Nanoscience of Soft Materials

Jon Otto Fossum

Norwegian University of Science and Technology - NTNU
Trondheim
Norway

Academic history

1217	Schola Cathedralis Nidrosiensis
1760	Royal Norwegian Society of Sciences and Letters
1910	Norwegian Institute of Technology (NTH)
1922	Norwegian Teachers' College [in Trondheim] (NLHT)
1950	SINTEF (the Foundation for Technical and Industrial Research at NTH)
1955	Norwegian Academy of Technological Sciences (NTVA) (Trondheim)
1968	University in Trondheim (UNIT)
1973	Trøndelag Music Conservatory
1974	Department of Medicine (from 1984: The Faculty of Medicine)
1979	Trondheim Academy of Fine Art
1980	Norwegian College of General Sciences (AVH) (previously NLHT)
1994	University Colleges in Sør-Trøndelag, Gjøvik and Ålesund are established
1996	Norwegian University of Science and Technology
2010	Trondheim celebrates 250 years as an academic city
2016	University Colleges in Sør-Trøndelag, Gjøvik and Ålesund merge with NTNU

GOALS AND SOCIAL MISSION

- NTNU is Norway’s largest and leading provider of engineers and graduate engineers.
- NTNU is one of the country’s two largest institutions for teacher education.
- NTNU offers professional training that gives students relevant work experience throughout their entire studies in cooperation with the business and professional community.
- NTNU has Norway’s largest educational offerings in the arts and aesthetic subjects

Overarching goals

- Highly regarded at an international level, with a number of top-level research groups.
- First-class laboratories and infrastructure.
- Attractive to the best students and employees.
- Students and employees who are proud of being associated with NTNU.

NTNU BY THE NUMBERS

Organization, budget and staff

- 14 faculties and 70 departments and divisions
- Operating income: NOK 7.6 billion.
- FTE: 6700, of which 4053 are in teaching,
  research and outreach positions (39 % female).
- Premises: 734 000 square metres either owned
  or rented.
- Close cooperation with SINTEF, St. Olavs Hospital and NTNU Social Research AS

Organization

(2014 and 2015)

- **101** organizational groups ("boxes") at levels 1–3
- **6 733** FTE in total
- Operating income of NOK **7.6 billion**
- **734 000 m^2** of owned and rented buildings
- **4 053** FTE in teaching, research and outreach positions (39 % female)

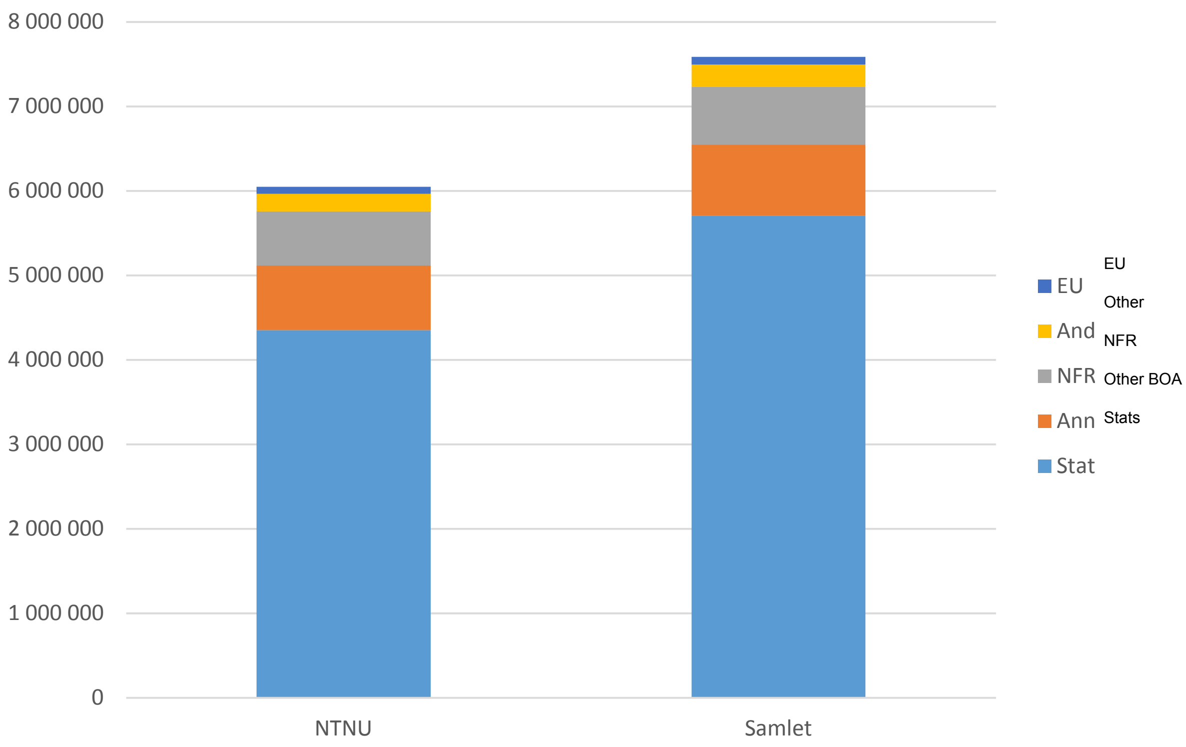
Studies

- 33 000 students in Trondheim, 3 500 students in Gjøvik and 2500 students in Ålesund (round numbers).
- 6553 graduated with a completed degree in 2014.
- 6000 participants in continuing education courses with credit in 2014.
- 3000 international students.
- 340 doctoral degrees awarded in 2015.

Research and industry partnerships

- PhDs: 340 doctoral degrees awarded in 2015.
- Approximately 120 laboratories.
- Norway's largest participant in the EU's Horizon 2020 (H2020).
  Participant in 38 projects, of which 2 are ERC projects and 10 for which
  the university is coordinator.
- Four strategic research areas from 2014–2023.
- University Library with 17 library branches, 2 million printed books,
  950 000 e-books, 16 000 electronic journal subscriptions, 3 000 printed
  journal subscriptions and 450 databases. More than 3 million downloads

