BPU11 CONGRESS
Serbian Academy of Sciences and Arts
Belgrade, Serbia, August 28 – September 1, 2022

Nature-inspired novel nanomaterials for multifunctional applications

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2. GaN/ZnO micro-nano-architectures. Aerogalnite – the first artificial nanomaterial with dual hydrophilic-hydrophobic properties
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5. Stationary and pulsed rotation of liquid marbles. Helicopter effect
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7. Conclusions

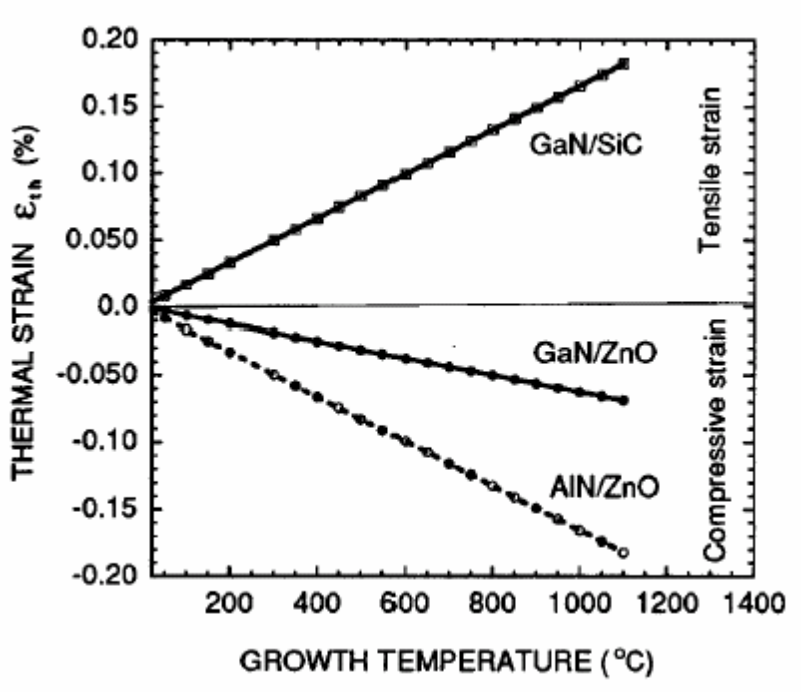
GaN / ZnO

Mismatch 1.8 %

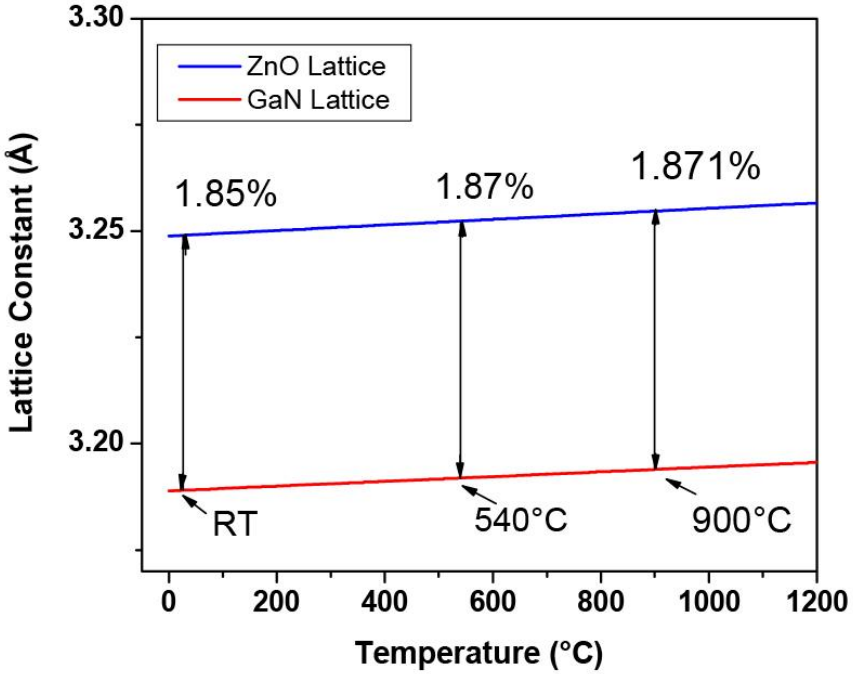
GaN stabilizes the ZnO interface layer in a unique fashion

Nano Energy, Vol. 56, pp. 759-769 (2019)

Thermal strain versus growth temperature



Temperature dependence of lattice constants



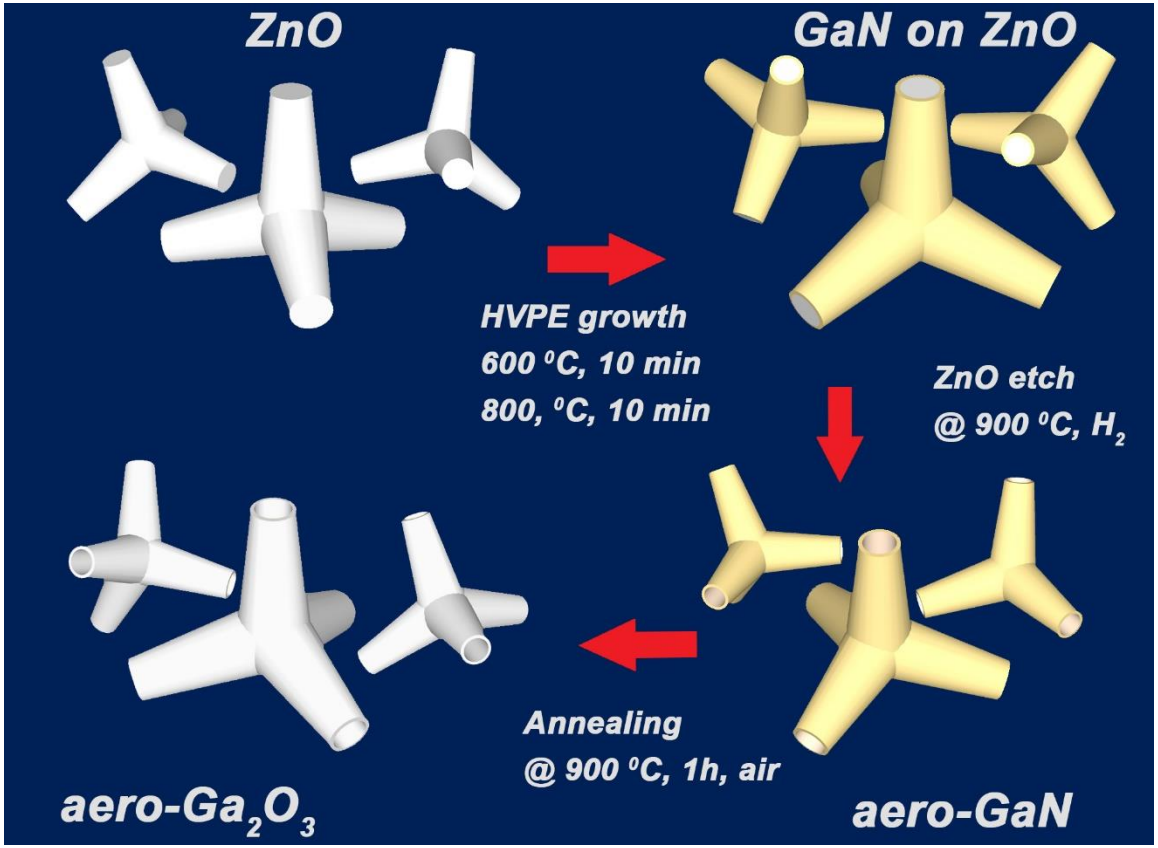
Variation of thermal strain with growth temperature calculated for GaN/ZnO, AlN/ZnO, and GaN/SiC heterostructures.

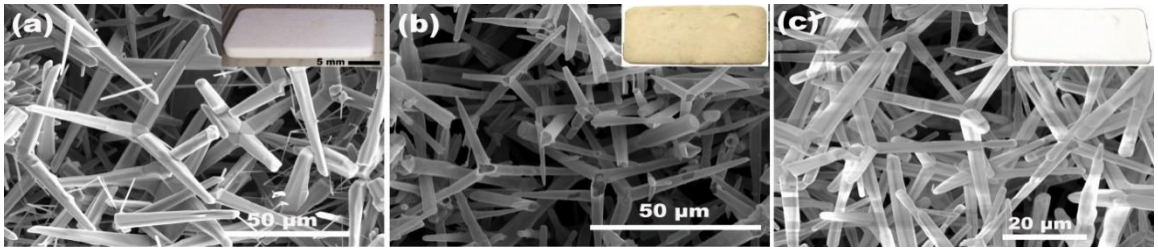
Owing to the close thermal expansion coefficients between GaN and ZnO, the thermal strain in GaN/ZnO is about half that of GaN/SiC and AlN/ZnO, F.Hamdani et al, J. Appl. Phys., Vol. 83, 983 (1998).

GaN/ZnO three-dimensional micro-nano-architectures

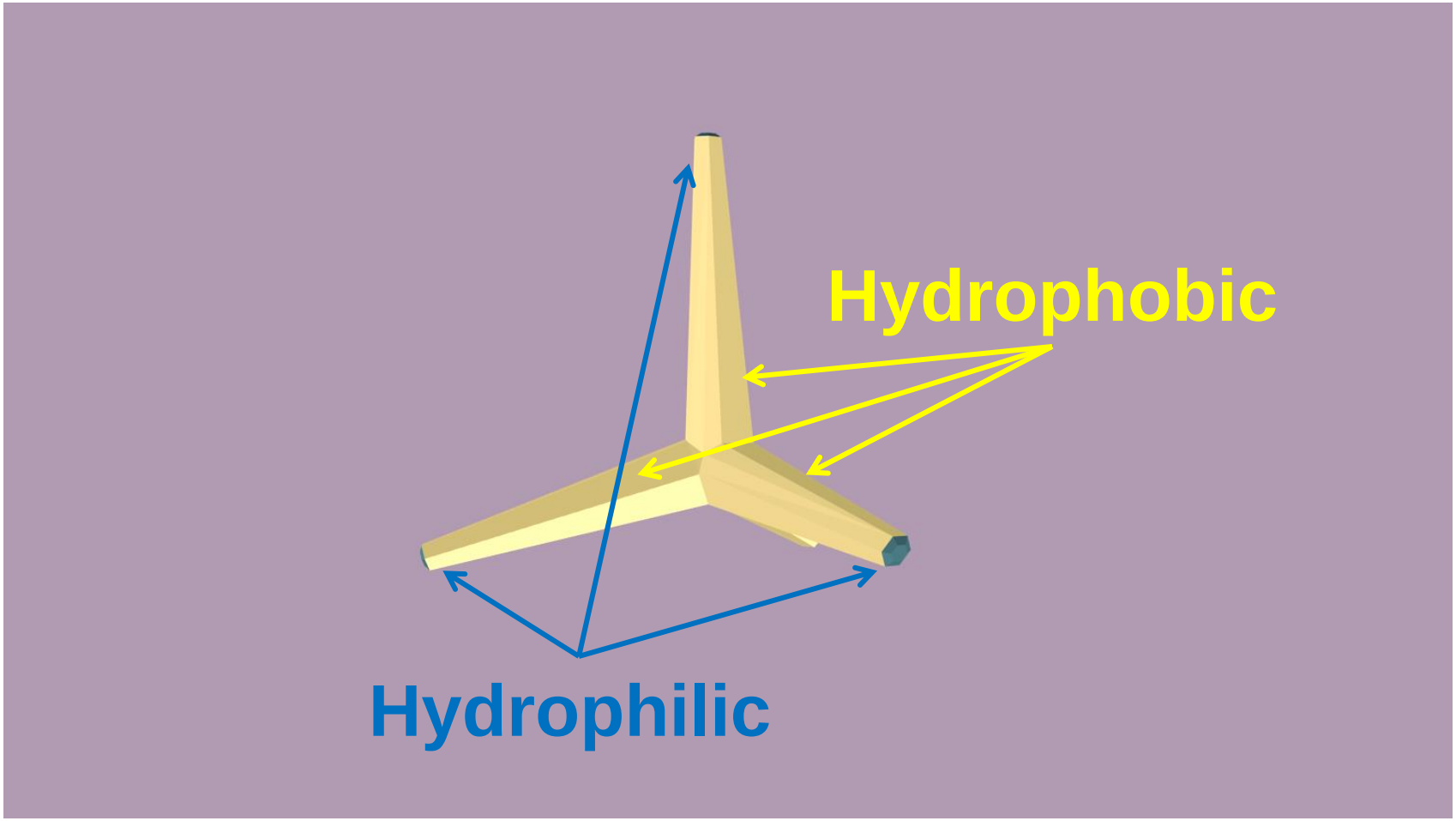
In collaboration with the Institute for Materials Science, Kiel University; Department of Civil, Environmental and Mechanical Engineering, University of Trento, Italy; University of New South Wales, Sydney, Australia; State University of Moldova.

Aero-GaN is prepared using HVPE growth of GaN on ZnO micro-tetrapods with the dissolution of the sacrificial ZnO





Dual hydrophilic-hydrophobic behavior



Aerogalnite

Aero-GaN

the first artificial material with dual hydrophilic/hydrophobic properties

Interaction

between fire ants

between artificial insects

Fire ants on water surface

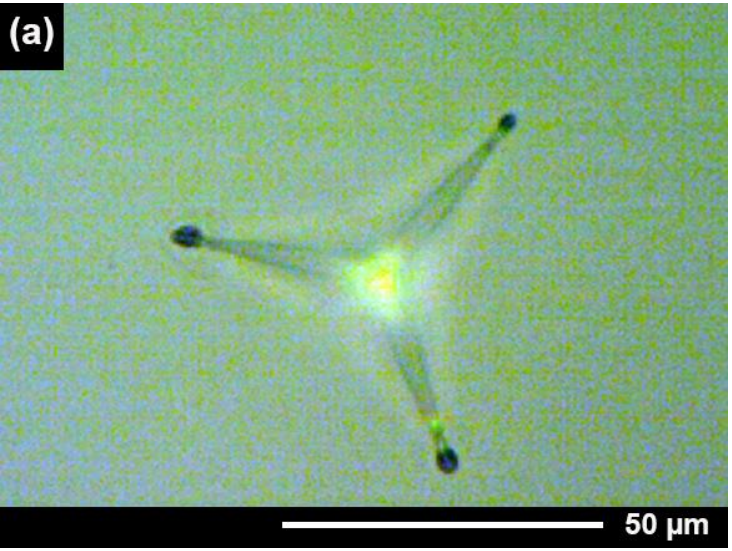
Scientific American, 2017


NAT GEO
WILD
NATGEOWILD.COM

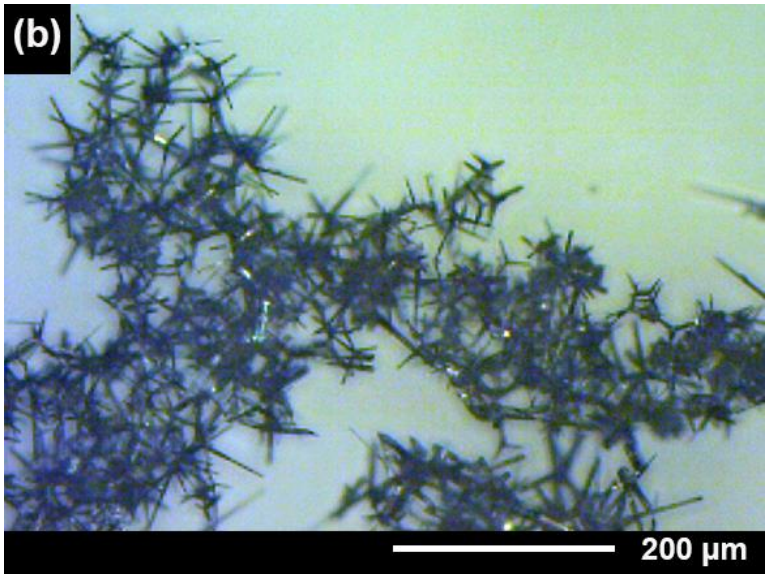
Flying water lily beetle tethered to the water by four hydrophilic claws

