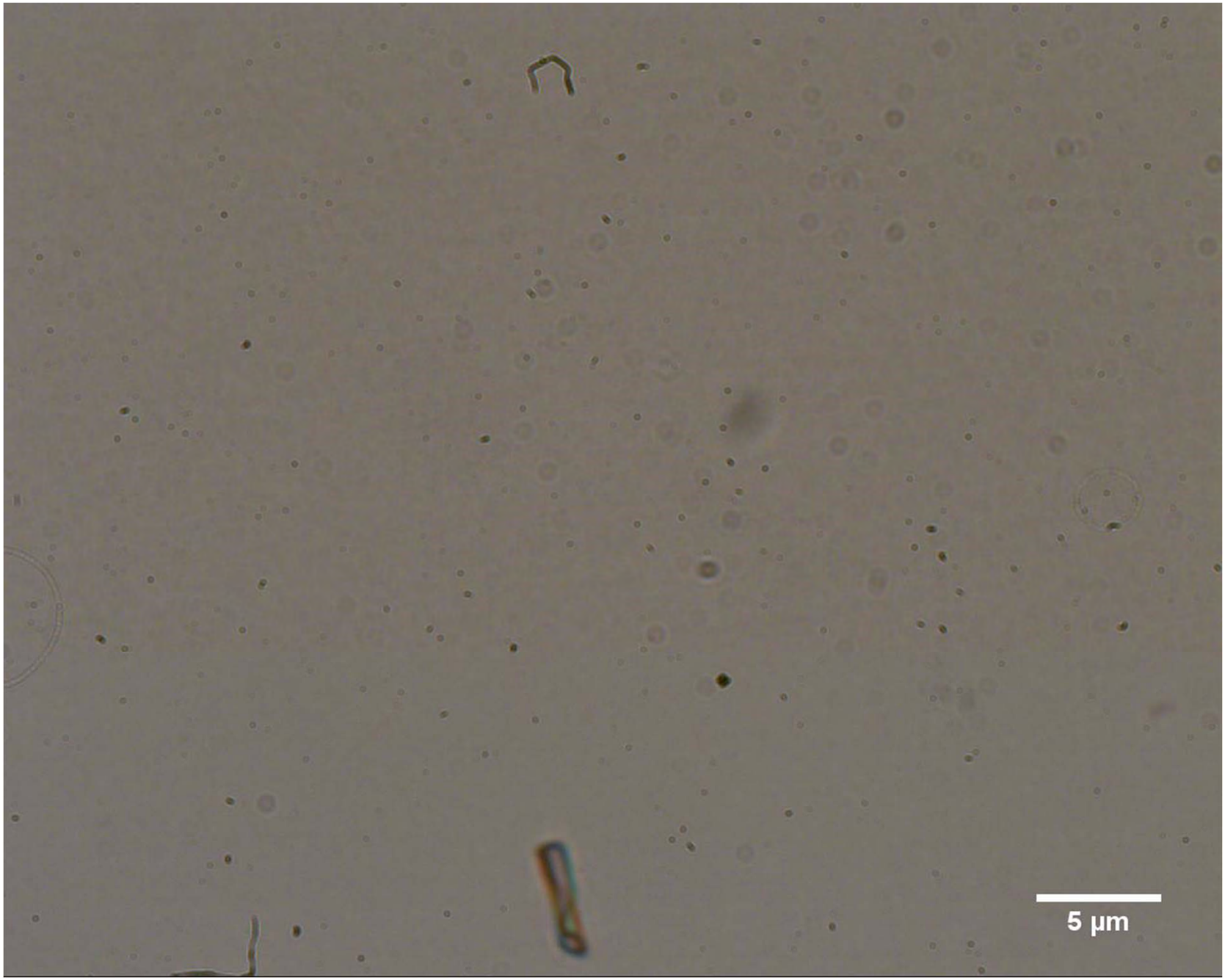
Strain-induced self-rolled-up GaN microtubes