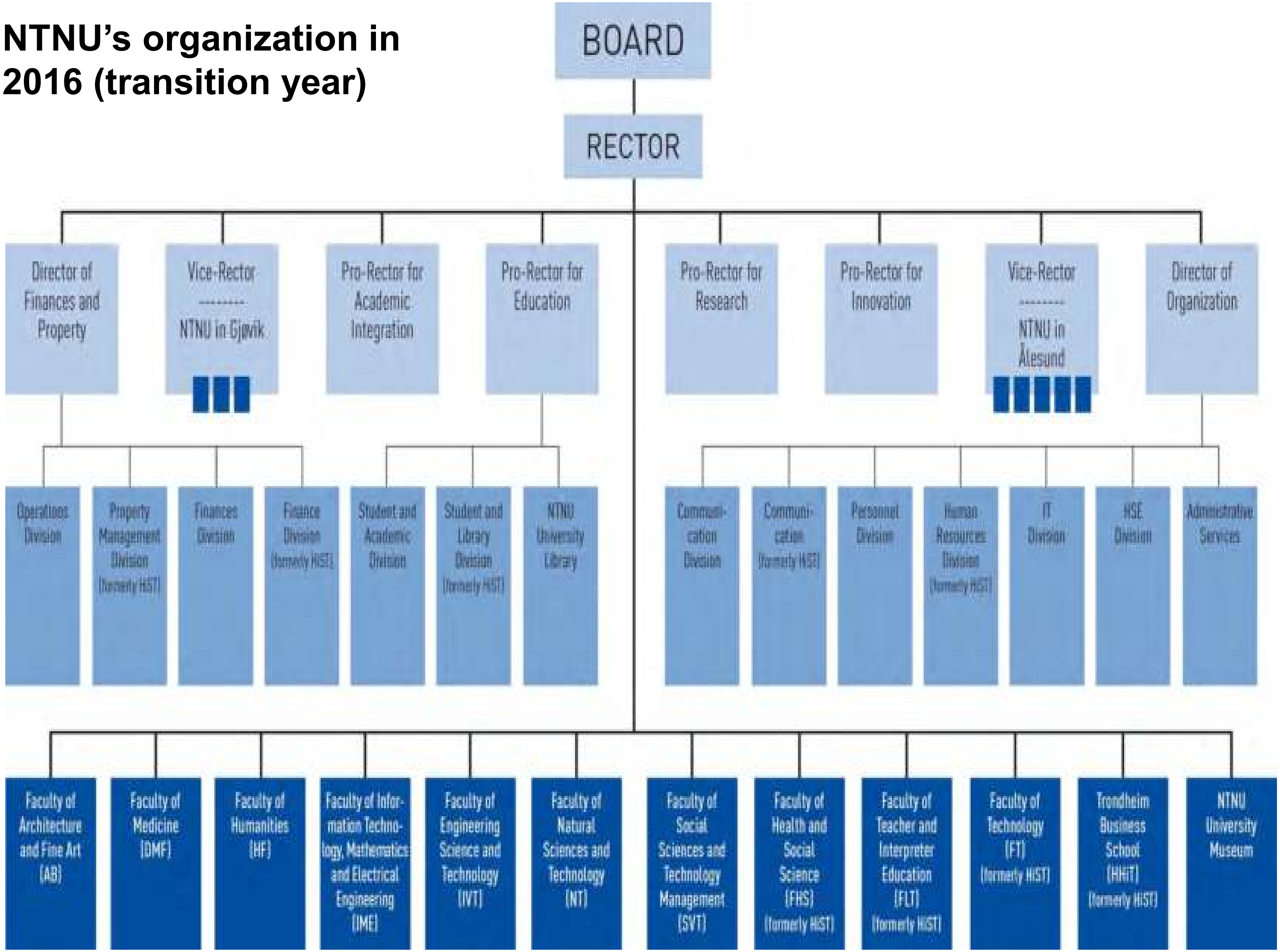
Finances (2014)



NTNU and the three former university colleges had combined operating revenues in 2014 of NOK **7.6 billion.**

ORGANIZATION

NTNU’s organization in 2016 (transition year)



RESEARCH

- Four strategic research areas (TSO)
- Four Norwegian Centres of Excellence (SFF)
- Host institution for seven and partner in eight Centres for Research-based Innovation (SFI)
- Host institution for two and partner in five Research Centres for Environment-Friendly Energy (FME)
- Approximately 120 laboratories
- Other large research programmes (NanoLab, HUNT)

STRATEGIC RESEARCH AREAS 2014–2023

NTNU
Norwegian University of Science and Technology

ENERGY

HEALTH

OCEANS

SUSTAINABILITY

2014 Nobel Prize

NTNU professors May-Britt Moser and Edvard Moser were awarded the 2014 Nobel Prize in Physiology or Medicine for their discovery of cells that constitute an “inner GPS” in the brain.

EDUCATION

An international university

- Main themes: Europe, China, international mobility, international researcher education.
- Approximately 350 international MoUs for cooperative research and teaching efforts.
- 11 % of NTNU's students are international students.
- 41 % of NTNU's graduated PhDs are international students (2012)
- Students and employees from more than 90 countries.

Education quality

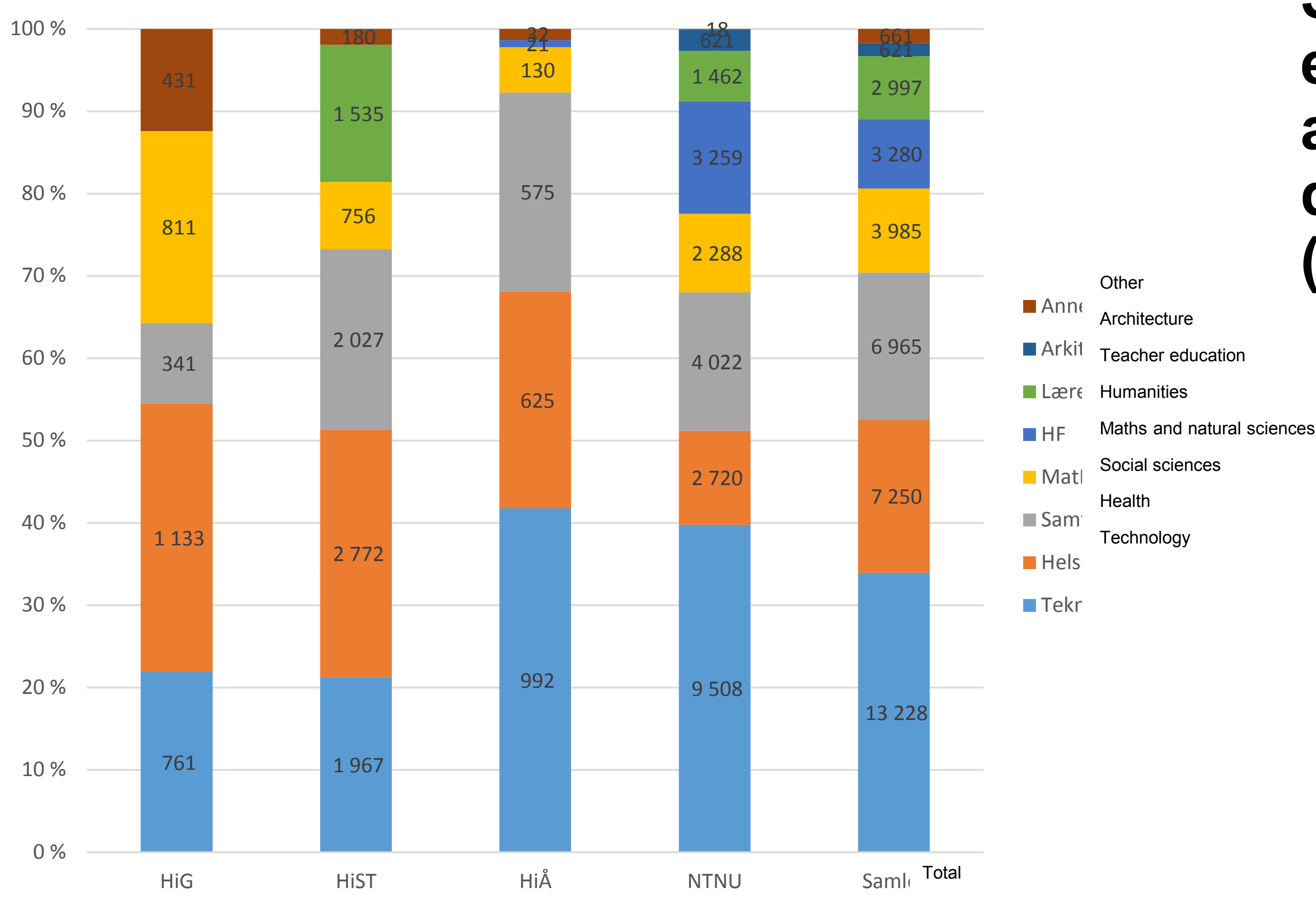
NTNU's Live Studio project at the Faculty of Architecture and Fine Art received an award presented by the Ministry of Education and Research for quality of education in 2015. Together with SINTEF, NTNU students designed and built a bold structure in timber. This is a cantilevered pier projecting 12 metres out over the Nidelva river.

Music

The Trondheim Soloists are among the world's foremost chamber ensembles. Several of the musicians are students or alumni from NTNU.