Science, 2014

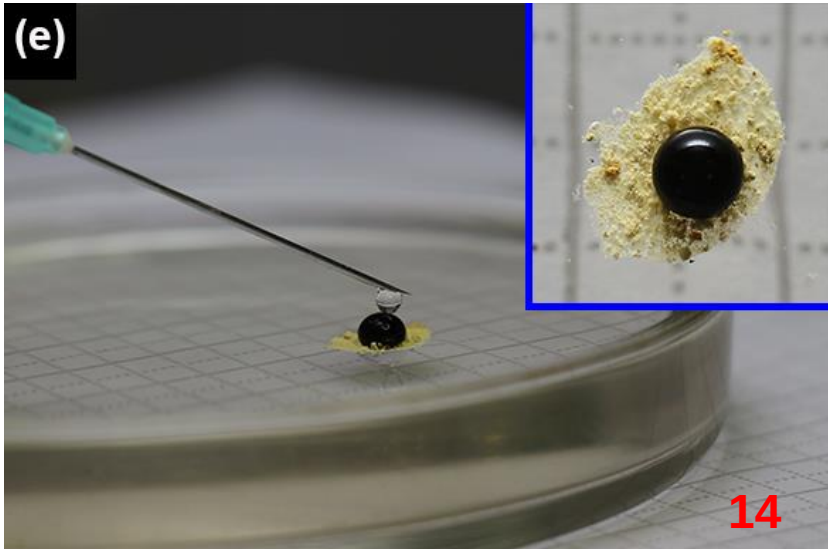
Weaving GaN/ZnO floating carpets



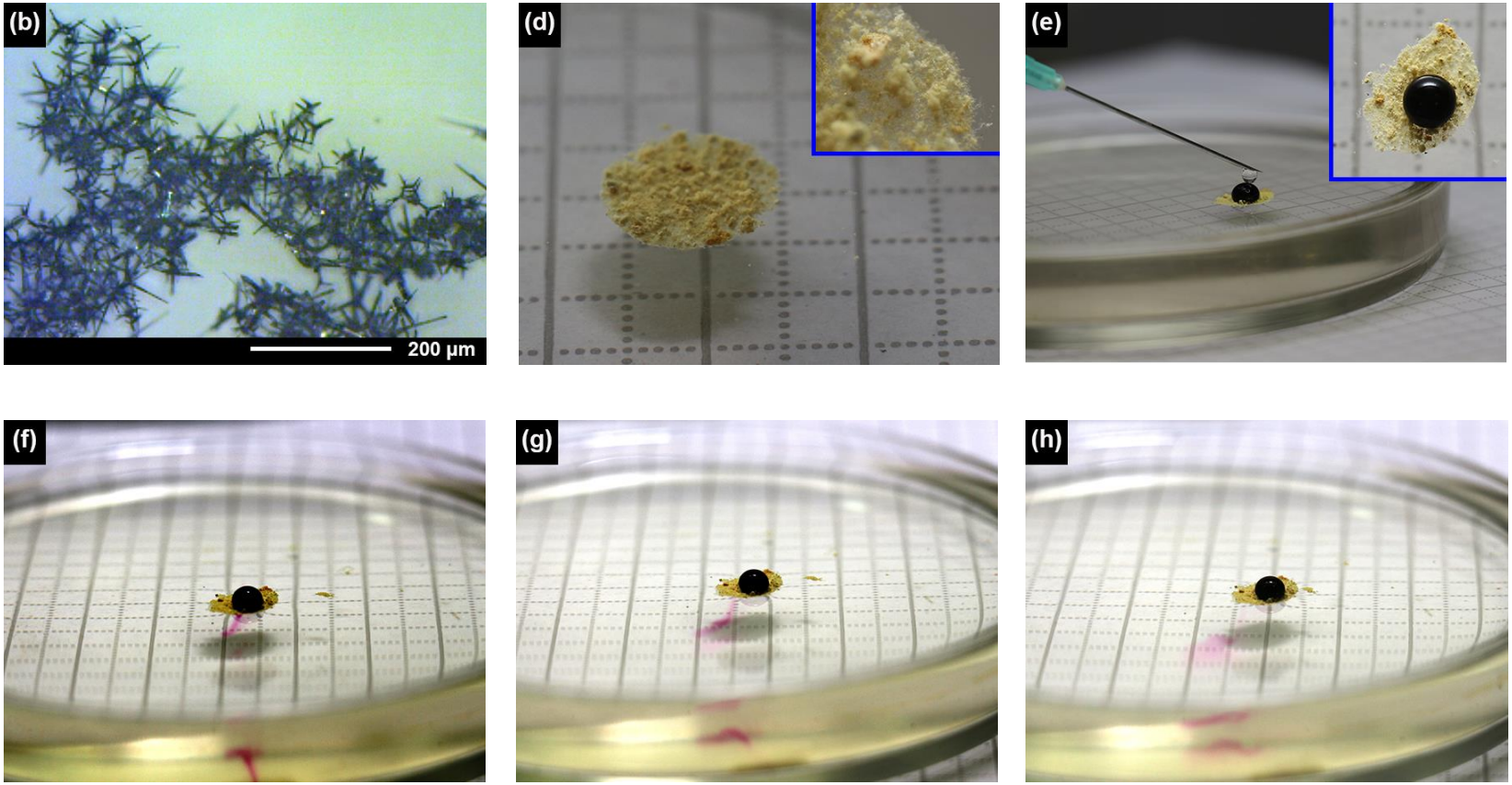
single GaN/ZnO hollow tetrapod on water surface



Interaction between many GaN/ZnO hollow tetrapods on water surface

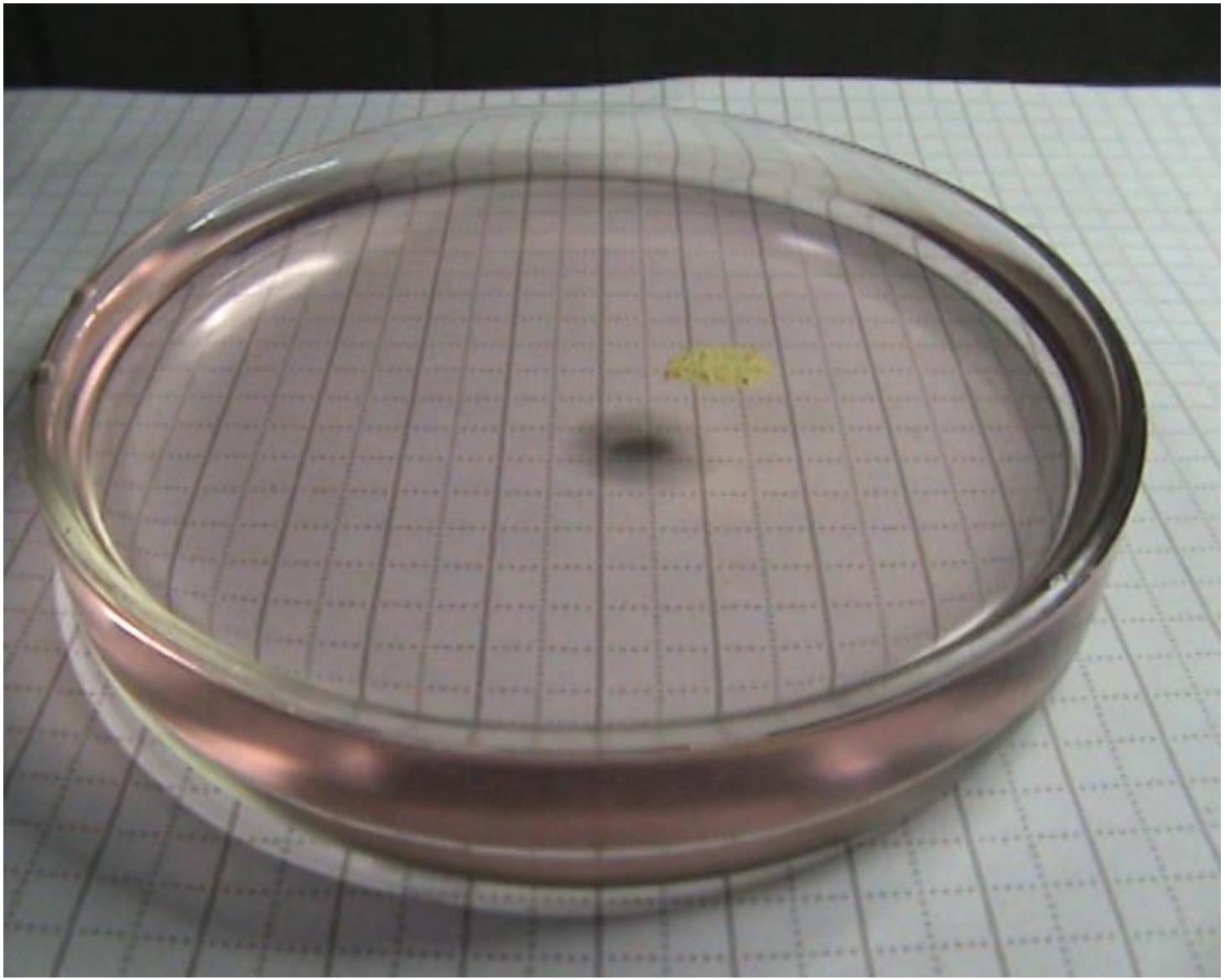


Weaving GaN floating carpets and their use as self-healing rafts

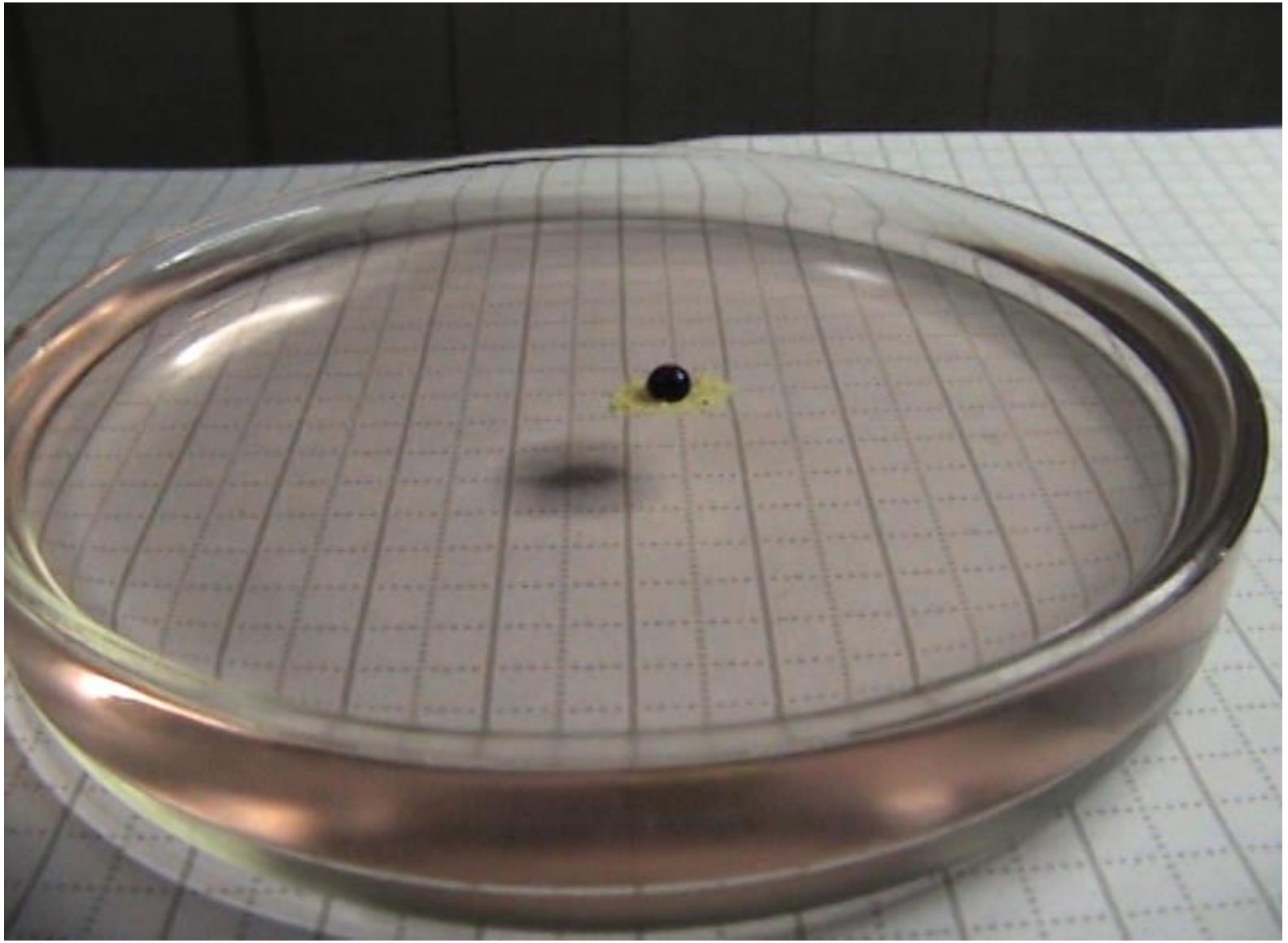


I. Tiginyanu, T. Braniste *et al*, Nano Energy, Vol. 56, pp. 759-769 (2019)

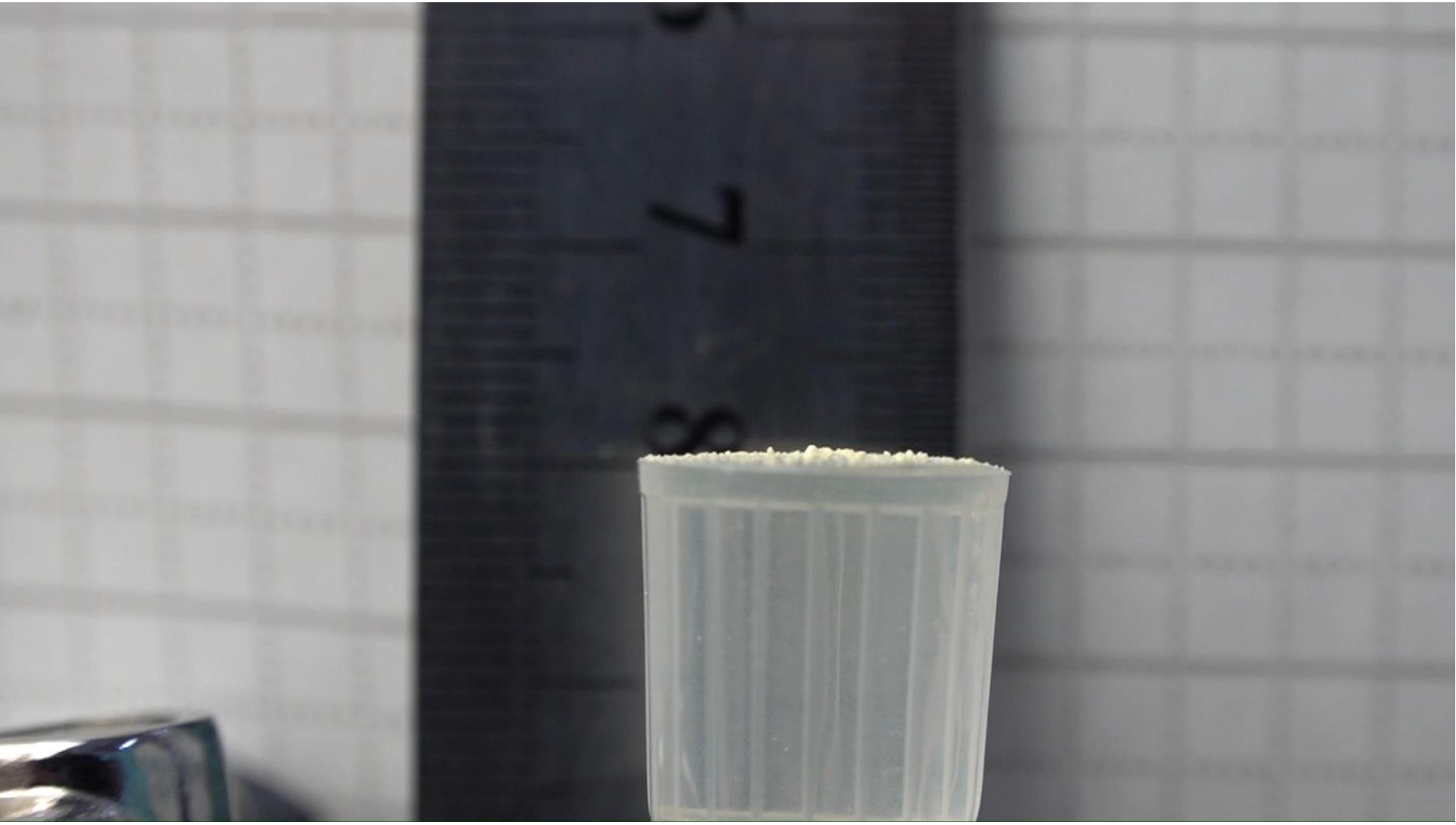
Dielectrophoretic actuation of a floating raft