as promising structures for the development of microengines





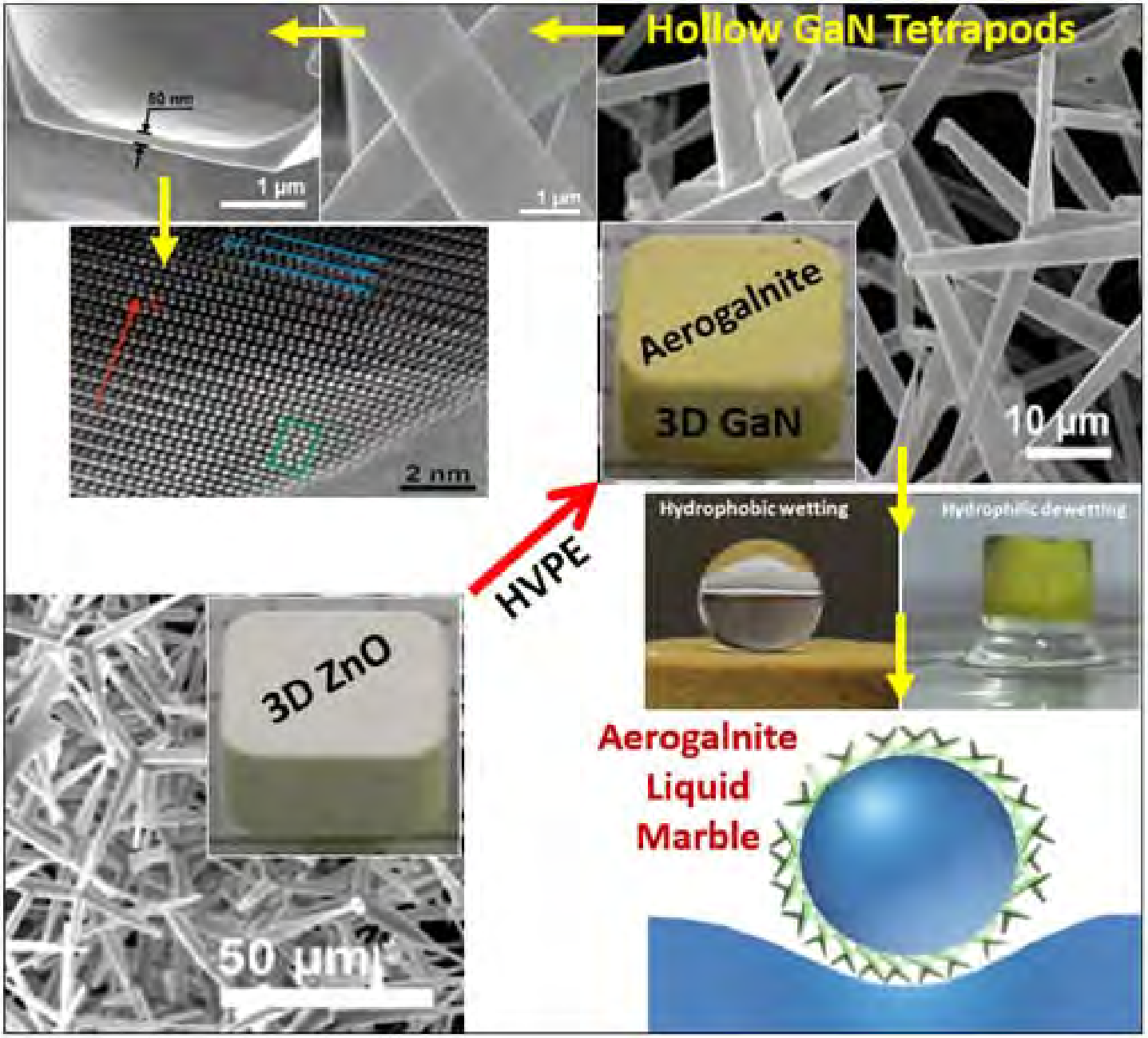



5 µm

Aerogalnite

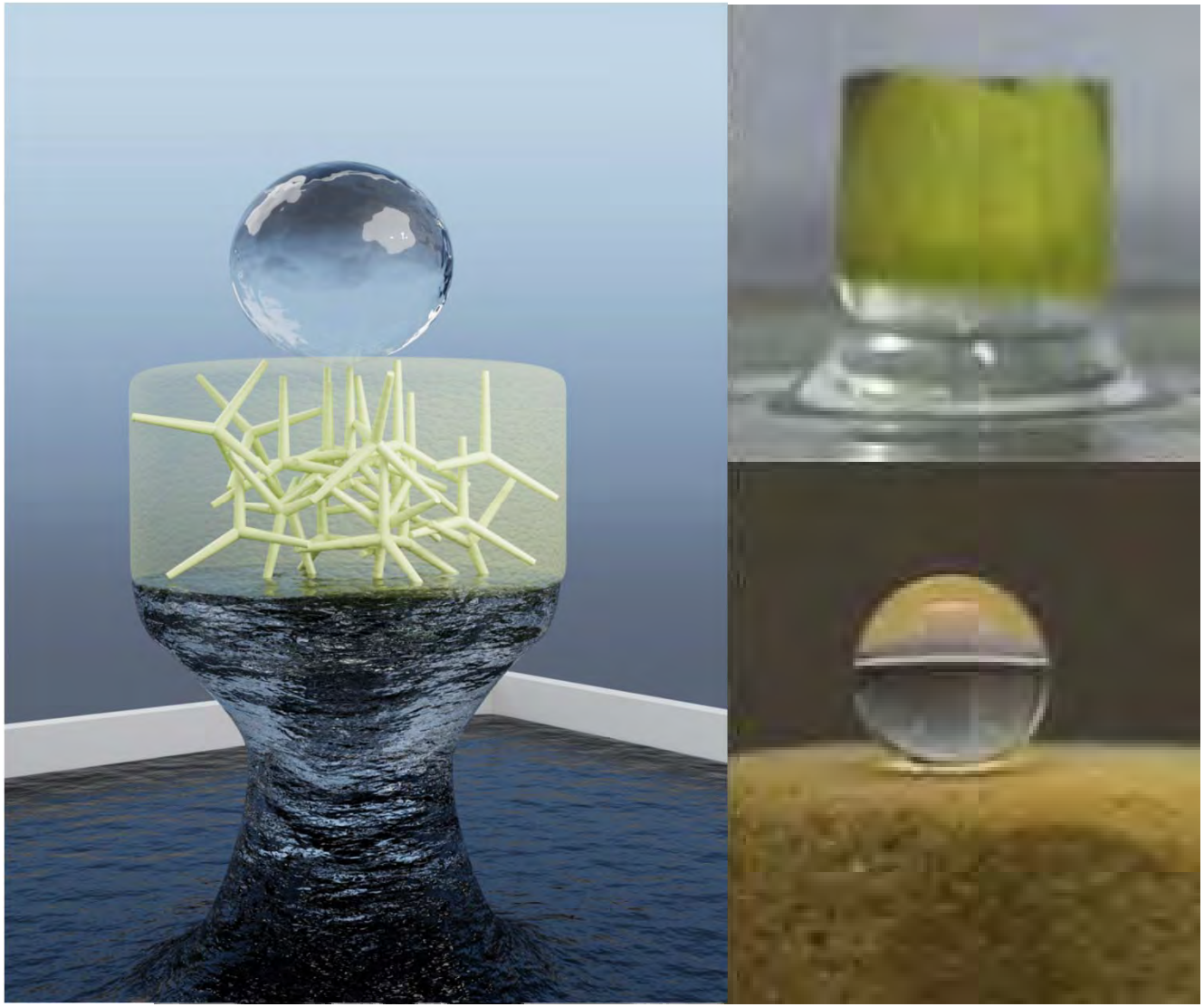
(Aero-GaN)