The Trondheim Soloists tour the world, have six Grammy nominations, and trust NTNU to educate the soloists of tomorrow.

Student enrolment according to discipline (2015)



NTNU and the three former university colleges have **734 000 m²** of their own and rented premises.

INNOVATION

NTNU has taken responsibility for innovation for more than 100 years. Innovation includes entrepreneurship and commercialization. Our innovation processes grow from education, research and artistic activities. Working together with other players, NTNU paves the way for more start-ups and development in existing firms.

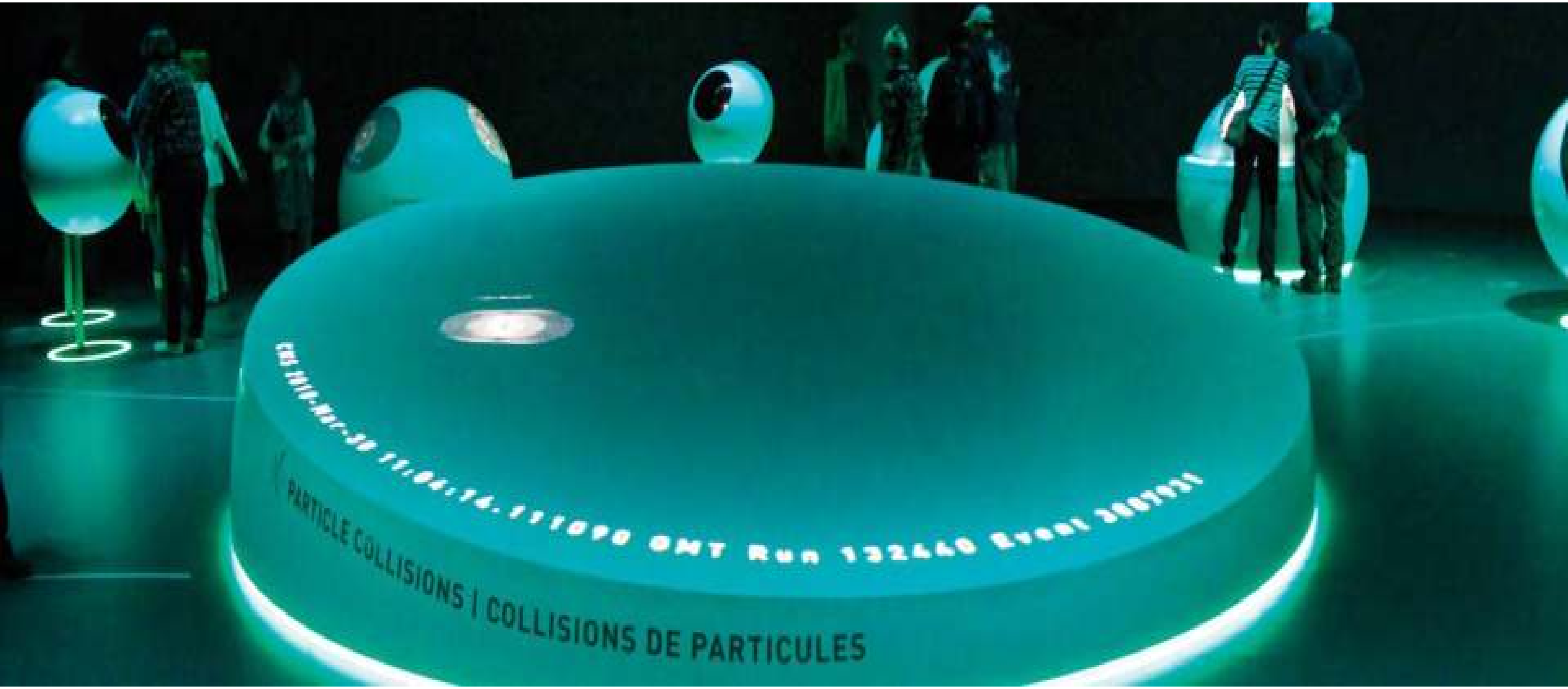
Students are our most important renewable resource. That's why student innovation is a high priority at NTNU.

Ultrasound

Together with GE Vingmed, NTNU developed Vscan, a pocket-sized ultrasound device. The medical imaging tool was one of TIME magazine's picks for the best inventions of the year. The device helps doctors make the correct diagnosis faster – and thus saves lives.

Nuclear physics

From 2014, NTNU has been a Business Incubation Centre for CERN technologies. This enables technology transfer from CERN, the European Organization for Nuclear Research, to NTNU for commercial development.

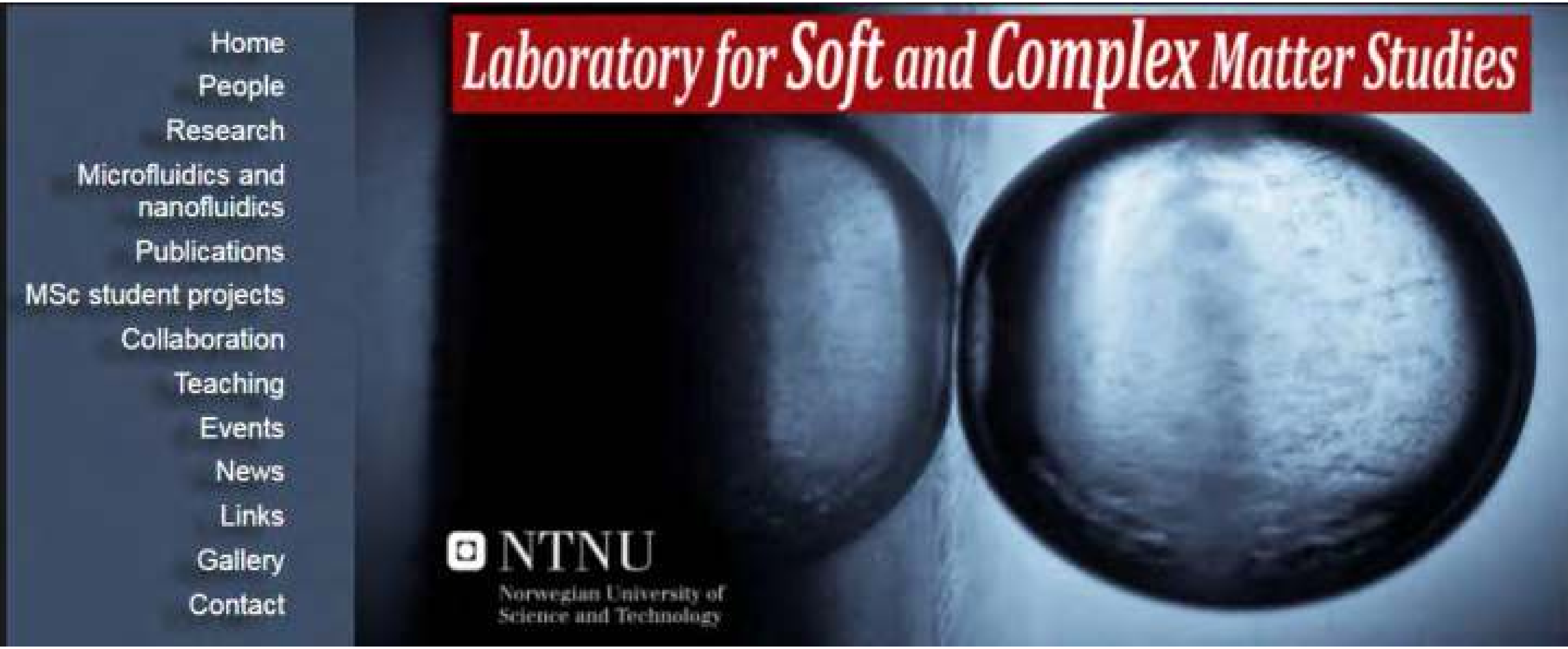


Information security

NISlab, the information security group at NTNU in Gjøvik, conducts research on methods for authentication and verification of users. Raghavendra Ramachandra is working on ways to improve face recognition to prevent forgery.