Dielectrophoretic actuation of a floating raft

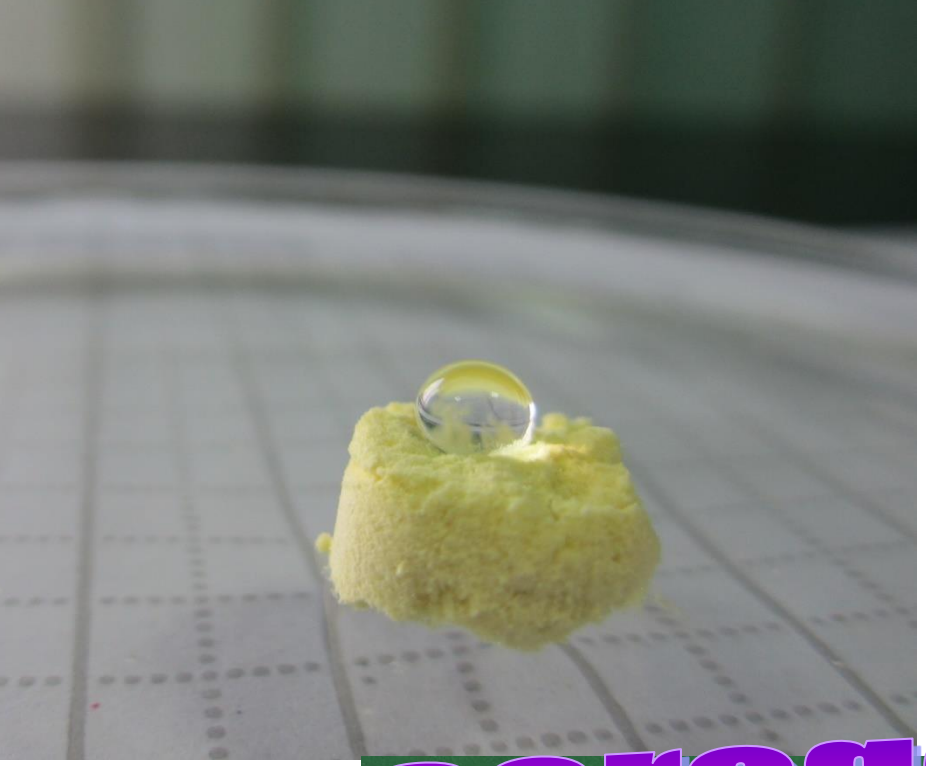


Superelasticity of Aerogalnite membranes

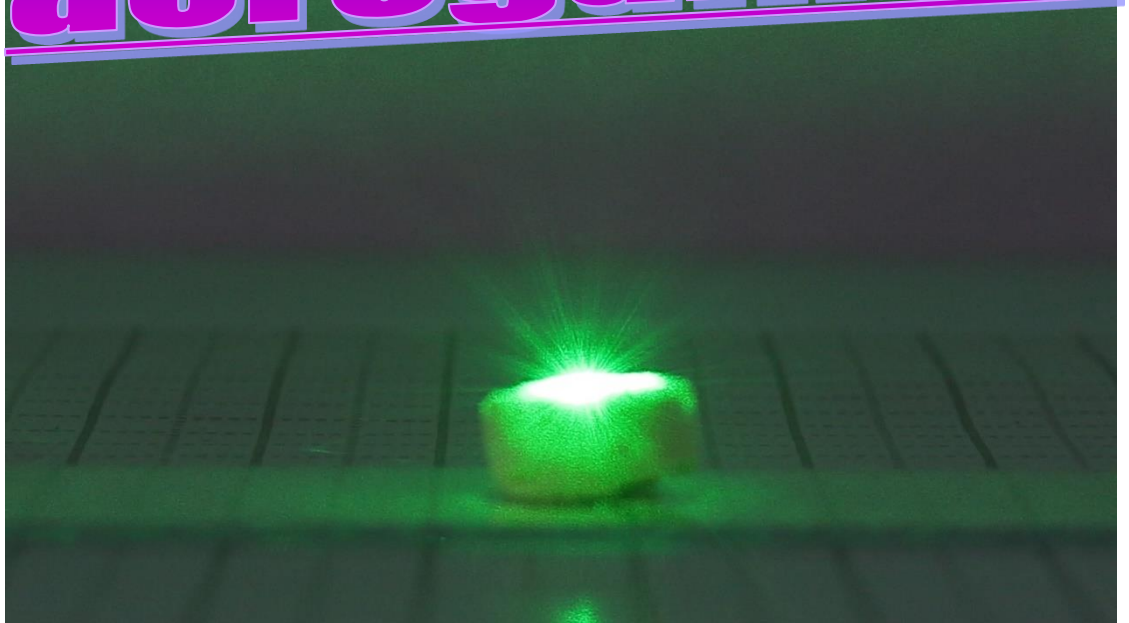


communication vessels

Above the threshold cracks appear, at successive stretches the cracks appear at different places on the membrane (self-healing effect).

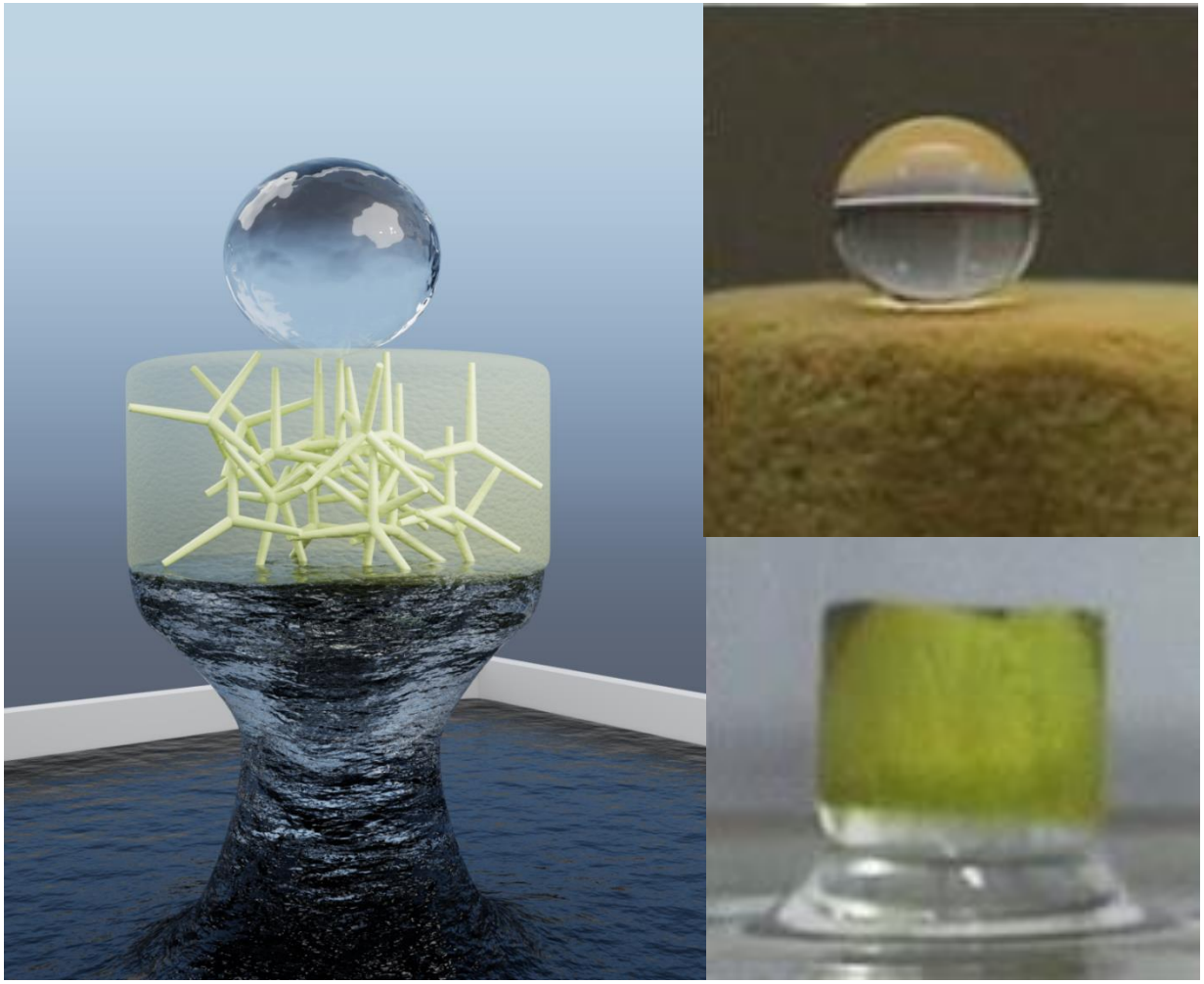


aerogalnite



Physics World

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

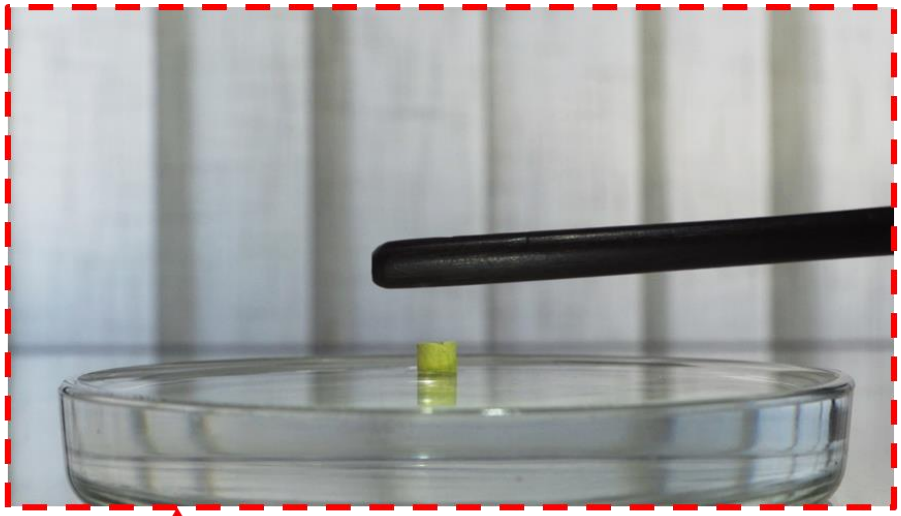


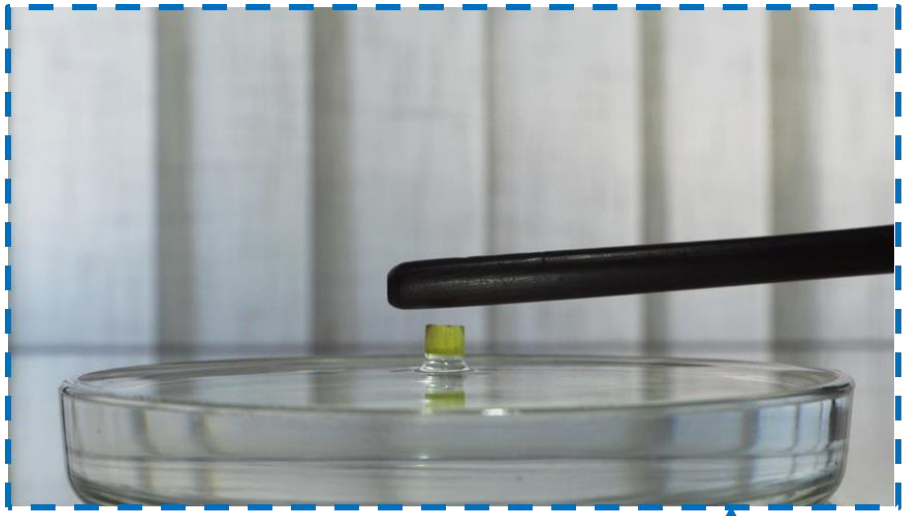
Hydrophobic wetting

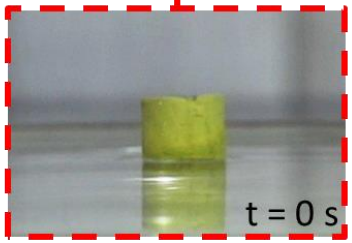
Hydrophilic dewetting

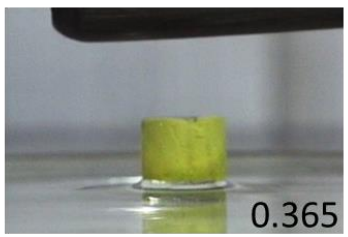
Ion Tiginyanu, Tudor Braniste, Daria Smazna, Mao Deng, Fabian Schütt, Arnim Schuchardt, Marion A. Stevens-Kalceff, Simion Raevschi, Lorenz Kienle, Nicola Puglo, Yogendra K. Mishra, Rainer Adelung, Self-organized and self-propelled aero-GaN with dual hydrophilic-hydrophobic behaviour, Nano Energy 56,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