Aero–GaN


Hollow GaN Tetrapods
50 nm
1 μm
1 μm
2 nm
Aerogalnite
3D GaN
10 μm
HVPE
Hydrophobic wetting
Hydrophilic dewetting
3D ZnO
50 μm
Aerogalnite
Liquid
Marble

Physics World

https://physicsworld.com/a/hydrophobic-or-hydrophilic-aero-gallium-nitride-is-both/

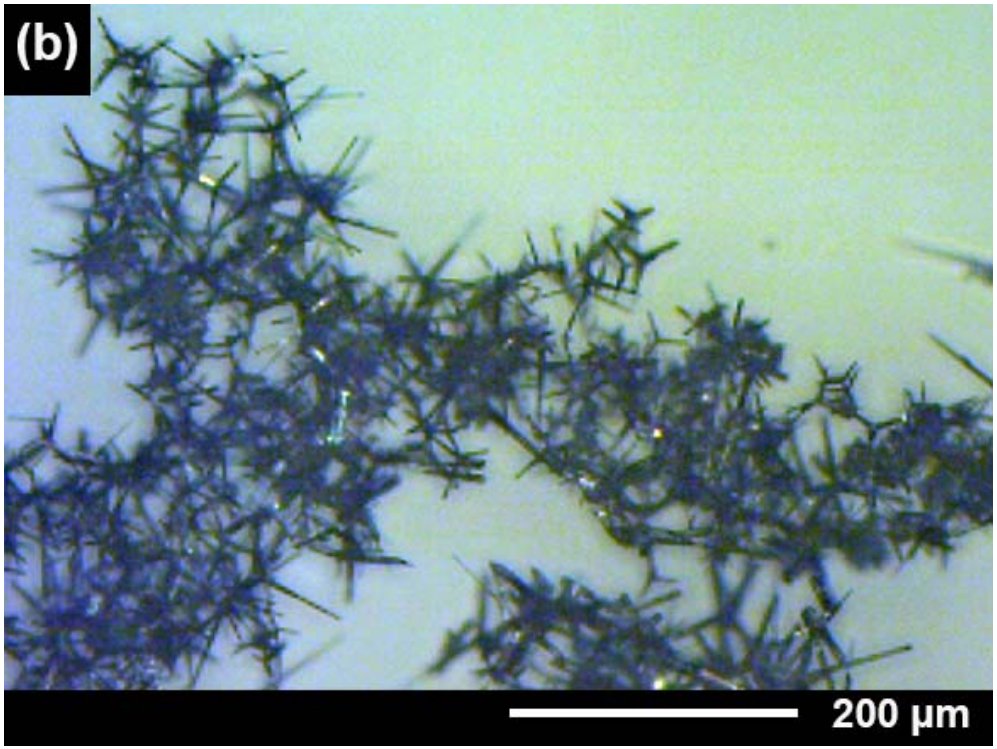


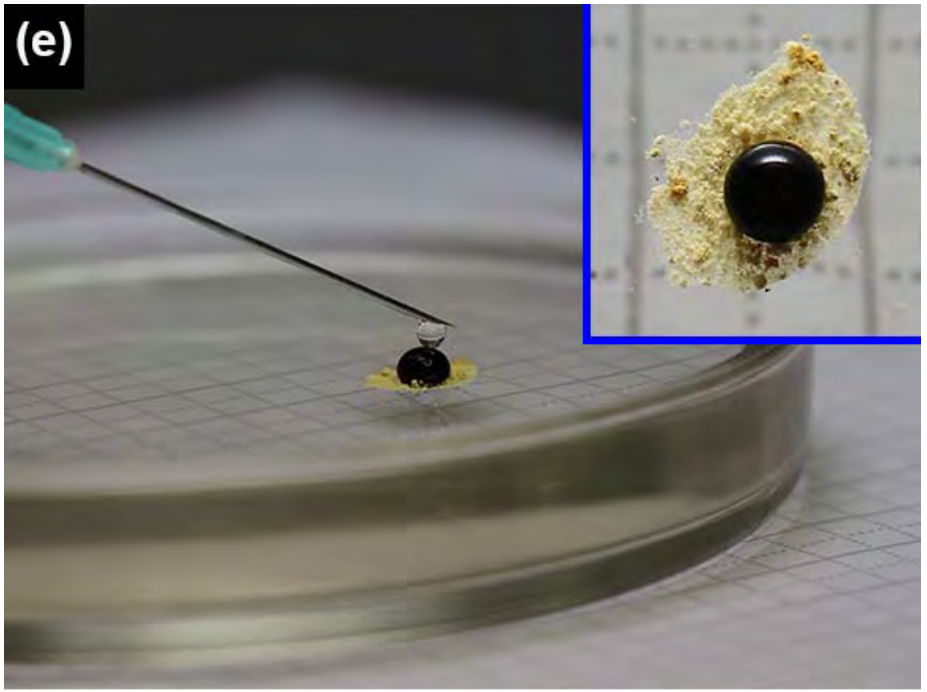
Hydrophilic dewetting

Hydrophobic wetting

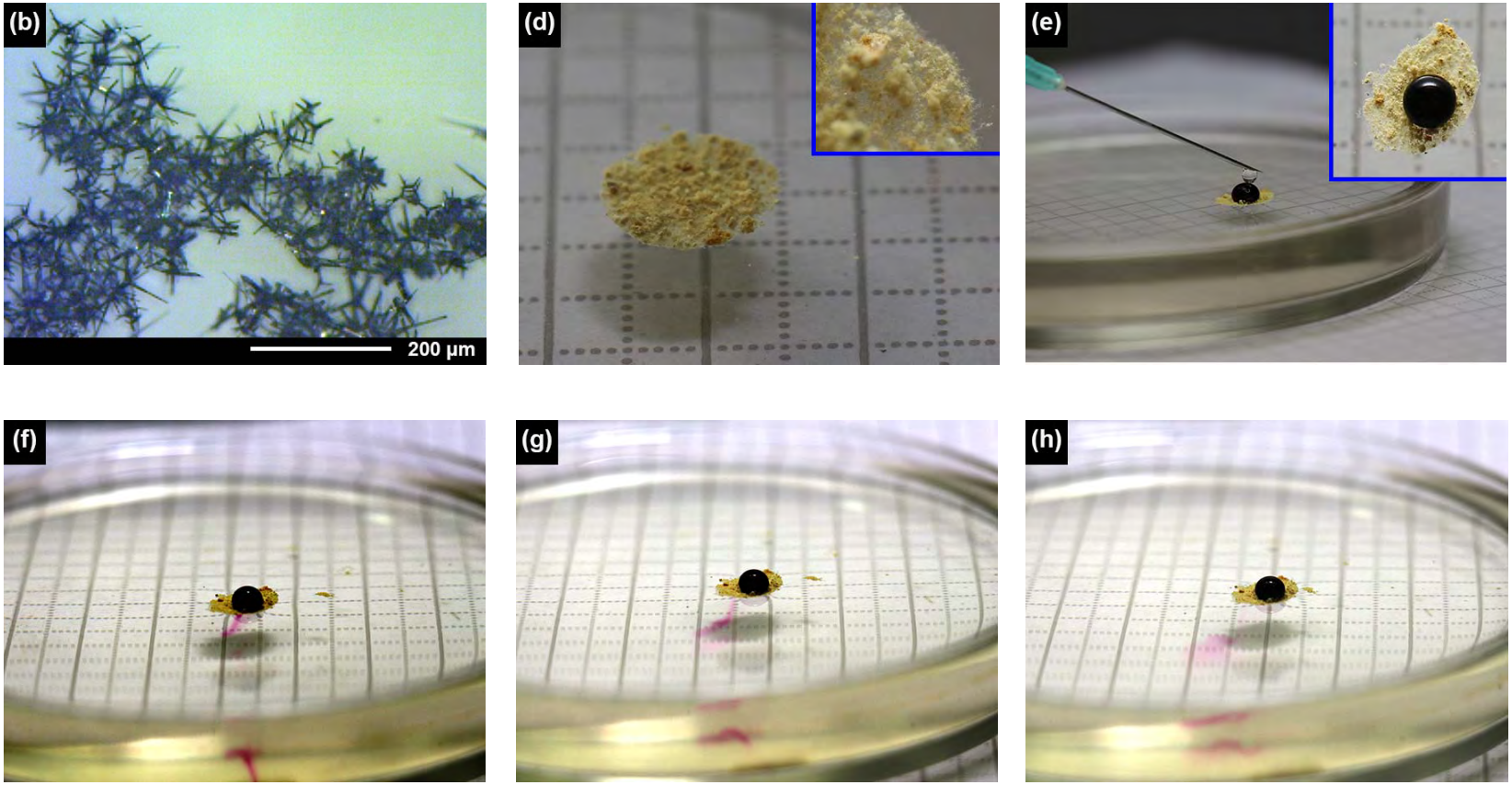
I. Tiginyanu, T. Braniste *et al* Nano Energy, Vol. 56, pp. 759-769 (2019).