Maritime innovation

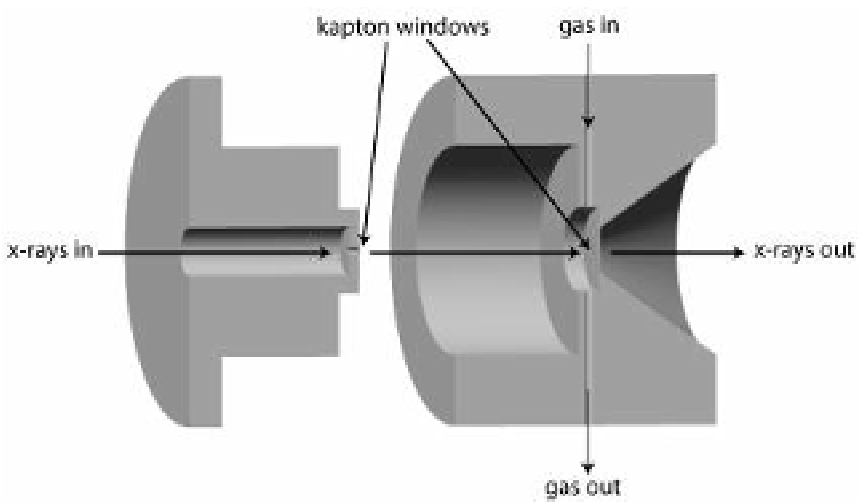
NTNU in Ålesund works in close partnership with the maritime sector in areas including product development and innovation. The maritime cluster in Norway's Møre region is in the global forefront in maritime technology and operations.



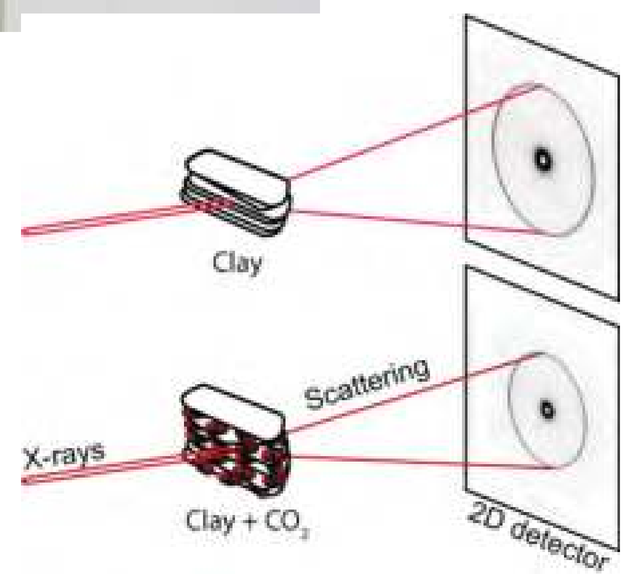
http://folk.ntnu.no/fossumj/lab

Our research is focused on probing and understanding how nano-/meso-/micro-structures in complex composites of natural materials manifest themselves in macroscopic material properties and functionalities.

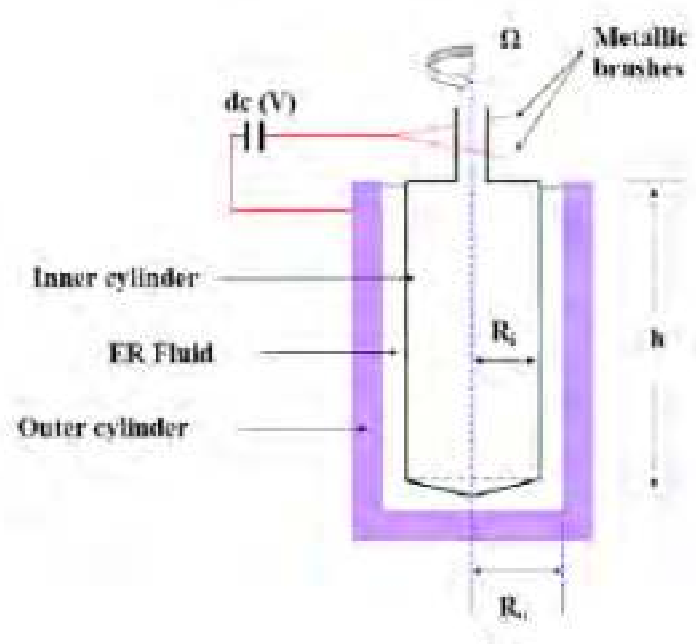
Nano-scale tools:
AFM, Small-Angle X-ray Scattering: SAXS, etc.



Home made sample cell



Macro-scale tools:
Physica MCR 300 Rheometer, etc.

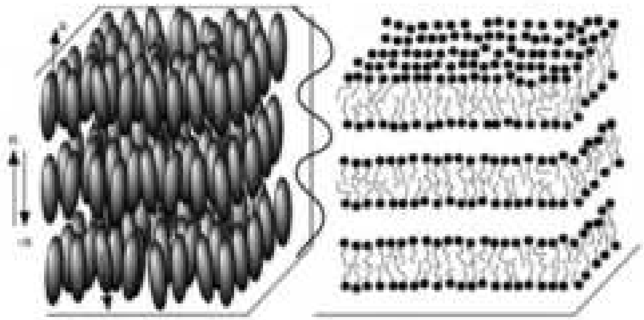


Soft condensed matter:

Materials which are easily deformable by external stresses, electric or magnetic fields, or even by thermal fluctuations.

Soft materials are typically shear-thinning, i.e. they possess a threshold yield stress below which thay are elastic materials, and above which they are viscous fluids (Viscoelasticity).

These materials typically possess structures which are molecular scales; the structure and dynamics at nano-/me physical properties of these materials.



The goal of soft matter research is to probe and understand how nano-/meso-structures translate into macroscopic properties and behaviors.

Researchers study natural, synthetic and biological materials in this context.

Interests extend from fundamental physics to technological applications, from basic materials questions to specific biological problems = Multidisciplinary field.

The tools used include light, X-ray, Neutron scattering, microscopy, rheometry, microfluidics, special purpose table-top experiments, numerics, theory.

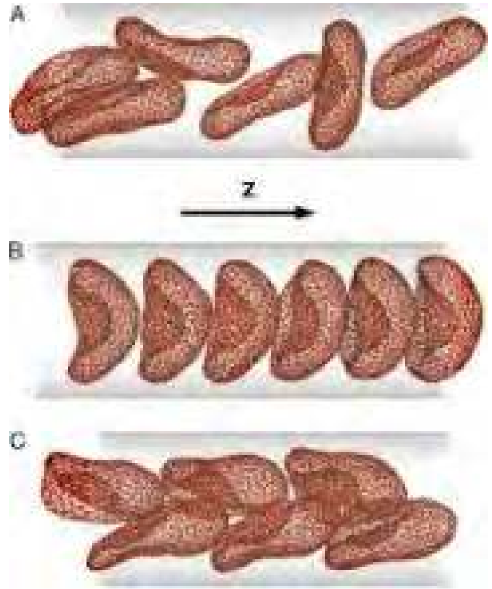
The founder of soft matter science:

Pierre-Gilles de Gennes

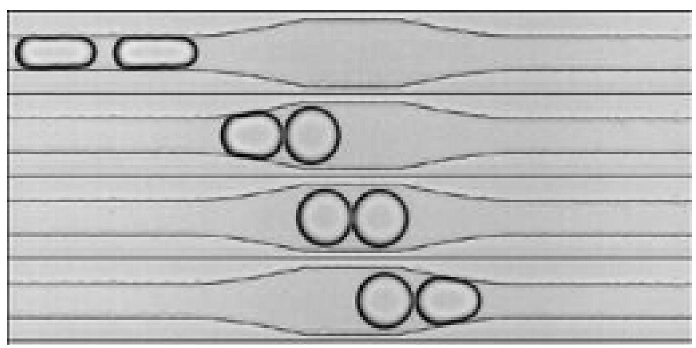
French physicist : 1932 –2007,
Nobel Prize laureate in physics in 1991

Food is Soft Matter

Biomatter is Soft Matter



Cell elasticity and deformation in flow



Colloidosome deformation in microfluidic flow

Unprotected drop coalesence in microfluidic flow

Current trends in Soft Matter Science:

Major examples:

Active Matter and links/analogies to biology:

Active nano-/meso-structures (Bacteria, rotating colloidal particles, activated drops, etc). Biomimicry: Learn from bionature, apply in materials science.