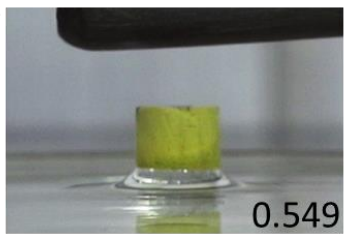
Demonstration of hydrophilic dewetting

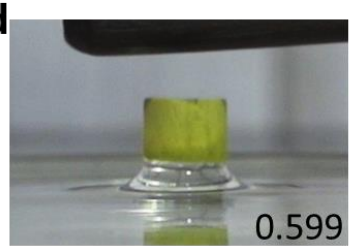


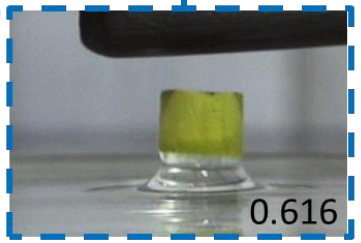


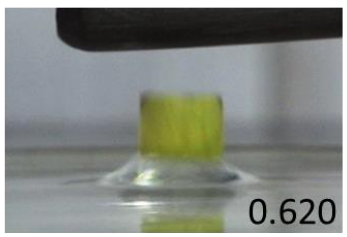


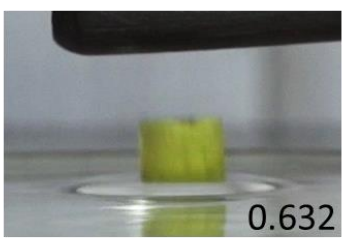


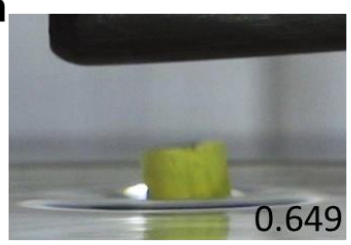


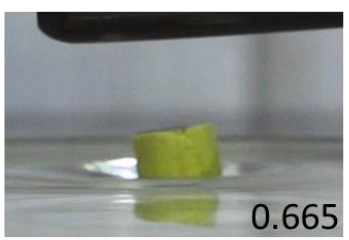


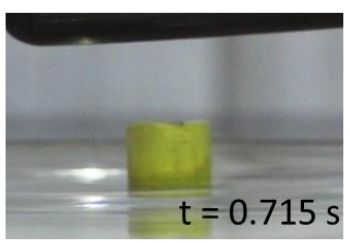




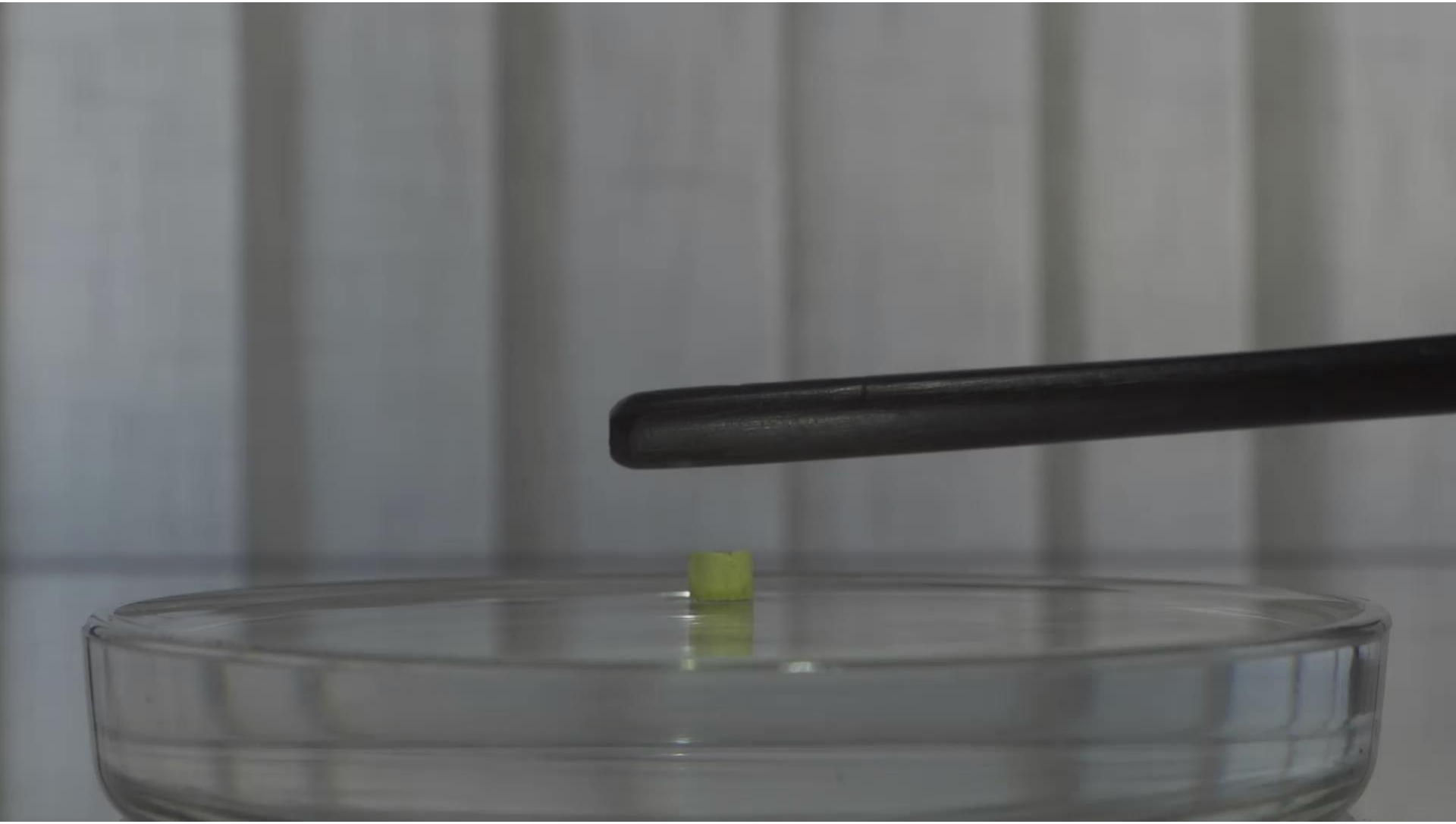




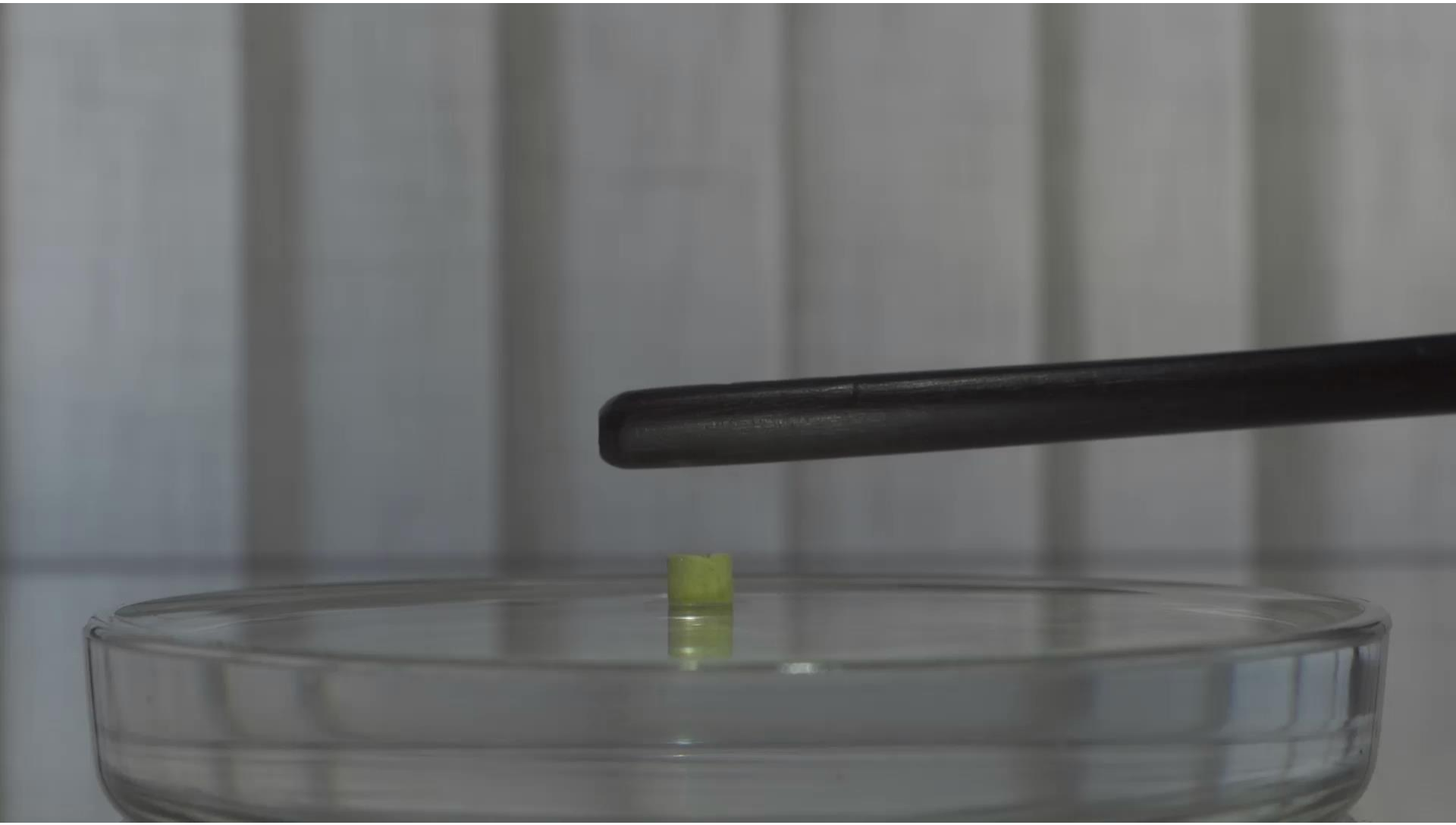




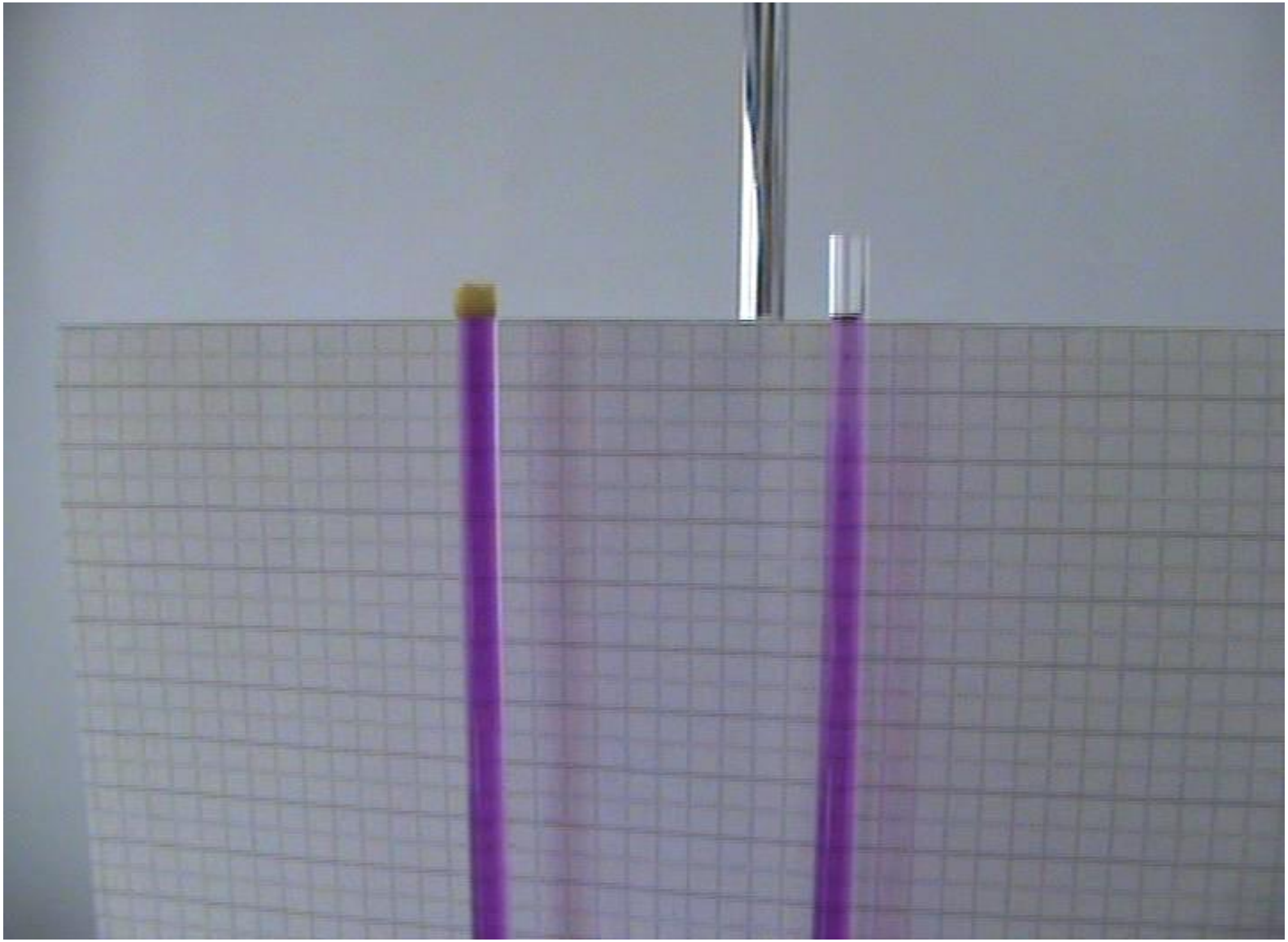
Demonstration of hydrophilic dewetting



15 times slower



Demonstration of hydrophilic dewetting



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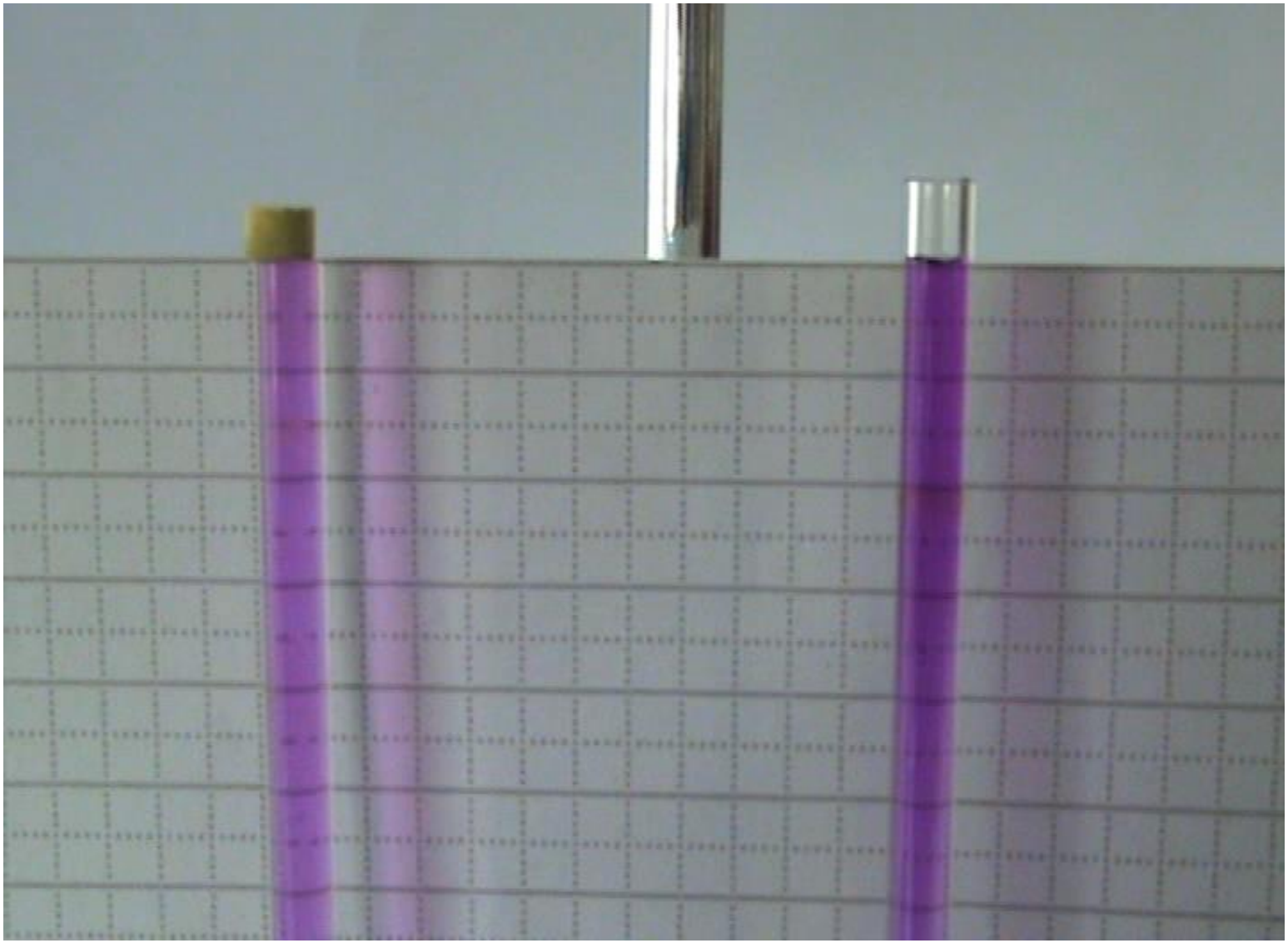
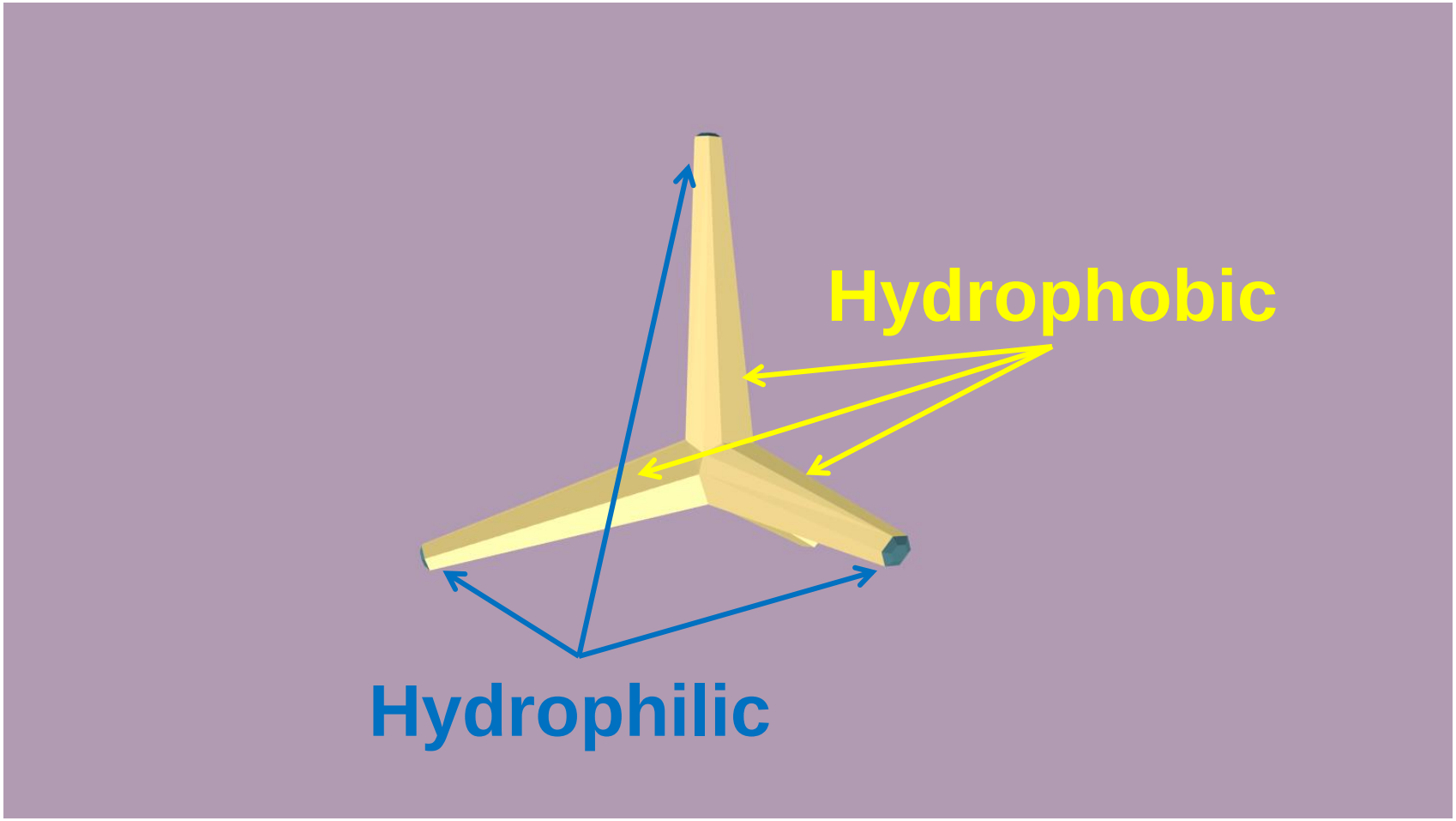
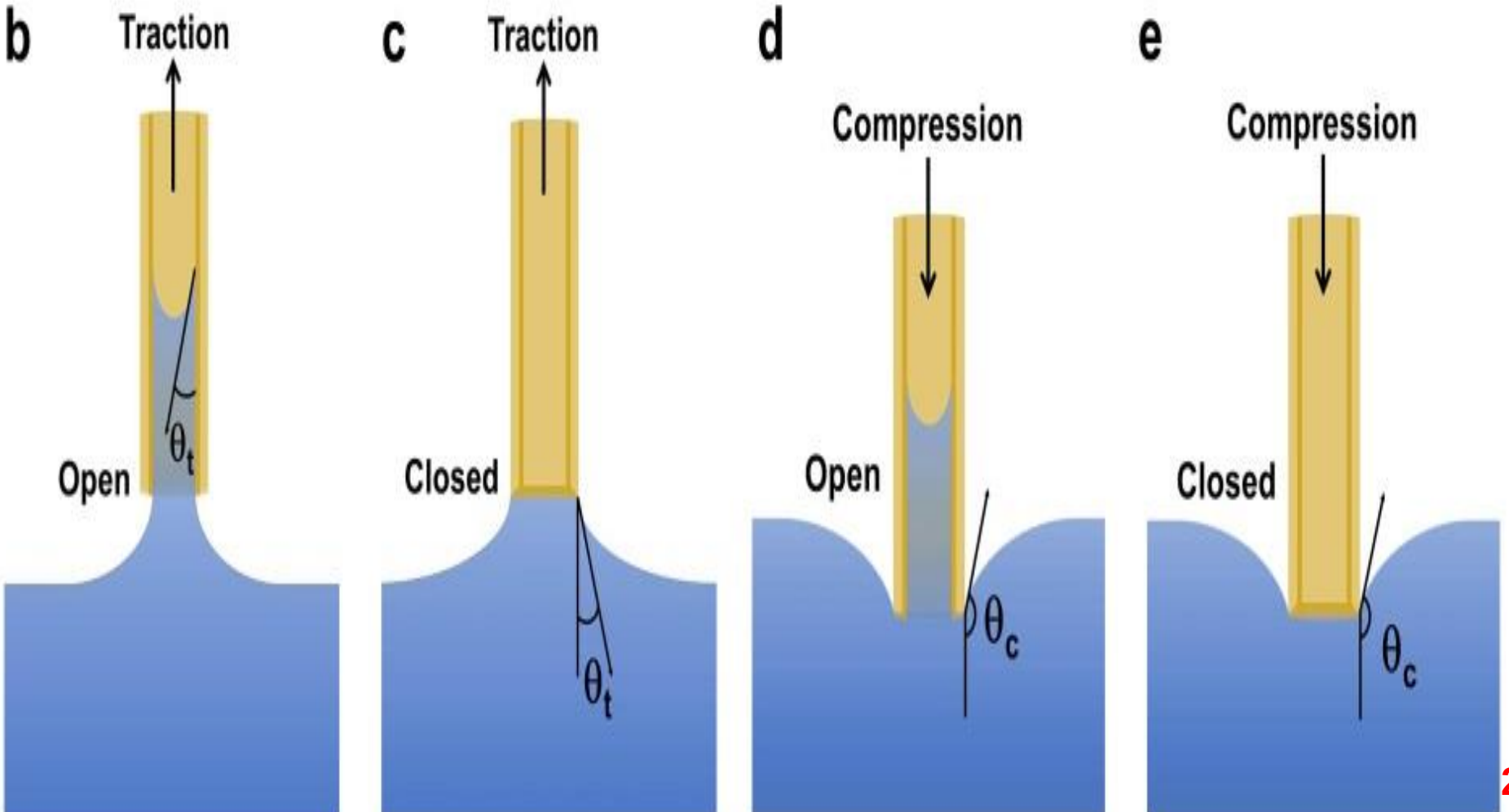