Weaving GaN floating carpets



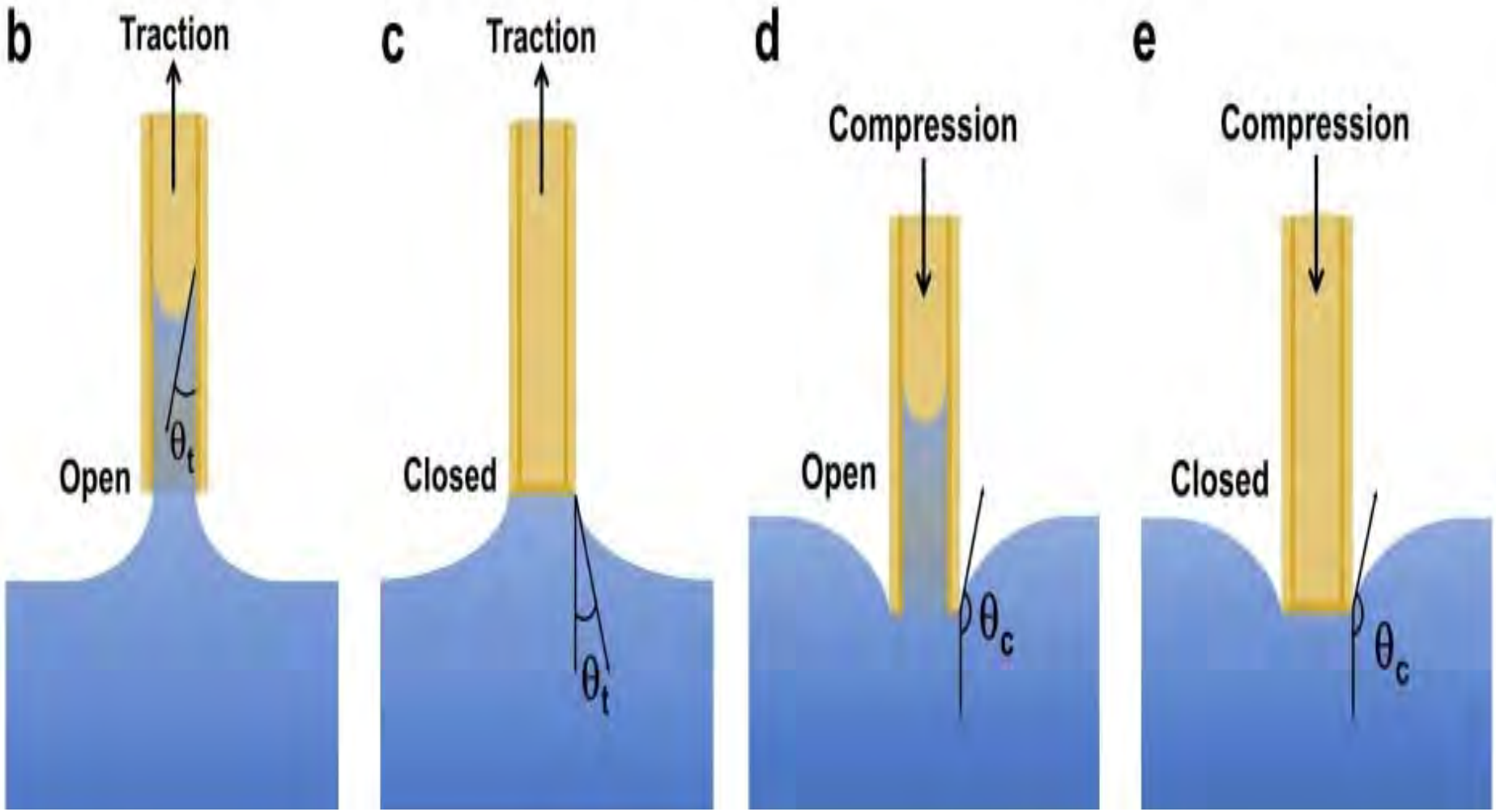


Weaving GaN floating carpets and their use as self-healing rafts

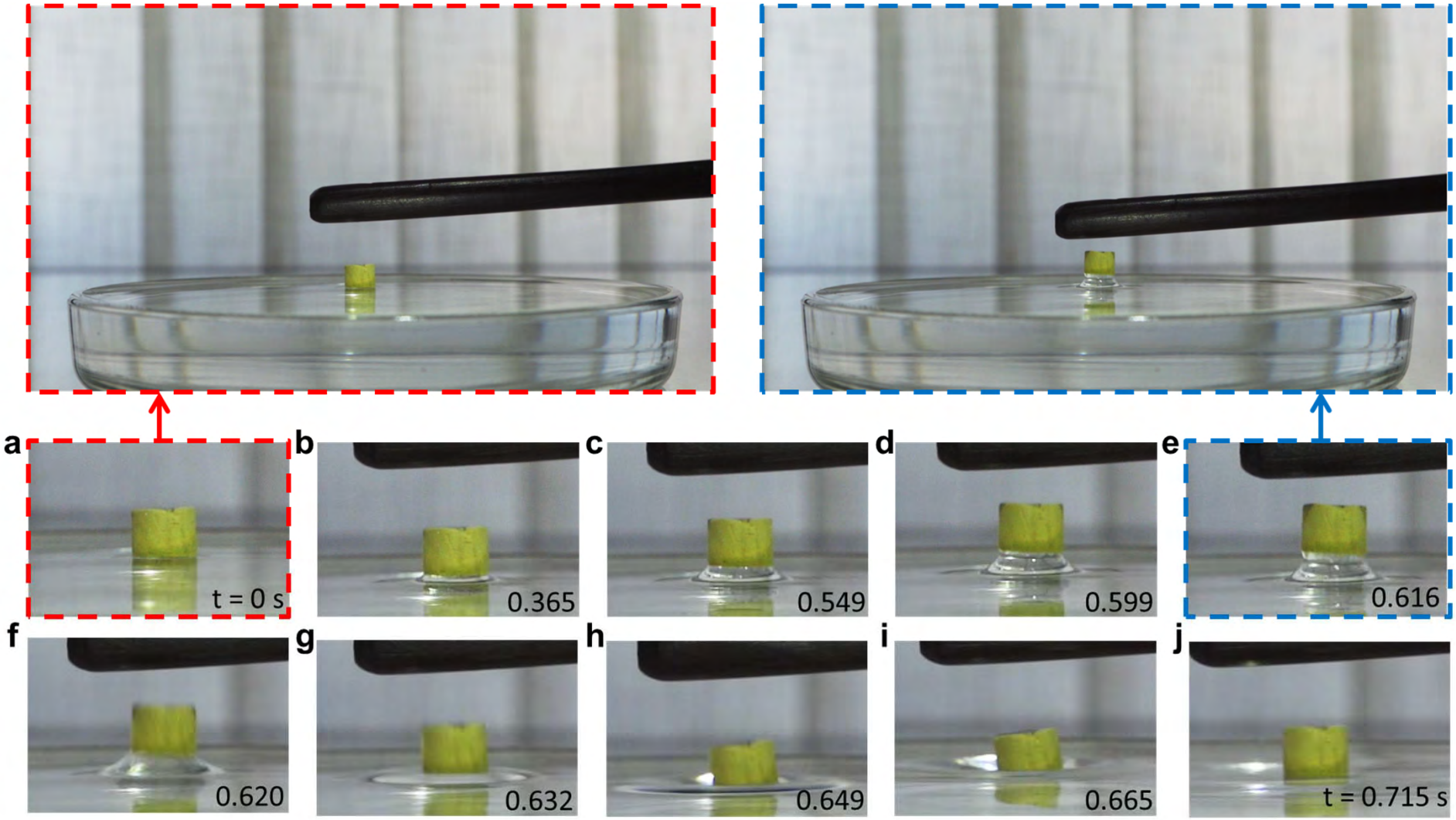


I. Tiginyanu, T. Braniste *et al* Nano Energy, Vol. 56, pp. 759-769 (2019).

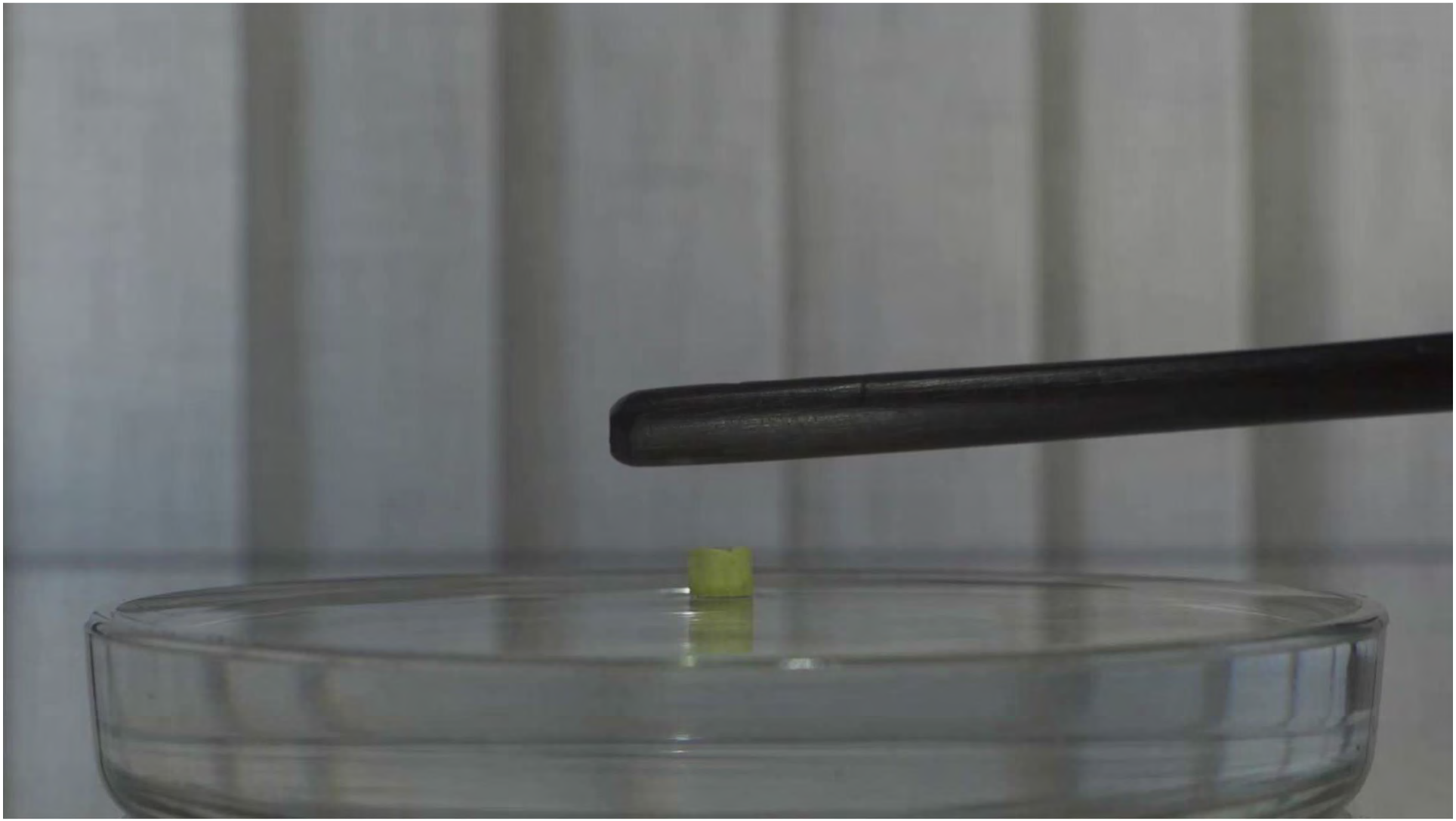