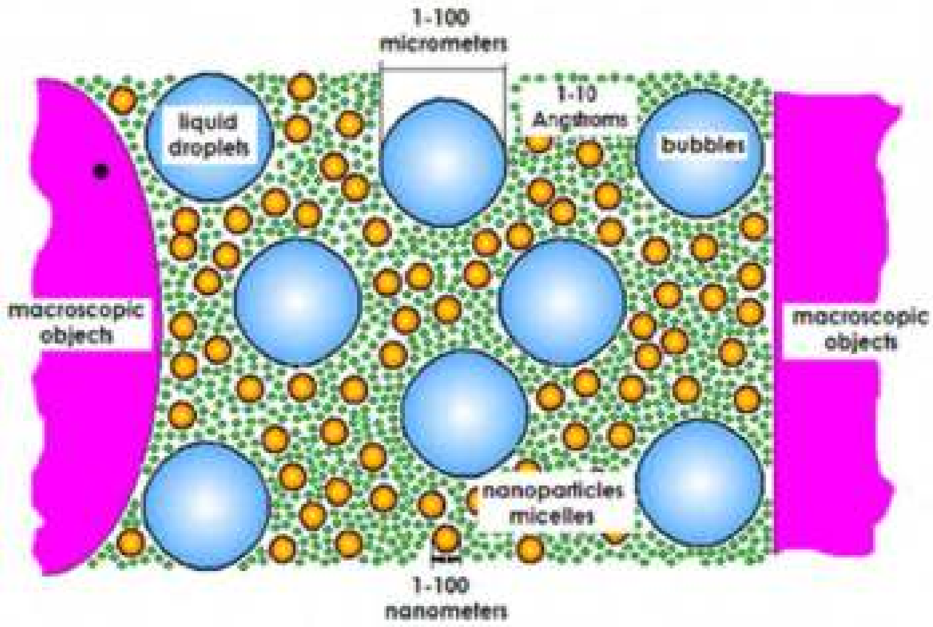
Self-assembly, including Janus and «patchy» particles:

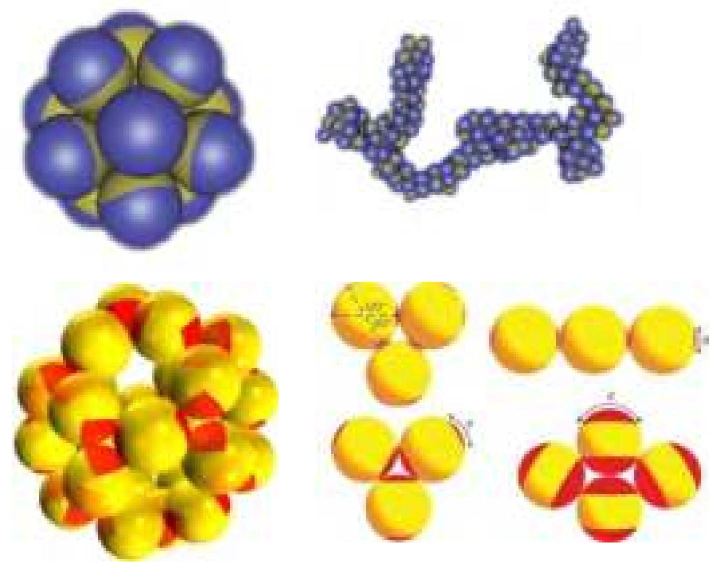
Guided interactions on nano-/meso-scale («Colloids with valence»).

Soft Matter in Confined Environments:

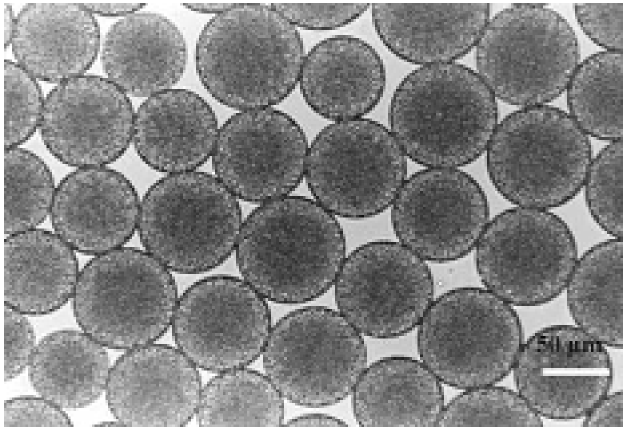
Soft and/or active matter inside porous structures. Microfluidics. Drops.

Etc.





Monodisperse emulsions



18 materialstoday APRIL 2008 | VOLUME 11 | NUM

Designer emulsions using microfluidics

We describe new developments for the controlled fabrication of monodisperse emulsions using microfluidics. We use glass capillary devices to generate single, double, and higher order emulsions with exceptional precision. These emulsions can serve as ideal templates for generating well-defined particles and functional vesicles. Polydimethylsiloxane microfluidic devices are also used to generate picoliter-scale water-in-oil emulsions at rates as high as 10 000 drops per second. These emulsions have great potential as individual microvessels in high-throughput screening applications, where each drop serves to encapsulate single cells, genes, or reactants.

Rhutesh K. Shah[a], Ho Cheung Shum[a], Amy C. Rowat[a], Daeyeon Lee[a], Jeremy J. Agresti[a], Andrew S. Utada[a], Liang-Yin Chu[a,b], Jin-Woong Kim[a,c], Alberto Fernandez-Nieves[a,d], Carlos J. Martinez[a,e], and David A. Weitz[a,f]*