The force of detachment is 4.4 mN (meaning a specific force or tensile strength of 35 mN/cm^2).

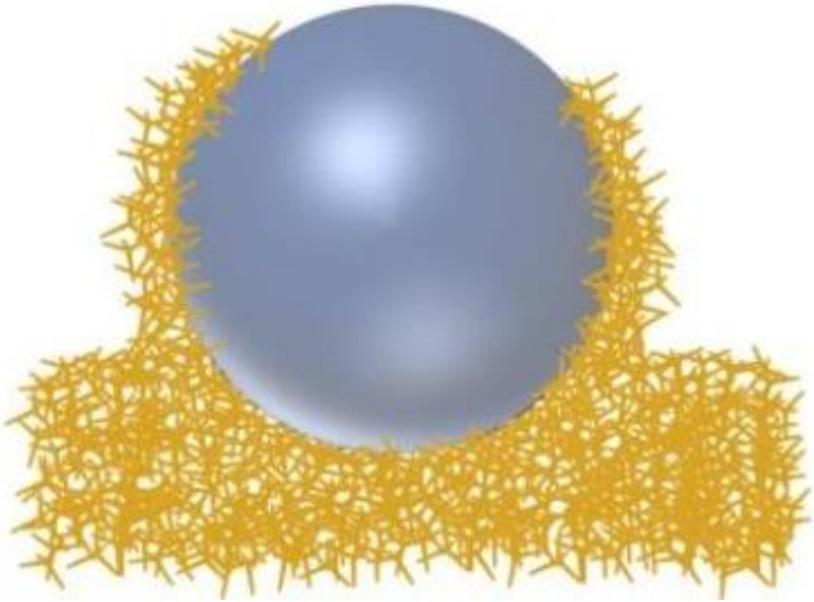
Dual hydrophilic-hydrophobic behavior

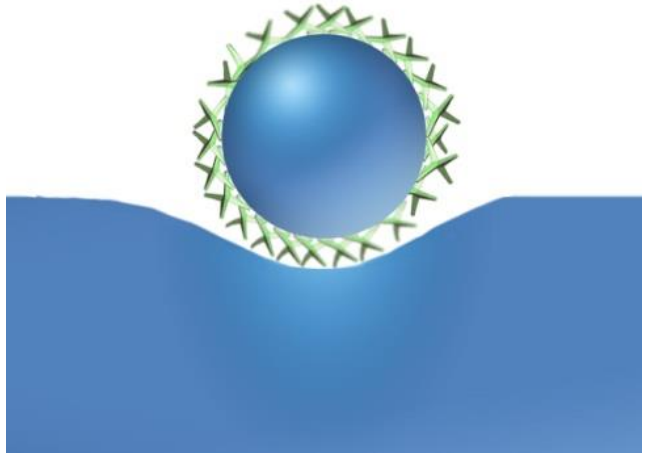


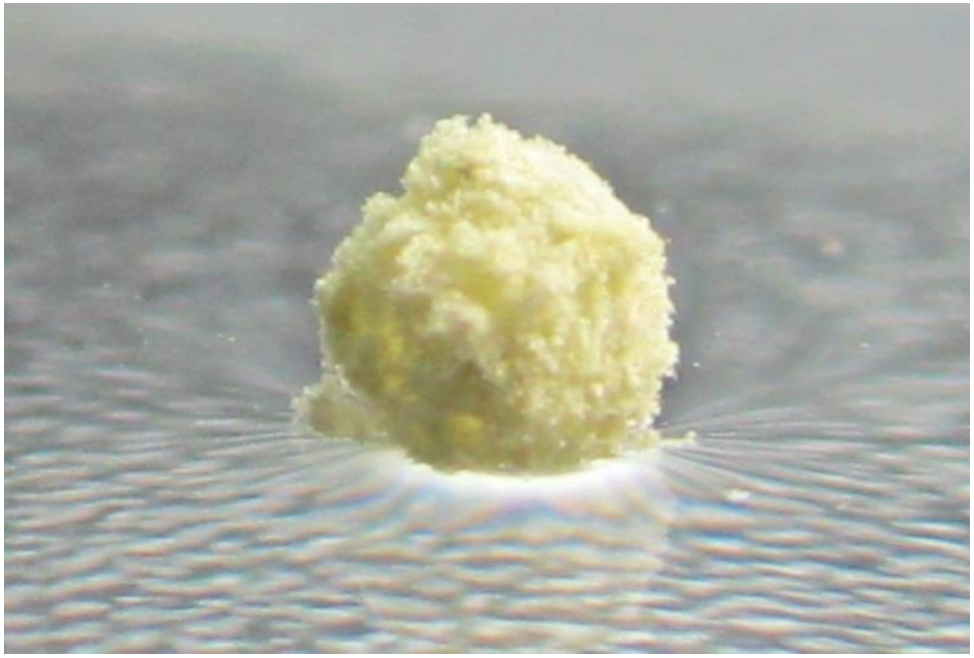
Hydrophilic-hydrophobic nature



Aerogalnite liquid marbles







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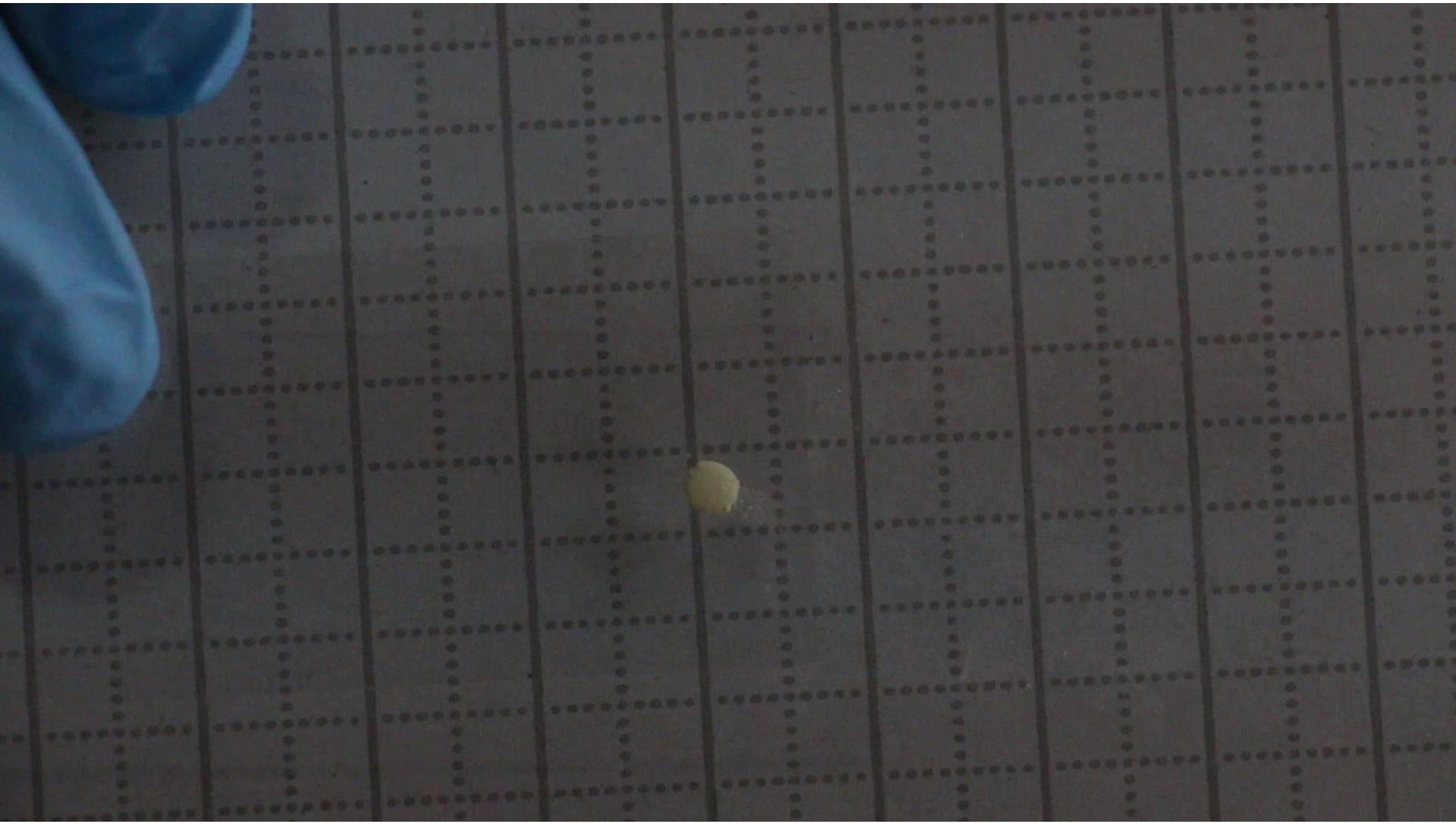
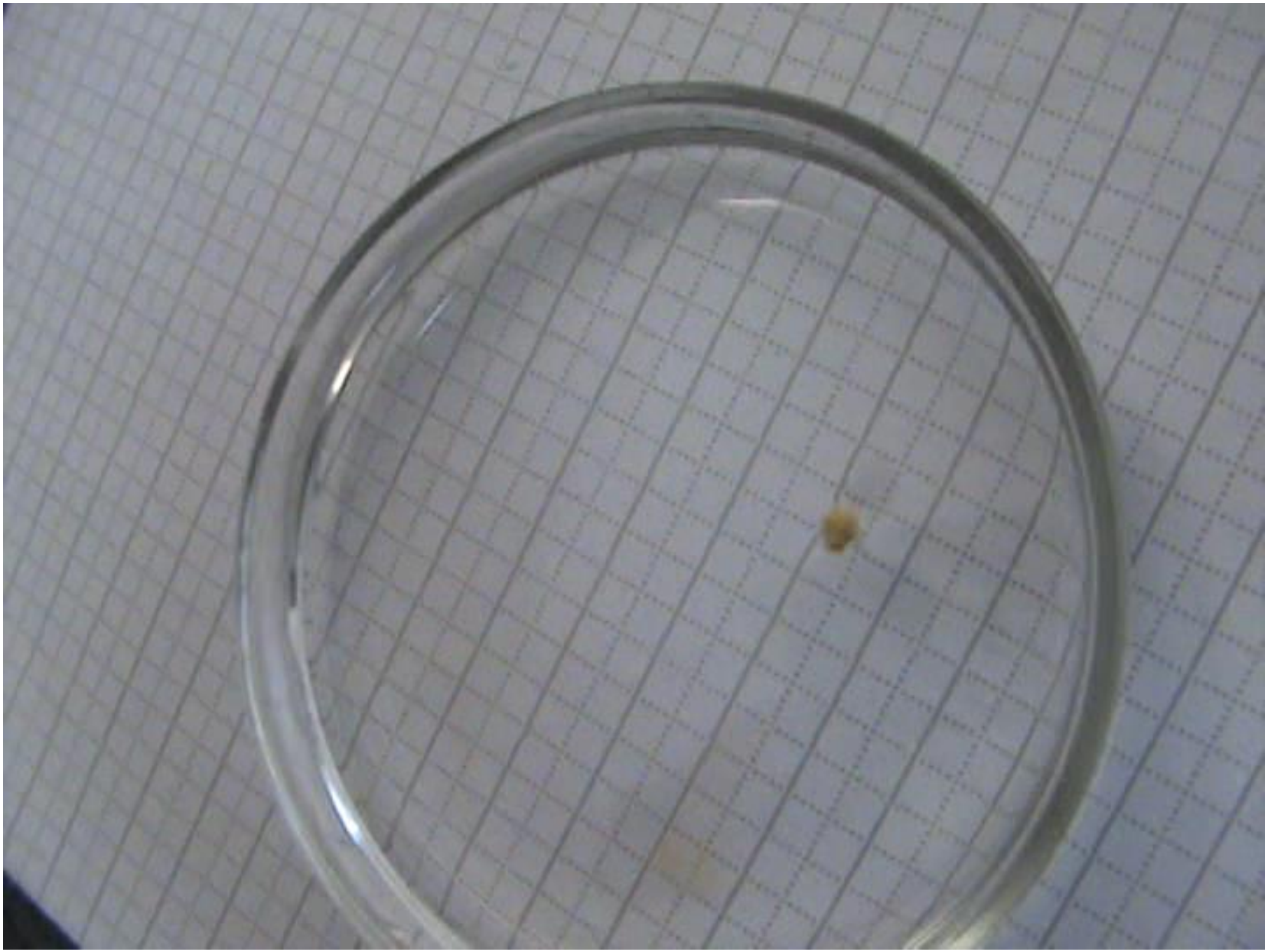
Mechanical stability of consolidated liquid marble