Hydrophilic-hydrophobic nature



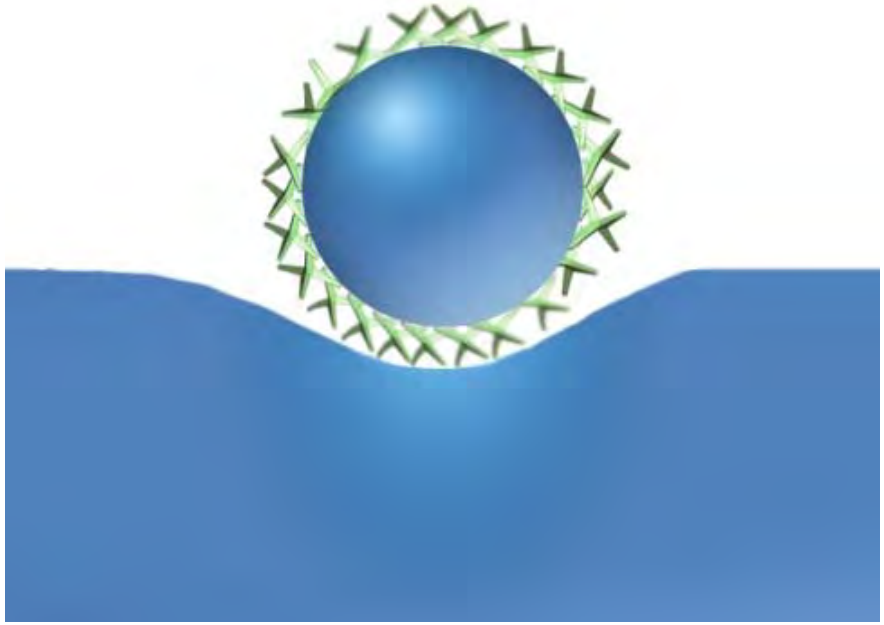
Demonstration of hydrophilic dewetting

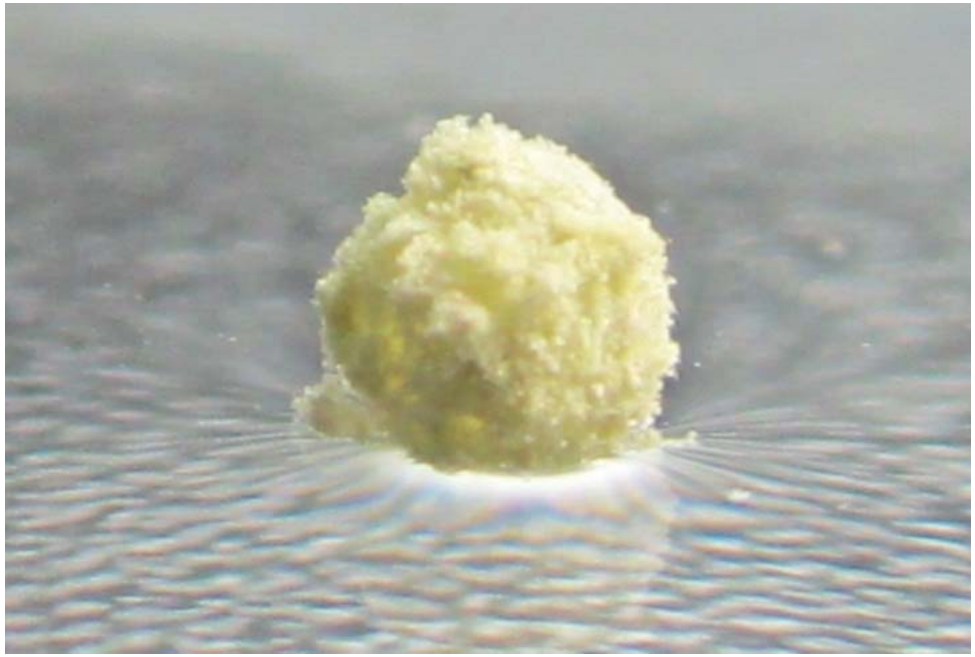


Demonstration of hydrophilic dewetting



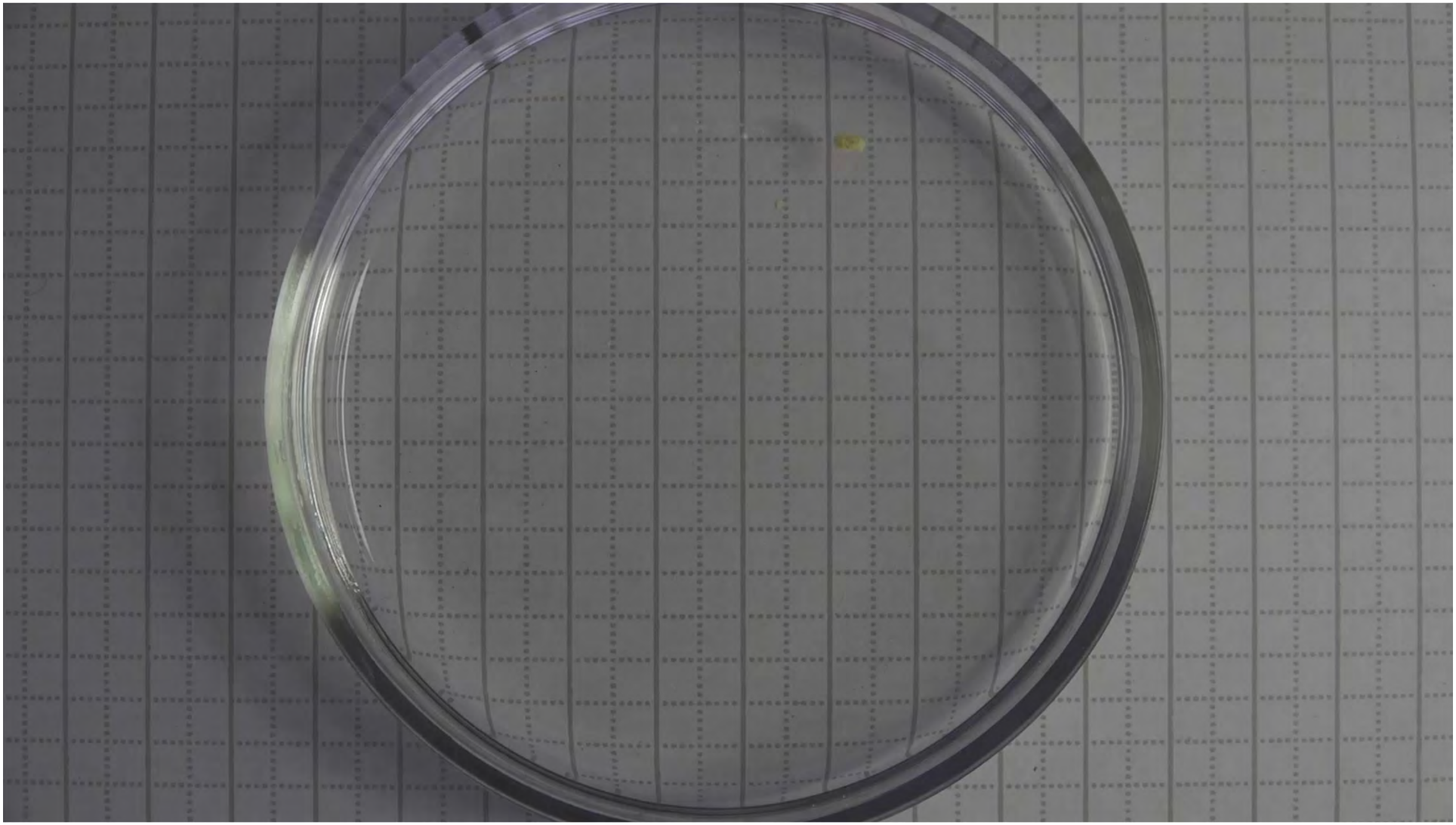
Rotating liquid marbles





Ion Tiginyanu, Tudor Braniste, Daria Smazna, Mao Deng, Fabian Schütt, Arnim Schuchardt, Marion A. Stevens-Kalceff, Simion Raevschi, Lorenz Kienle, Nicola Puglo, Yogendra K. Mishra, Rainer Adelung, Self-organized and self-propelled aero-GaN with dual hydrophilic-hydrophobic behaviour, Nano Energy 56, 759-769 (2019).