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Monodisperse emulsions

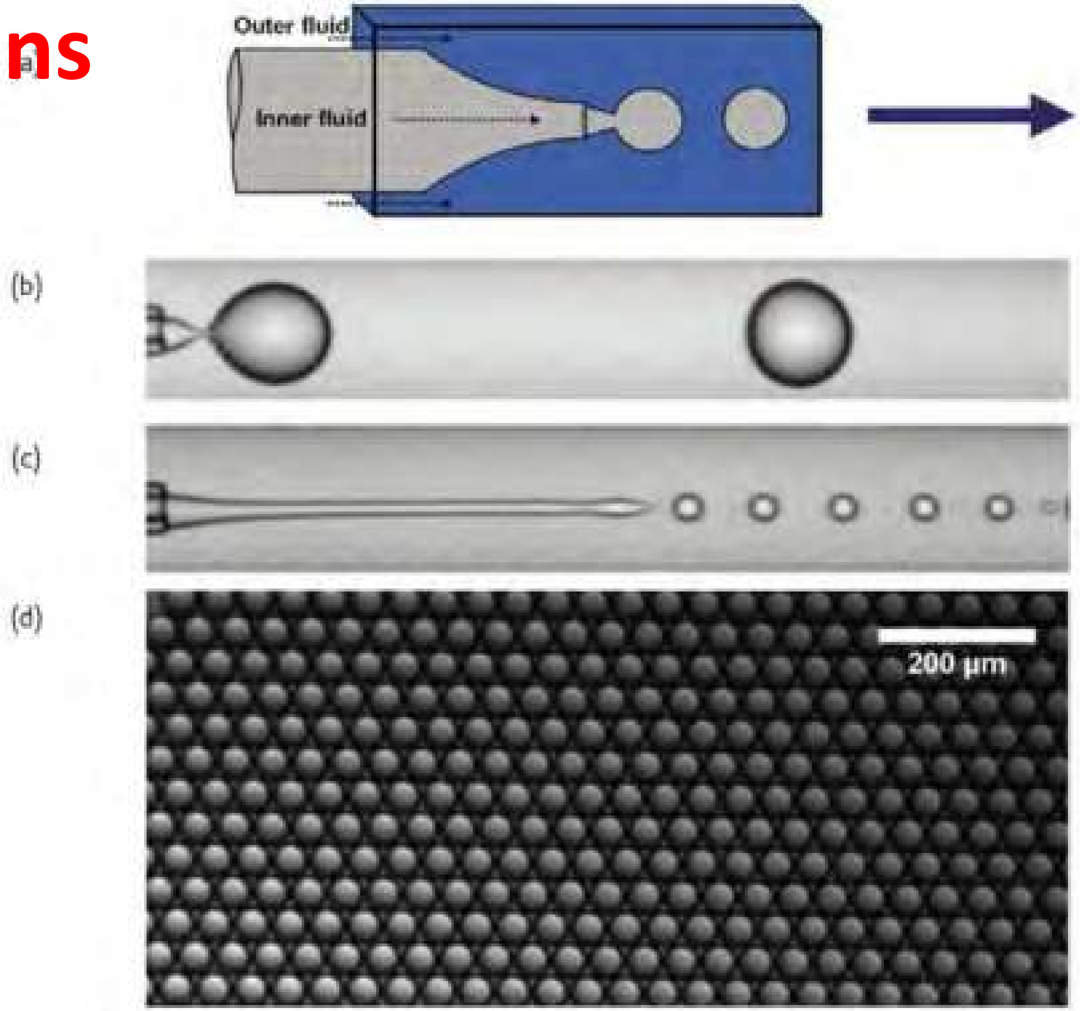
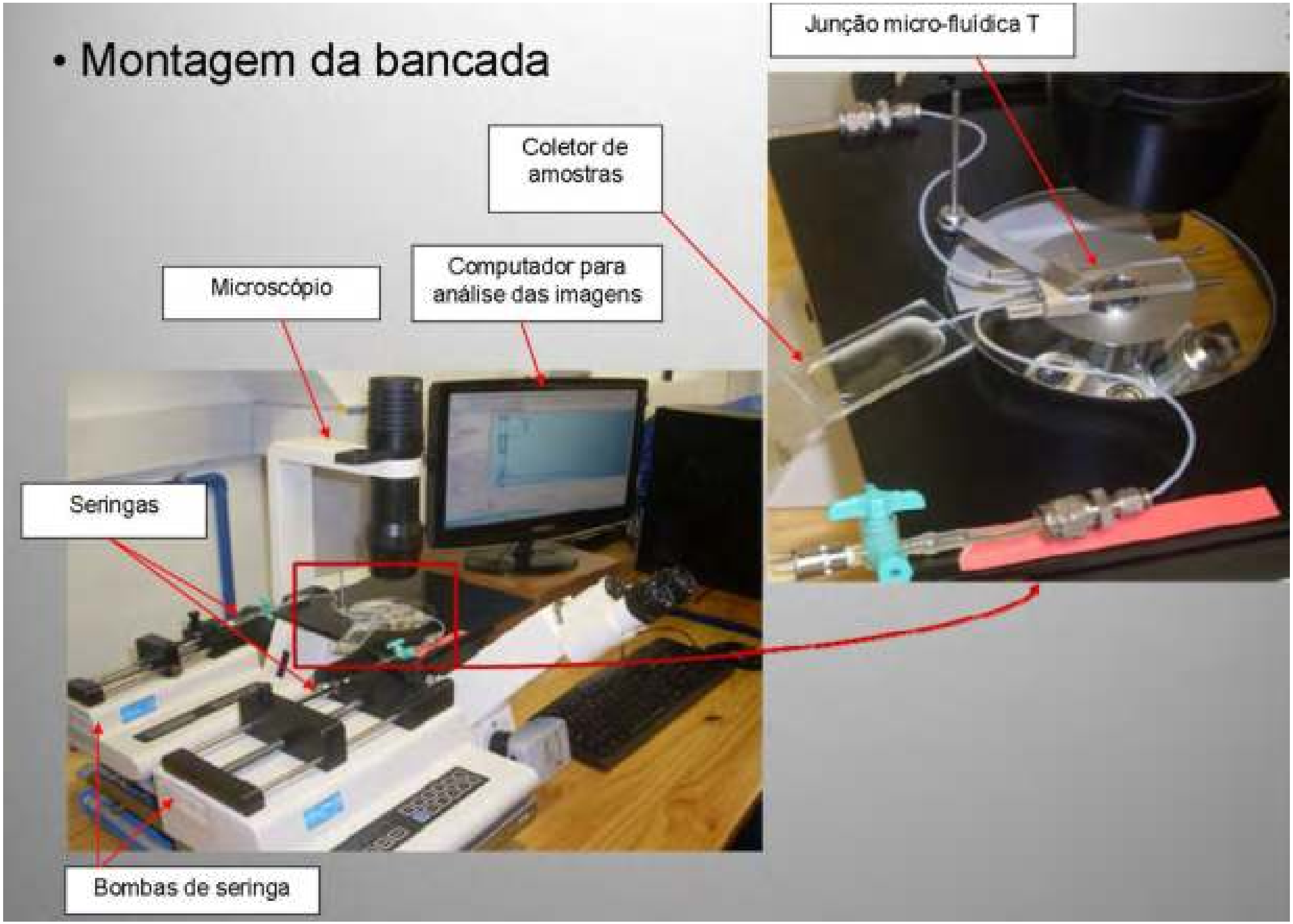