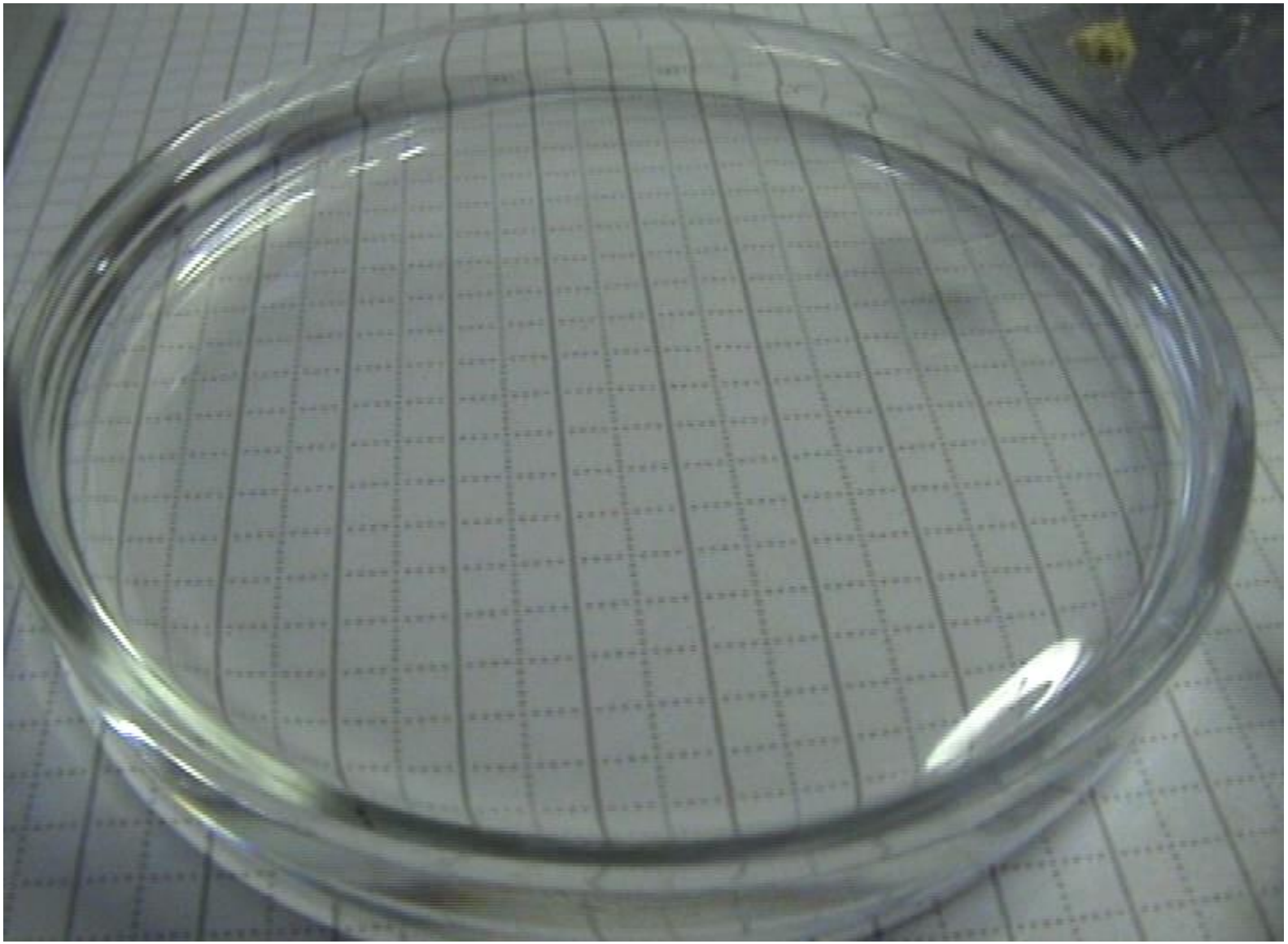
They survive e.g. on the surface of water subjected to intense ultrasonic treatment.

Liquid marble actuation by magnetic field

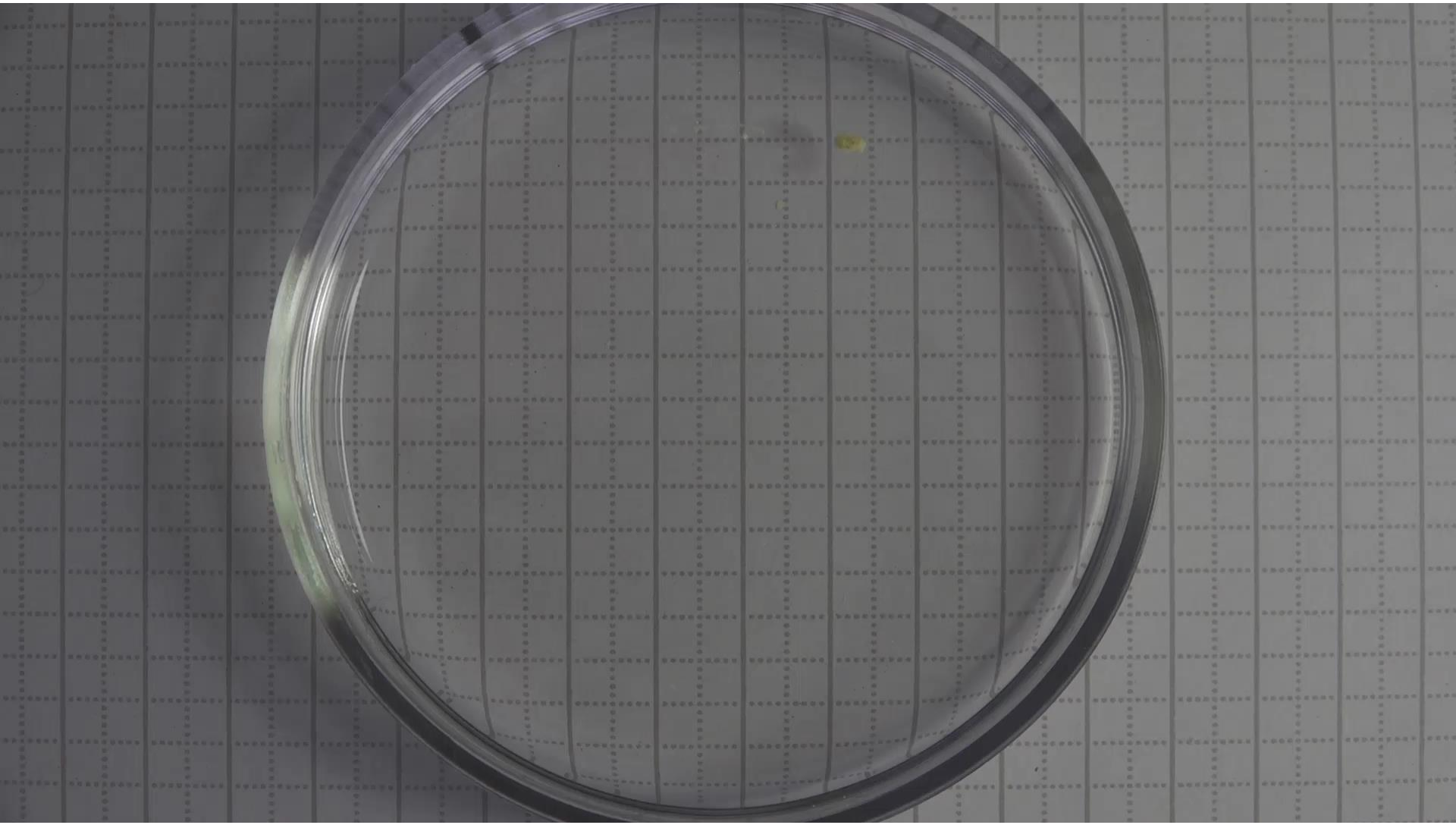


Self-propelled liquid marbles based on aero-GaN

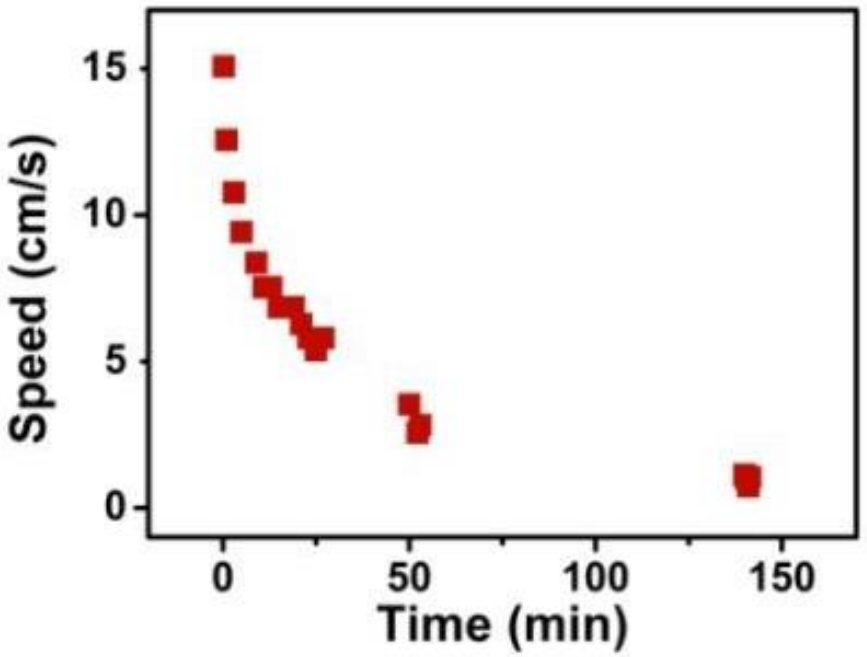
Rectilinear movement of liquid marble



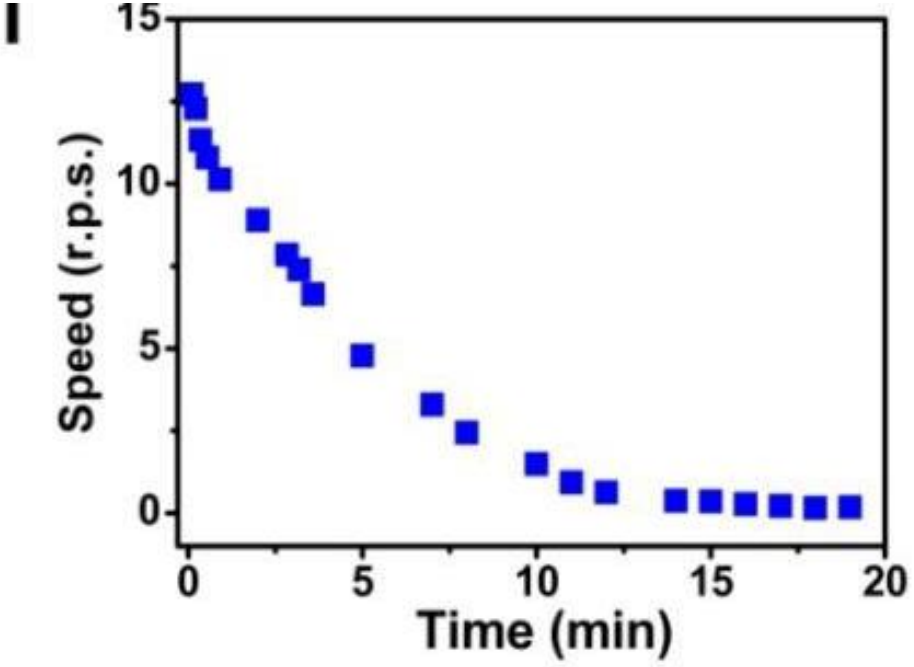
Rotating liquid marble
(stationary rotation)