Rotating liquid marbles



Consortium NanoMedTwin

Technical University of Moldova	Moldova
Hannover Medical School (MHH)	Germany
Royal Institute of Technology (KTH)	Sweden
University of Bristol (UNIVBRIS)	UK
Joint Research Centre (JRC)	Italy Belgium
EFPC Ltd (EFPC)	Israel

Project objectives

1. Promotion of the links between NANO and BioMedicine fields (multidisciplinarity)

2. Training of a new generation of highly-skilled researchers

3. Developing a strategic programme focusing on the field of nanomaterials for biomedical applications, establishing links with medical institutions in Moldova and building of capacities for the promotion of technology transfer

4. Extending networking and collaboration and creation of capacities for broader participation of NCMST and other linked research groups in Moldova with the Horizon 2020 Programme and future FP9 Programme

The International Conference on Nanotechnologies and Biomedical Engineering

ICNBME-2011

ICNBME-2013

ICNBME-2015

ICNBME-2019

Conference site: http://www.icnbme.sibm.md/

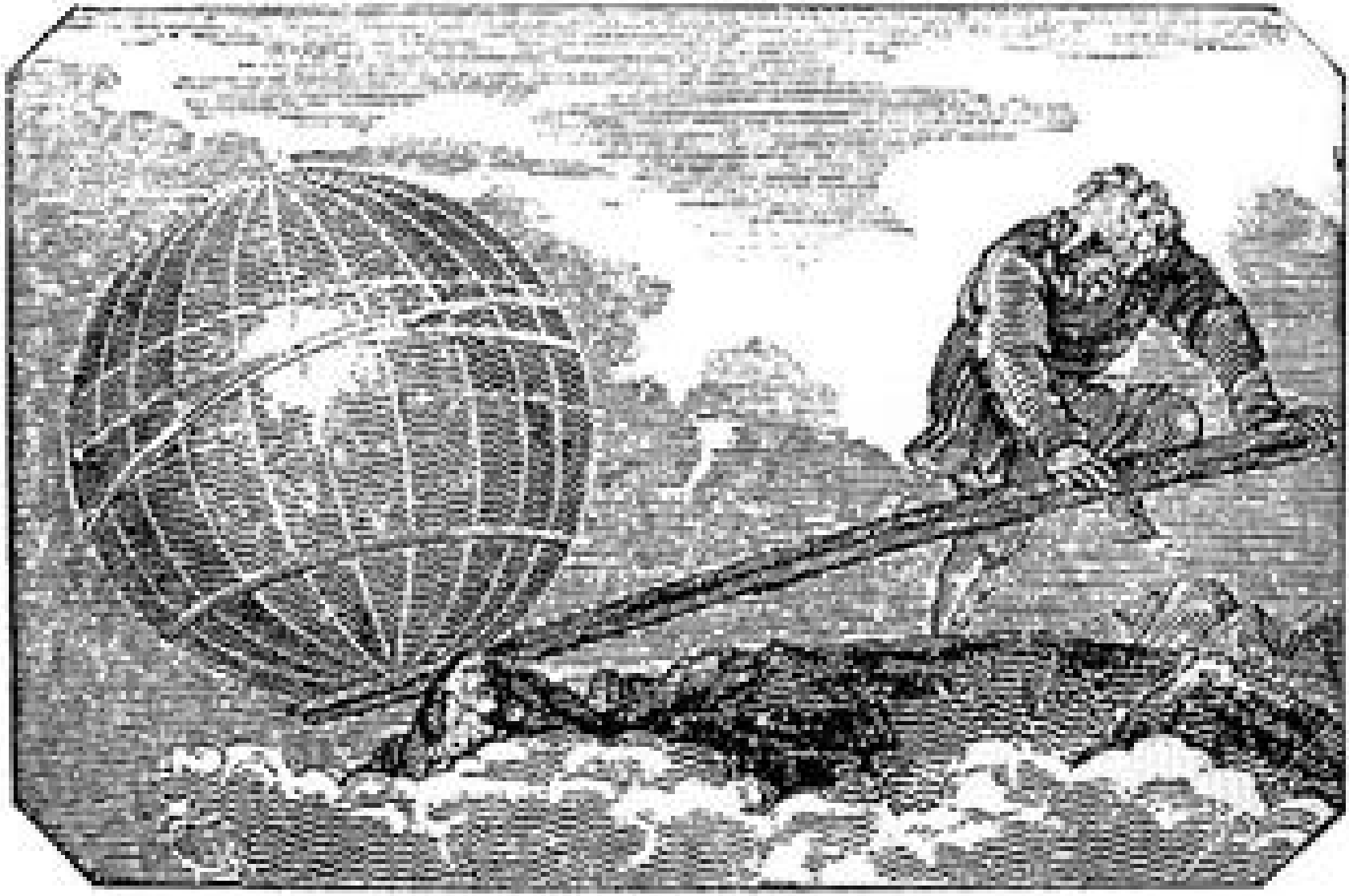
Conclusions

- GaN hollow nanoparticles were developed and their biocompatibility and uptake by living cells have been demonstrated;

- GaN-based ultrathin membranes as well as flexible two-dimensional photonic crystals with embedded waveguides, beam splitters and ring resonators have been fabricated;

- GaN-based microtubes with ultrathin walls and flexible three-dimensional architectures have been developed for biomedical and microfluidic applications.

Knowledge moves the world



Thank you

for your kind attention!