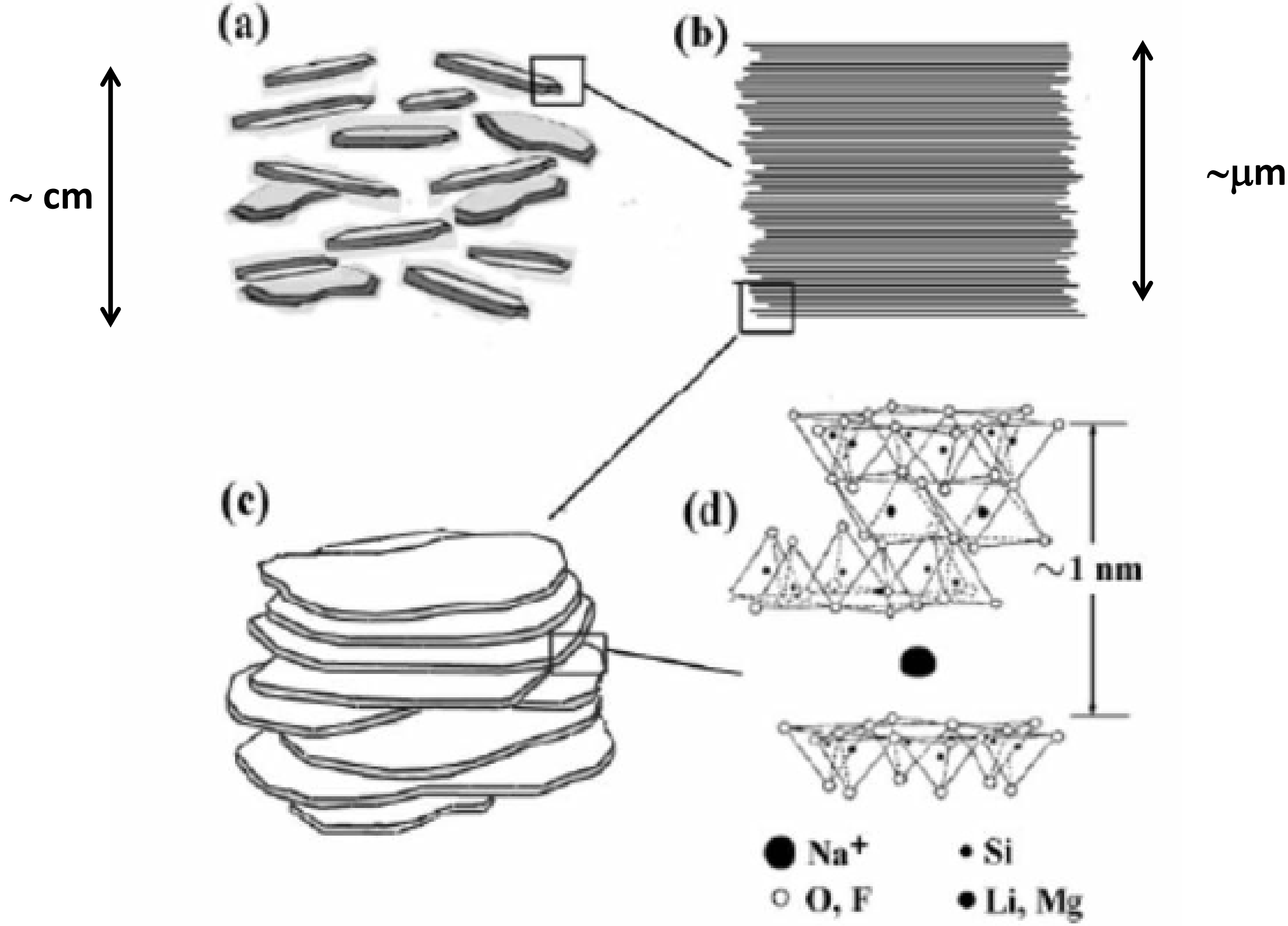
Fig. 2 Single emulsions in a co-flow microfluidic device. (a) Schematic of a co-flow microcapillary device for making droplets. Arrows indicate the flow direction of fluids and drops. (b) Image of drop formation at low flow rates (dripping regime). (c) Image of a narrowing jet generated by increasing the flow rate of the continuous fluid above a threshold value while keeping the flow rate of the dispersed phase constant. (d) Monodisperse droplets formed using a microcapillary device. [Part (a) reproduced with permission from[26]. © 2007 Materials Research Society; parts (b) and (c) reprinted with permission from[27]. © 2007 American Physical Society.]

Table-top experiment:




Soft (rheology),
sticky (adhesion),
slippery (friction)
Health and
well-being
MUD
is Soft Matter
Soft matter =
Liquid + Solid
Complex materials
buildt from 2 or more
components
Soft in processing,
can be hard in use

The nano-/meso- structures behind clayey muddy behaviour



Some modern applications based on clay nano-/meso-structures:

From design to function.