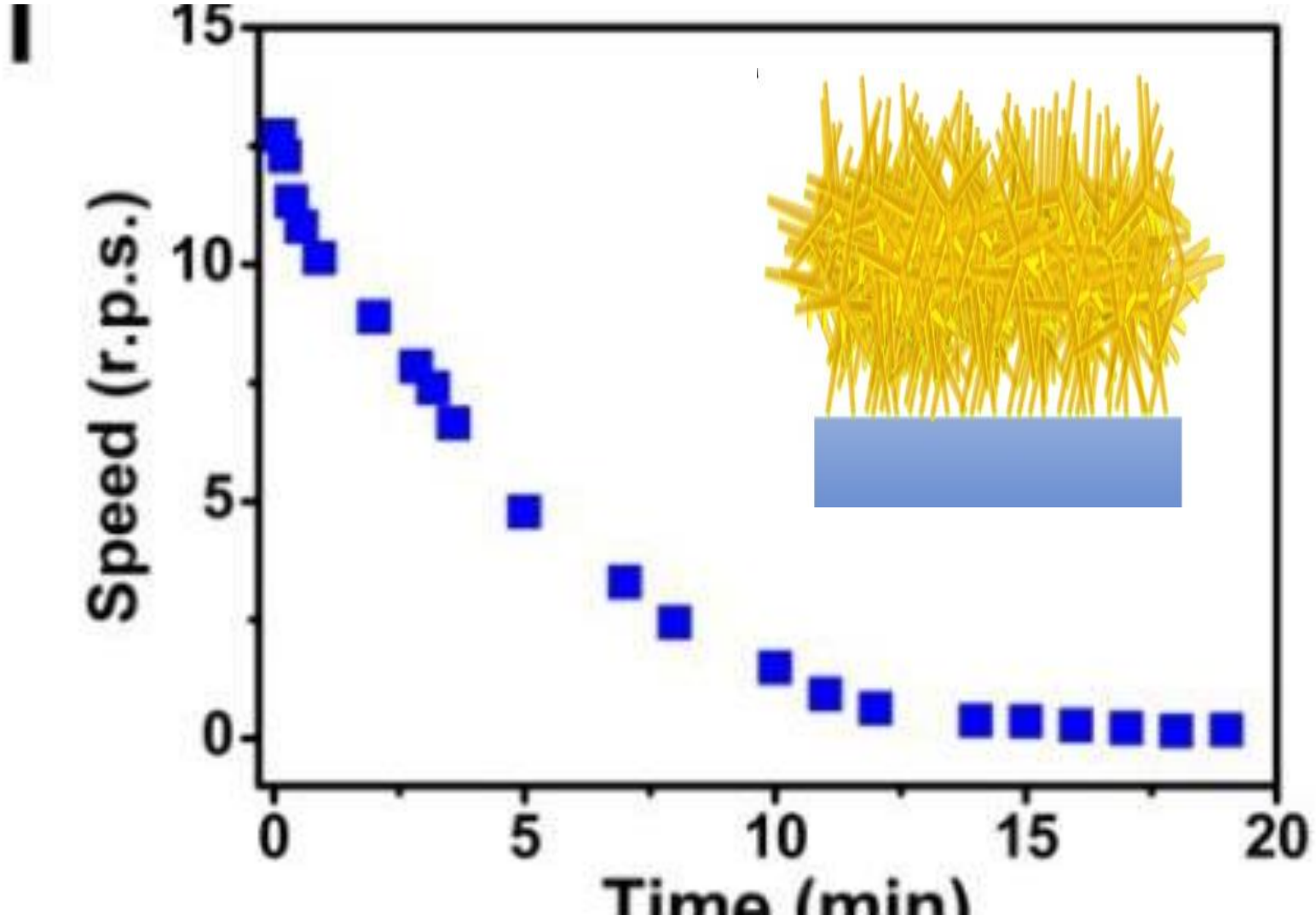
Rectilinear movement of liqiud marbles



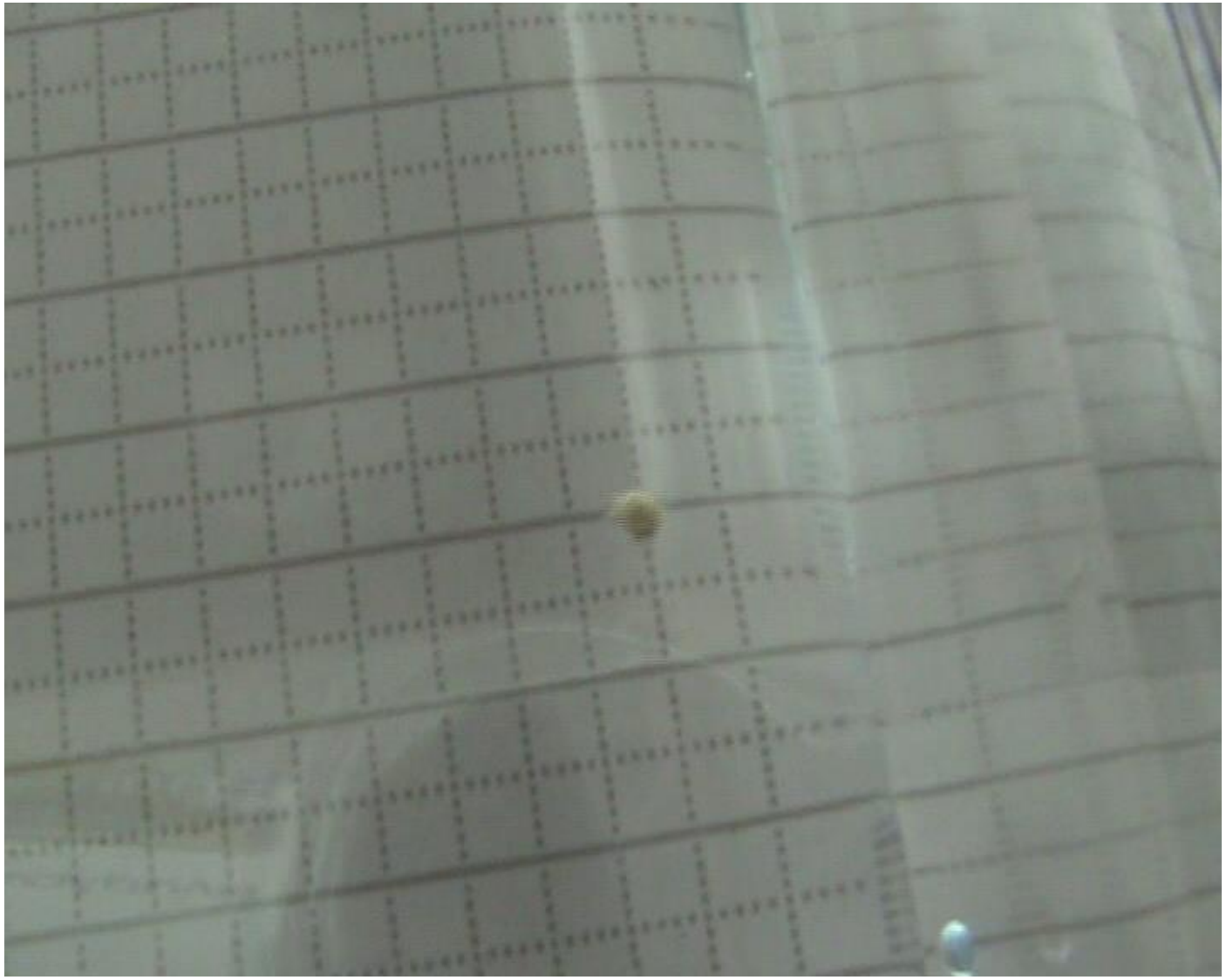
Rotation of liquid marbles



Rotation of liquid marbles



Liquid marble rotating in pulses

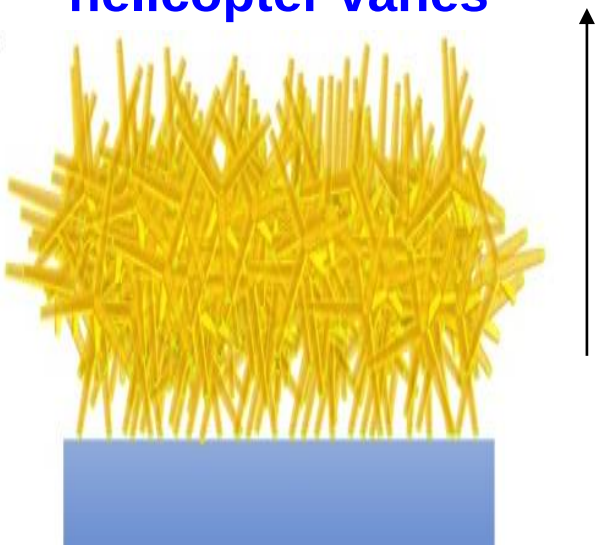


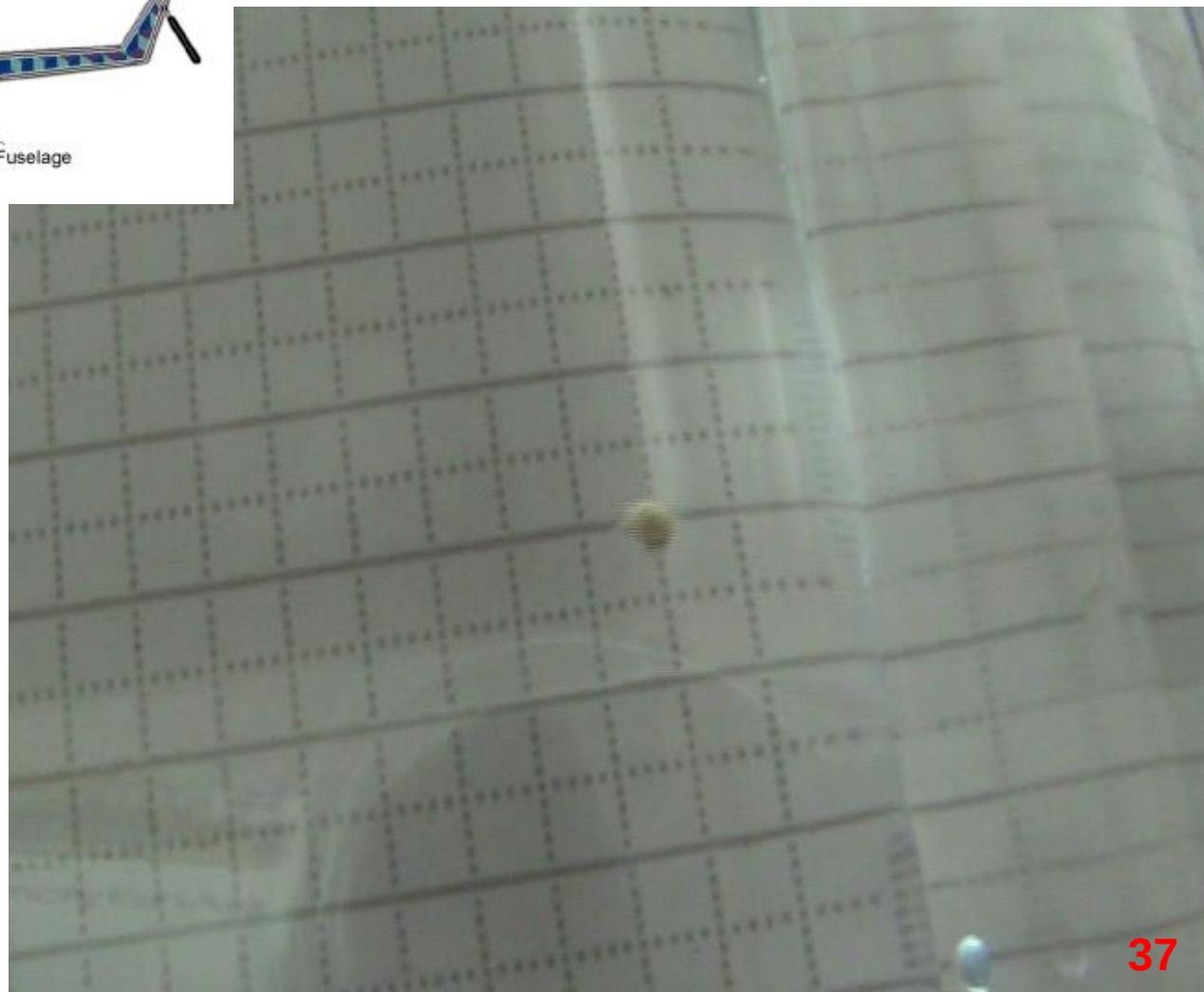
T. Braniste et al, Self-propelled aero-GaN based liquid marbles exhibiting pulsed rotation on the water surface, *Materials*, Vol. 14, no 7, 5086 (2021).

Liquid marble rotating in pulses

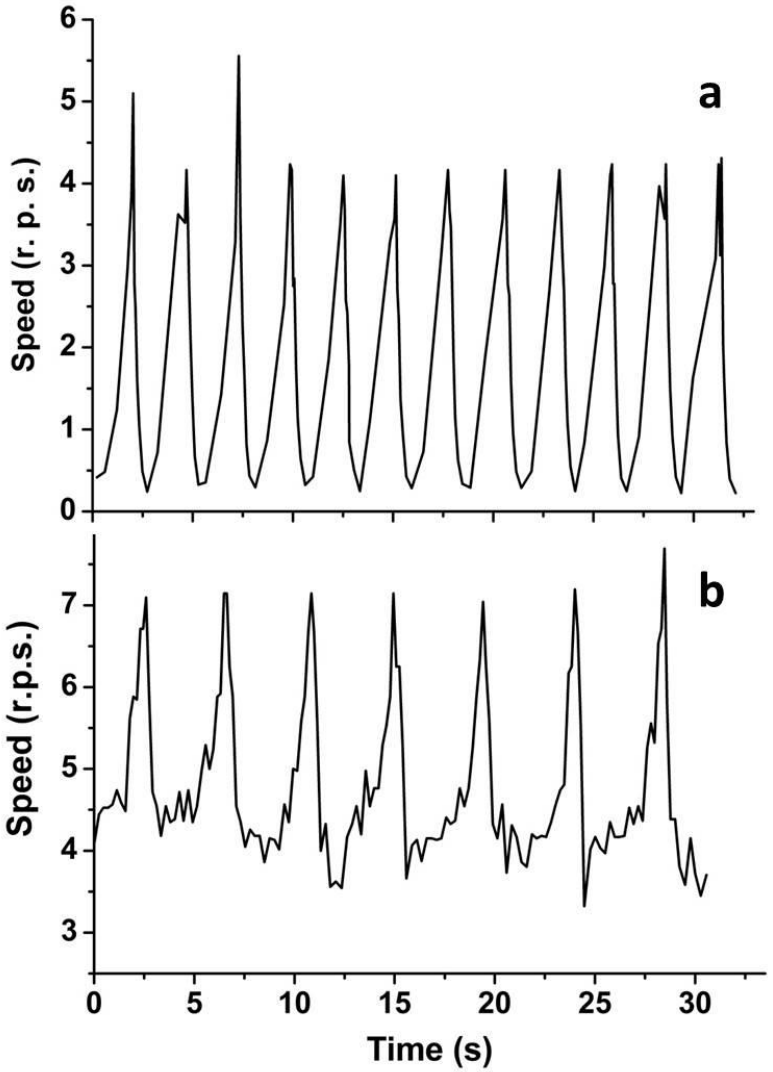
Helicopter effect

Some arms of tetrapods play the role of helicopter vanes





Time dependence of the speed of pulsed rotation for liquid marbles with different weights

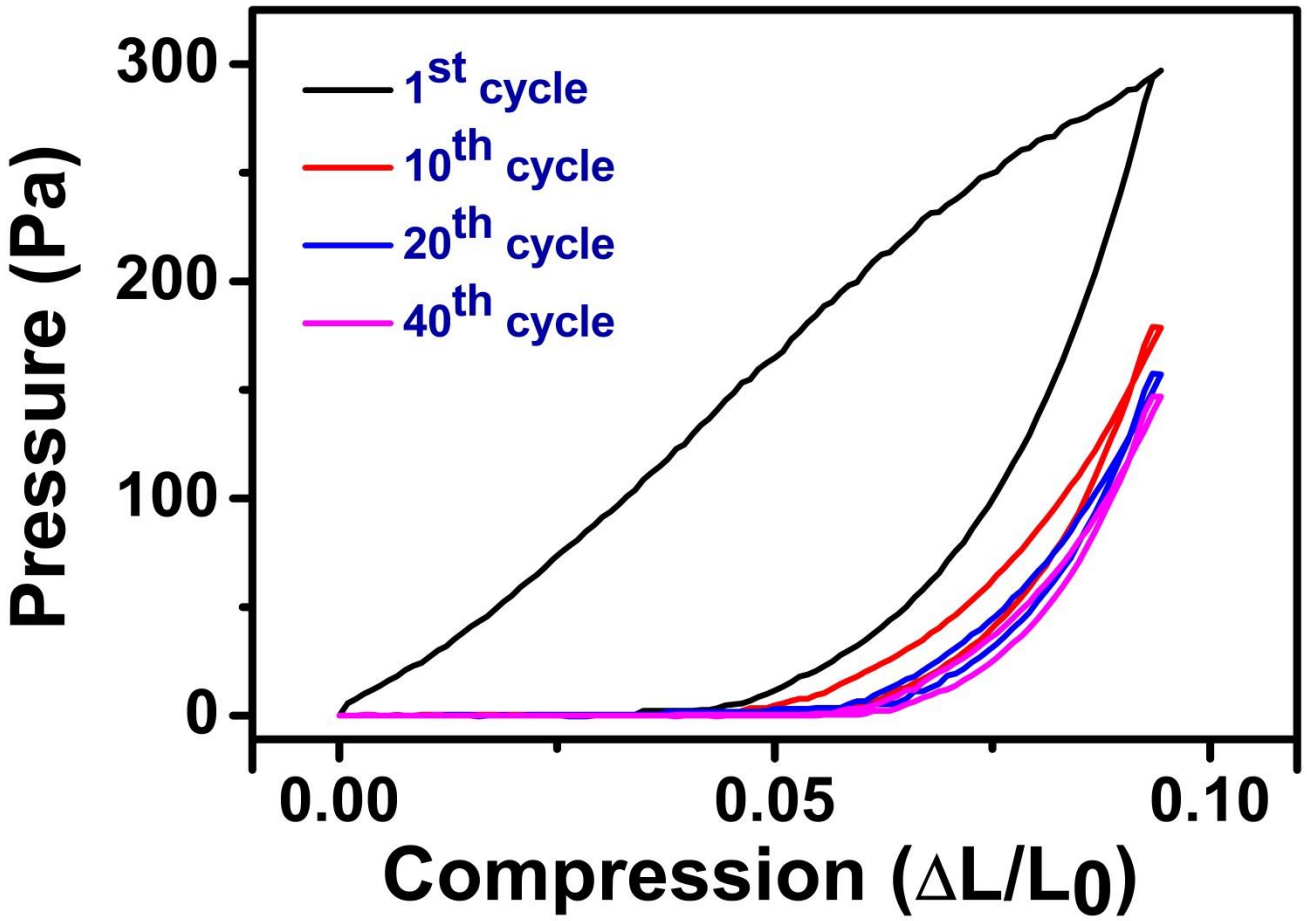


6.5 mg

14.5 mg

T. Braniste et al, Self-propelled aero-GaN based liquid marbles exhibiting pulsed rotation on the water surface, *Materials*, Vol. 14, no 7, 5086 (2021).

Elastic behavior of aerogalnite after many loading-unloading cycles



Compressive stress – strain response of the Aerogalnite architecture under cyclic loading and unloading

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

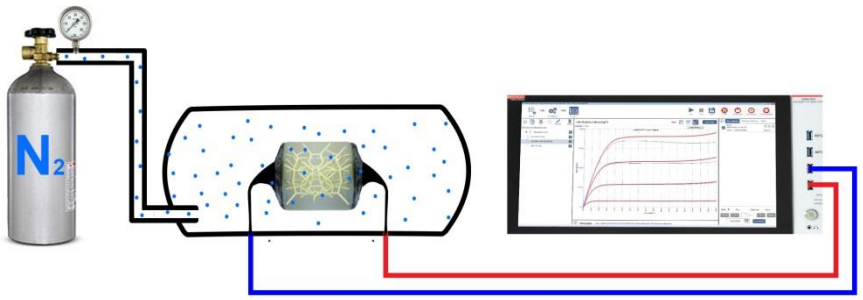
Dielectrophoretic actuation of aerogalnite

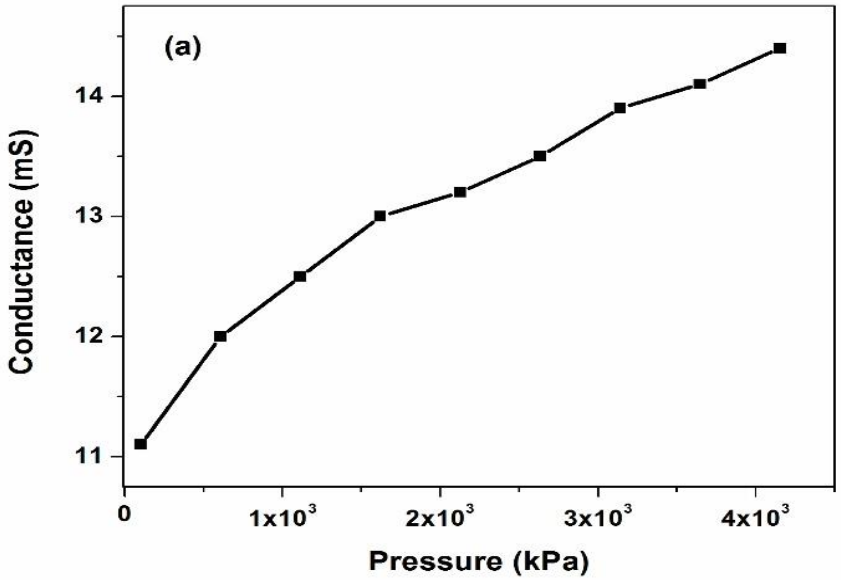
Applications of Aero-GaN

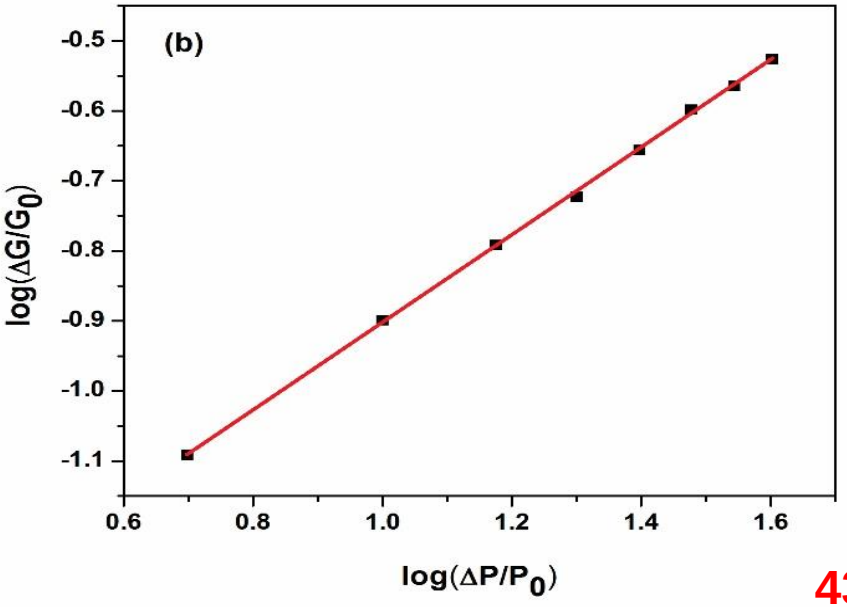
In collaboration with the Institute of Microtechnologies, Bucharest, Romania; Moscow Institute of Physics and Technology, Russia; Institute for Materials Science, Kiel University, Germany; State University of Moldova; University of Bucharest, Romania.

Pressure sensors based on Aero-GaN

Pressure sensor up to 40 atm based on Aerogalnite







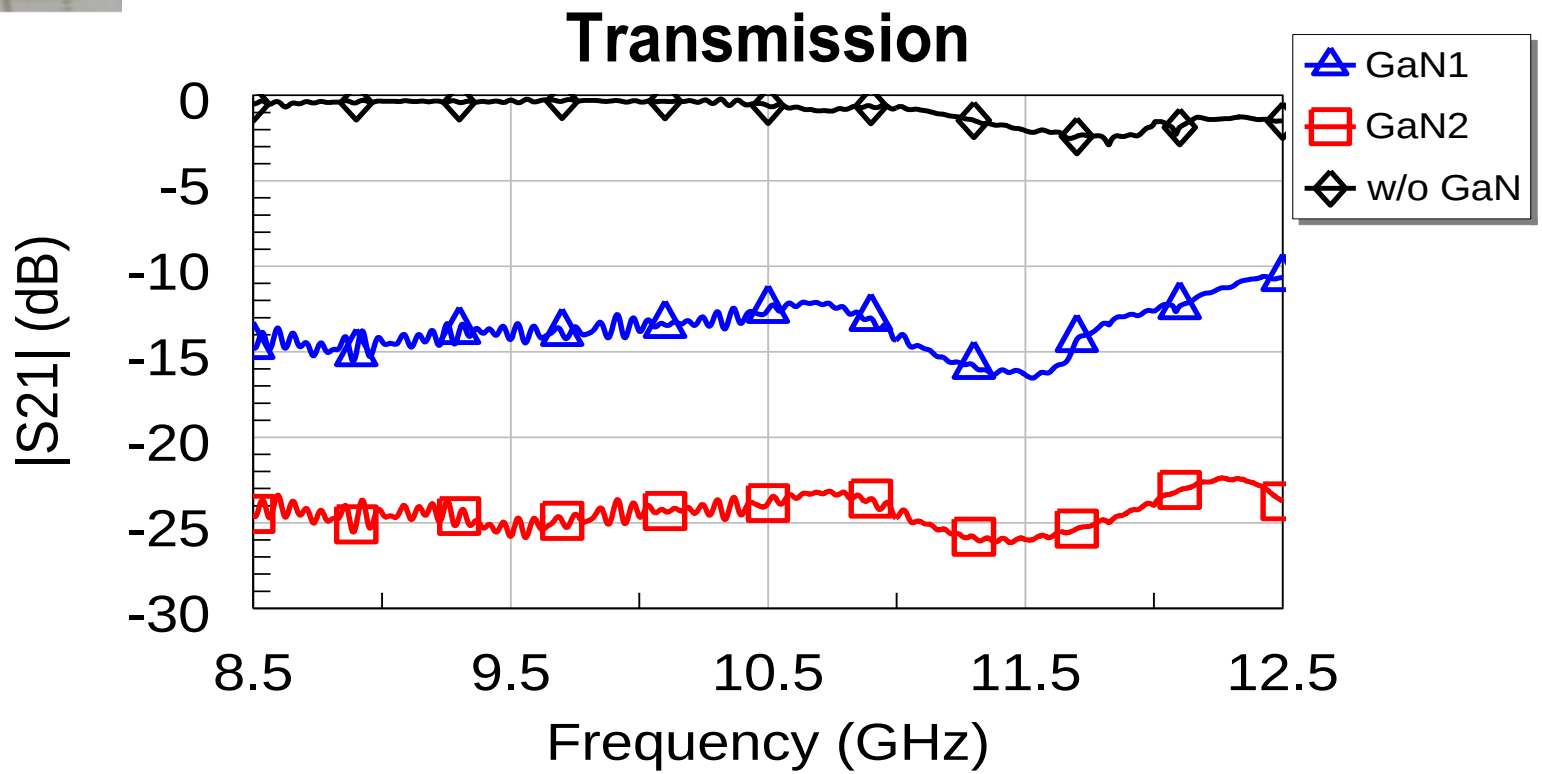
High sensitivity (16.2×10^{-3} at 5 atm and 7.4×10^{-3} at 40 atm) in conjunction with high currents of tens of milliamperes makes GaN aeromaterial feasible for exploitation in portable electrical equipment.

M. Dragoman, V. Ciobanu, S. Shree, D. Dragoman, Tudor Braniste, Simion Raevschi, Adrian Dinescu, Andrei Sarua, Yogendra K. Mishra, Nicola Pugno, Rainer Adelung, Ion Tiginyanu. Sensing up to 40 atm using pressure-sensitive aero-GaN.
***Physica Status Solidi – Rapid Research Letters*, V. 13, no 6, 1900012 (2019).**

Shielding in X-band (8-12 GHz) with Aero-GaN

Shielding in X-band with aero-GaN

X-band is important since most of radars work in this band and it is also allocated for terrestrial and space communications



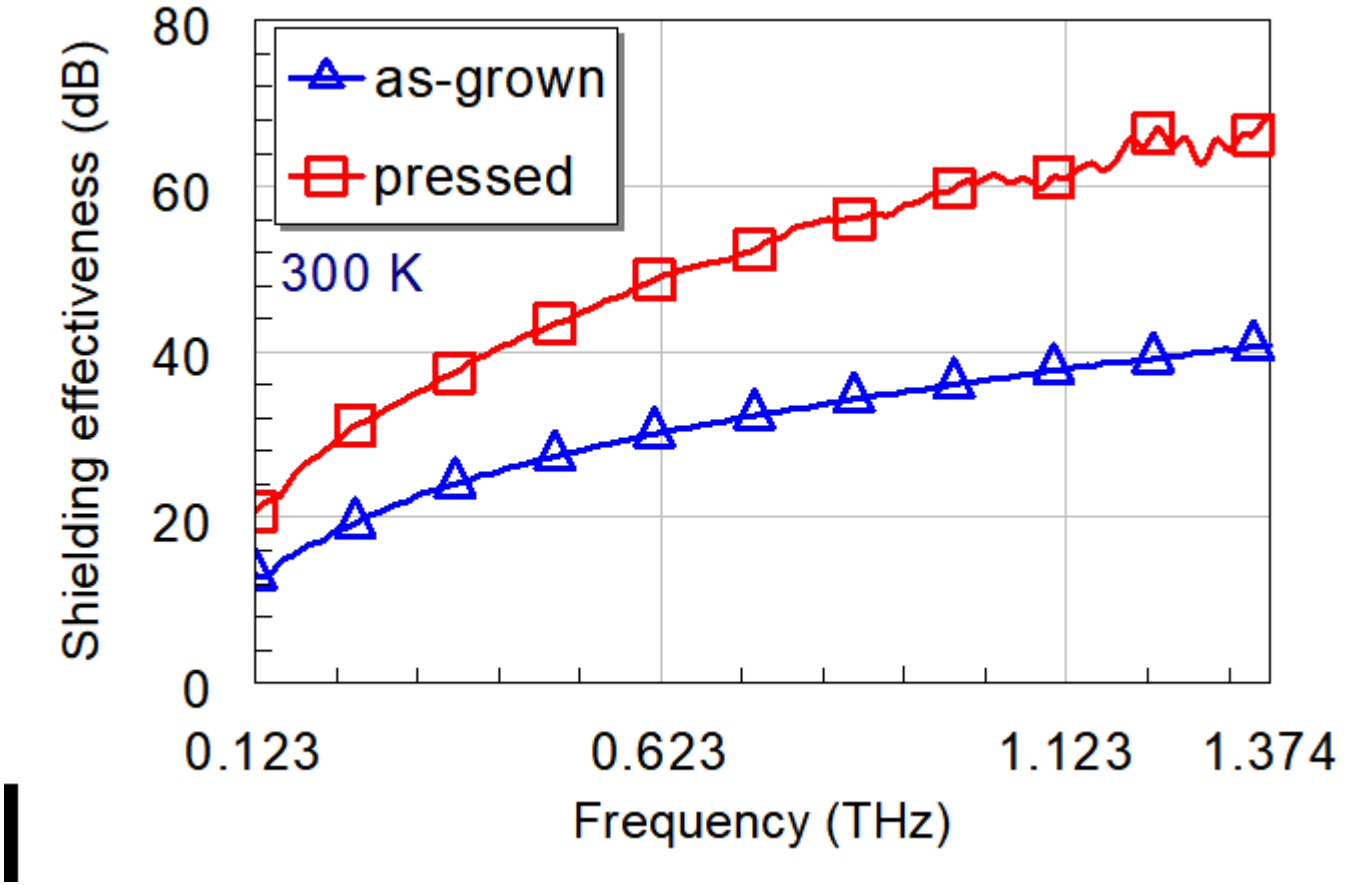
Two samples GaN1 and GaN2: Dimensions 24x12x2 mm^3, porosities 98.5 and 97 %, densities 0.089 g/cm^3 and 0.185 g/cm^3

Aero-GaN exhibits a specific shielding performance which is one order of magnitude greater than all carbon-based, metal-based and MXenes materials

M. Dragoman, T. Braniste, S. Iordanescu, M. Aldrigo, S. Raevschi, S. Shree, R. Adelung, I. Tiginyanu, Electromagnetic interference shielding in X-band with aero-GaN. Nanotechnology, Vol. 30, 34LT01 (2019).

GaN for Terahertz technology

Terahertz shielding properties of aero-GaN



Shielding effectiveness of pressed aero-GaN exceeds 40 dB in the range 0.25-1.37 THz being among the best THz shields known today. The value of 40 dB is required for industrial applications and is fulfilled in the frequency bandwidth of 1.12 THz.

Tudor Braniste , Sergey Zhukov, Mircea Dragoman, Liudmila Alyabyeva, Vladimir Ciobanu, Martino Aldrigo, Daniela Dragoman, Sergiu Iordanescu, Sindu Shree, Simion Raevschi, Rainer Adelung, Boris Gorshunov, Ion Tiginyanu. **Terahertz shielding properties of aero-GaN**, **Semiconductor Science and Technology 34, 12LT02 (2019).**

The 6th International Conference on Nanotechnologies and Biomedical Engineering

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Chisinau, Moldova, Sept. 20-23, 2023

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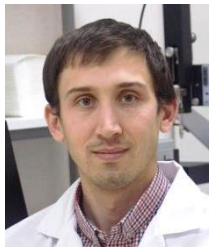
- State University of Medicine and Farmacy, Moldova
- Moldavian Society of Biomedical Engineering
- In collaboration with The International Federation for Medical and Biological Engineering
- Supported by European Commission under the Grant #810652 "NanoMedTwin"

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

PhD theses elaborated at the National Center for Materials Study and Testing

Dr. Vitalie Postolache (2019)
"Physical properties of one-and bi-dimensional semiconductor structures and composites"



Dr. Tudor Braniste (2017)
"Two- and three-dimensional nanoarchitectures based on GaN for engineering applications"

Dr. Olesea Volciuc (2011)
"Luminescence and THz wave emission from nanostructured materials based III-V semiconductor compounds"

Dr. Eduard Monaico (2009)
"Morphology and optical properties of porous stuctures on the basis of II-VI semiconductor compounds"

Dr. Alexandru Burlacu (2017)
"Luminescence and laser effects in ZnO nanostructured films and microstructures grown by chemical vapor deposition and electrochemical deposition"

Dr. Mihai Enache (2015)
"Morphology and optical properties of semiconductor and dielectric matrices based nanocomposits from InP, Al_2O_3 and TiO_2"

Dr. Lilian Sîrbu (2011)
"Fabrication and study of low-dimensional structures based on GaN"

Dr. Veaceslav Popa (2005)
"Morphology, luminescence and electrophysical properties of meso- and nanostructures based on GaN"

Conclusions

- Aerogalnite – the first artificial material with duel hydrophobic-hydrophilic properties has been developed.

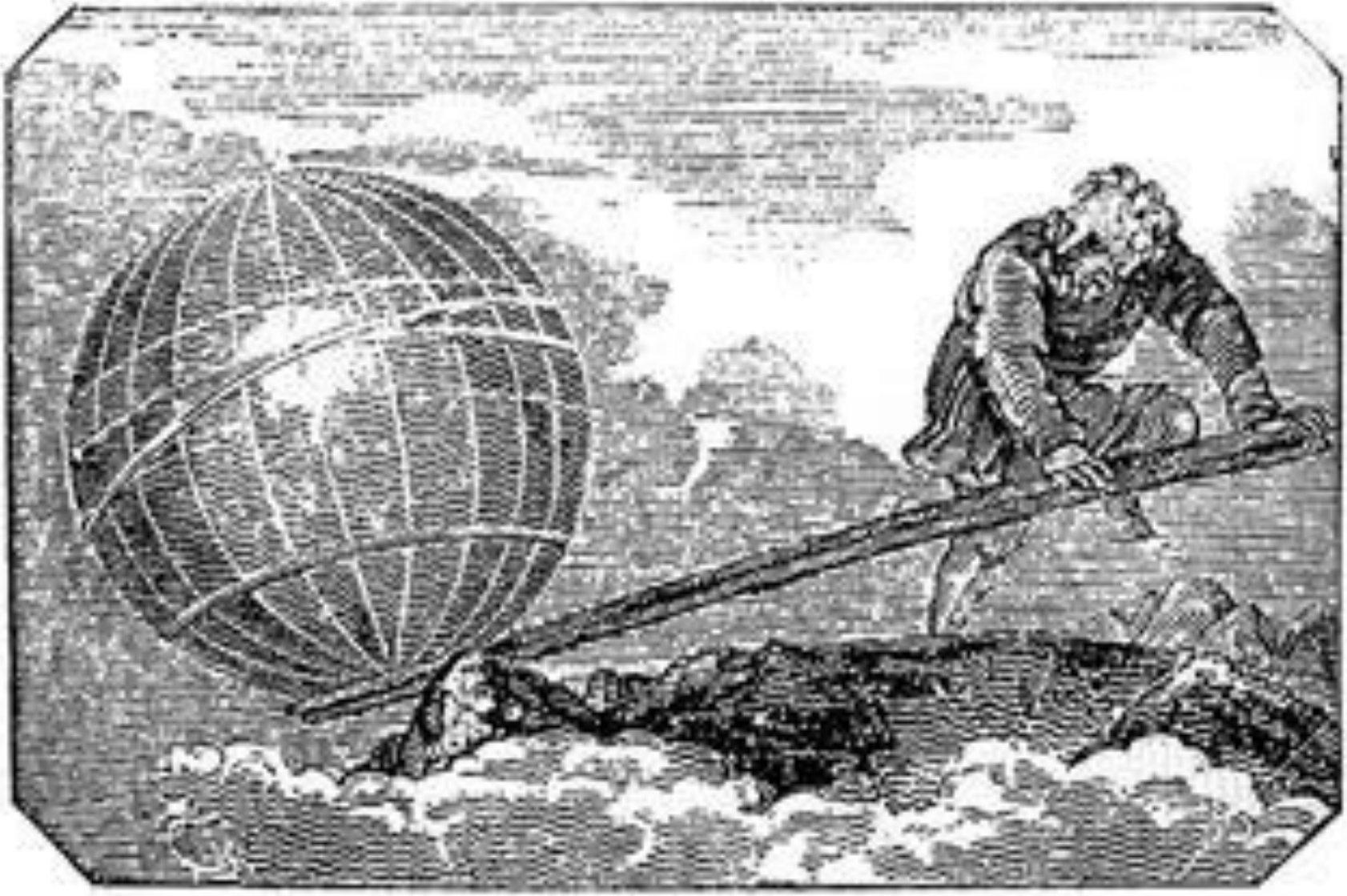
- Self-healing floating rafts with impressive cargo capabilities and super-elastic characteristics have been developed.

- Self-propelled aero-GaN based liquid marbles exhibiting rectilinear and rotational movements have been developed.

- Pulsed rotations of liquid marbles have been observed and explained on the basis of the proposed helicopter effect.

- Promising applications of aero-GaN have been identified in pressure sensors, materials shielding in X-band and THz regions, micro-bioreactors etc.

Knowledge moves the world



Thank you

for your kind attention!