Oil recovery

Oil refining

Medicine/pharmacy

Toothpaste

Paints

Cosmetics

Household products

Rubber strengther

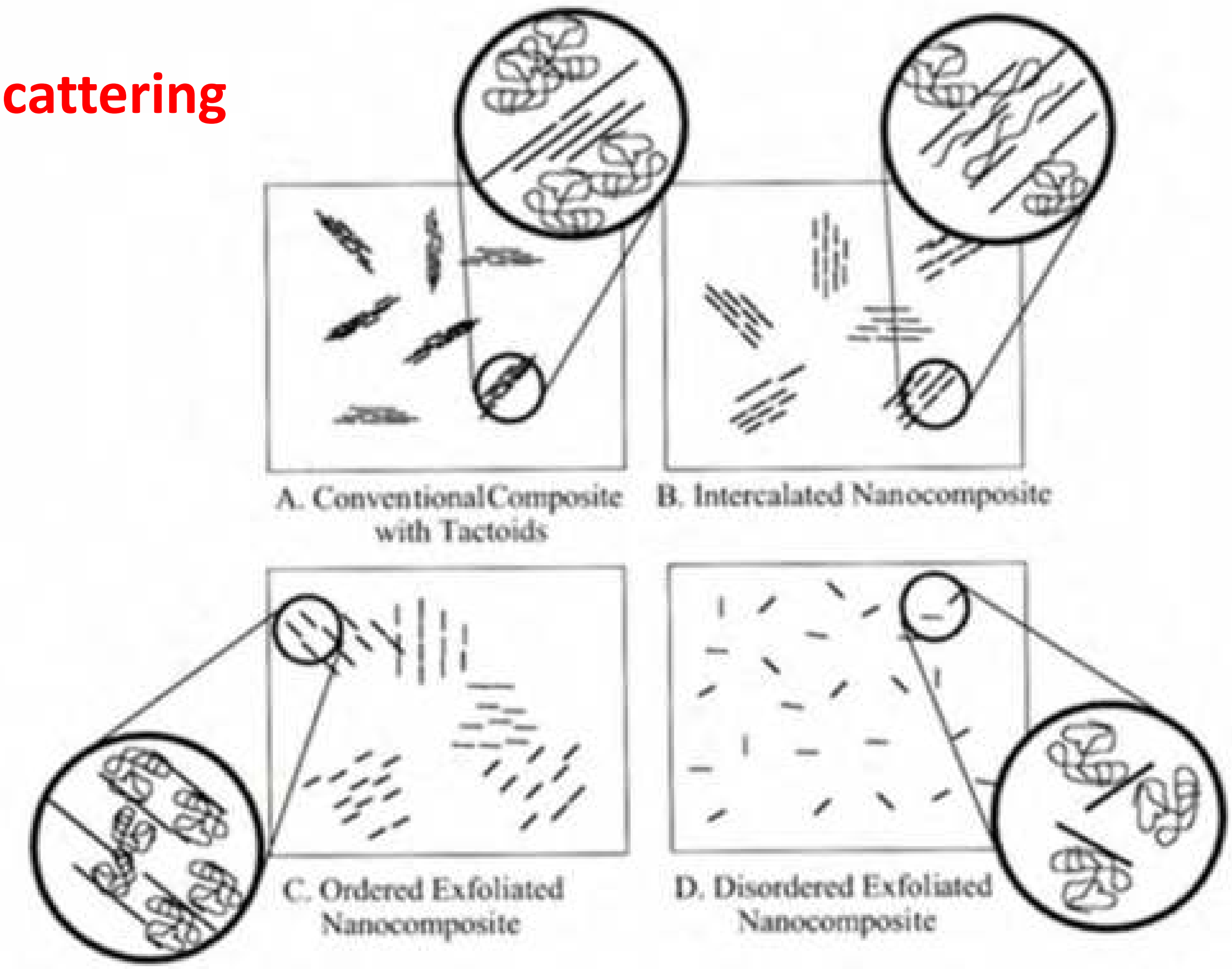
Plastics

Chocolate

Polymer-nano-composite materials

Nano-structures

Tools:
(Synchrotron) X-ray scattering
Neutron scattering

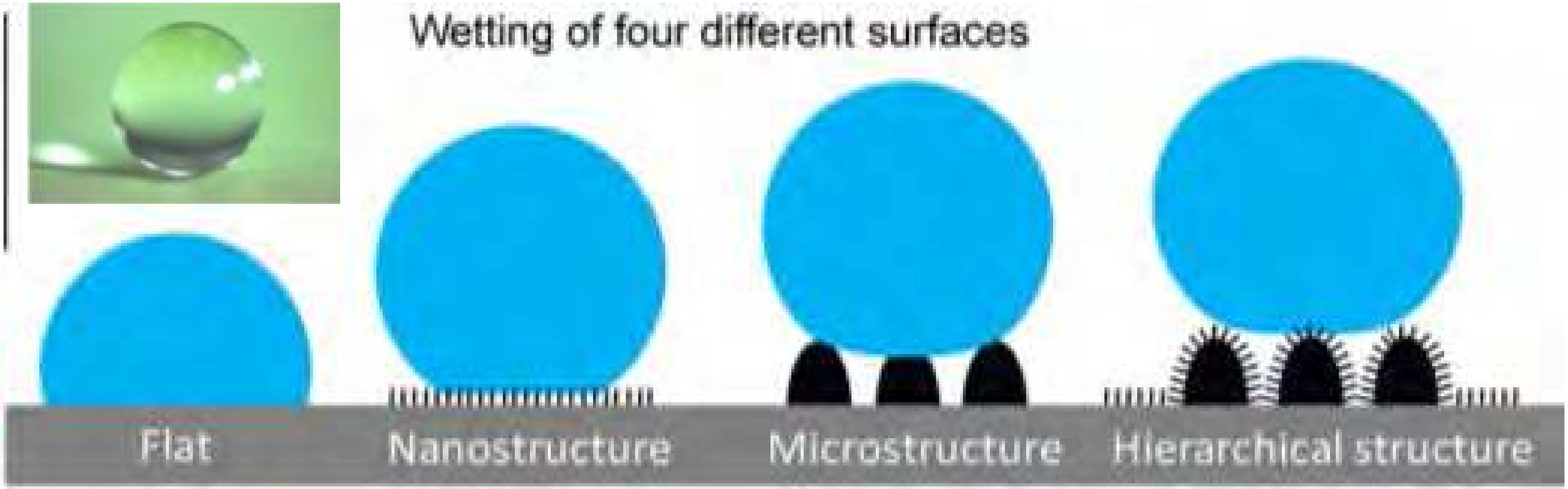


Running projects in the lab:

2016-2020: Research Council of Norway (RCN) NANO2021 project number 250619 "*Graphene Nano-Clay Systems*" is an RCN grant of 6 MNOK in total. 1 postdoc based at NTNU is employed in this project. Project manager is Prof. J.O. Fossum from Dept. of Physics NTNU.
The collaboration partners in this project are from NTNU, IFE-Kjeller, Univ. Oslo, Univ. Manchester (UK), and from Chalmers Univ. of Technology (Sweden). The Univ. Manchester group is in the Physics Dept. and is led by Prof. Sir Konstantin Novoselov who received the Nobel Prize in Physics 2010 for his work on graphene. The Chalmers Univ. Tech. group is led by Prof. Aldo Jesorka in the Dept. of Chemistry and Chemical Engineering.

2016-2020: RCN FRINATEK project number 250728 "*CO_2 Capture and Retention by Smectite Clays*" is an RCN grant of 9 MNOK in total. 1 researcher based at IFE-Kjeller, and 1 PhD student based at NTNU is employed in this project. Project manager is Senior Scientist K.D. Knudsen, IFE, who is also Adj. Prof. at Dept. of Physics NTNU. The collaboration partners are from IFE-Kjeller, NTNU, Univ. Copenhagen - Niels Bohr Institute Denmark, and from Univ. South Florida USA (Prof. Juergen Eckert).

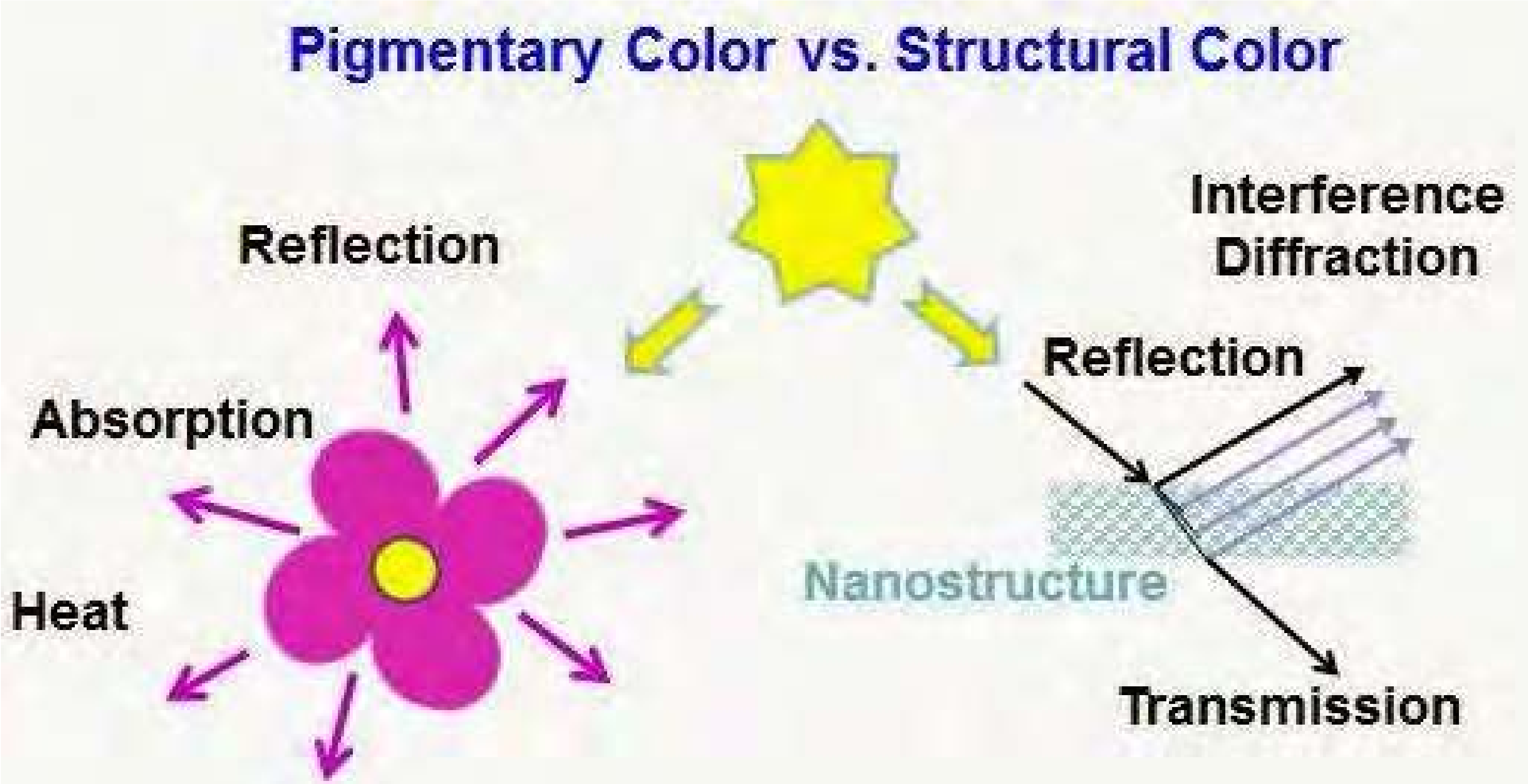
2017-2020: M-Era.Net (administrated by RCN NANO2021) project number 272919 "*Fabricating cellulose nanocomposites for structural coloration*" is a grant of 7 MNOK in total. 2 postdocs based at NTNU and 2 postdocs based in Lisboa are employed in this project. Project manager is Prof. J.O. Fossum from Dept. of Physics NTNU. The collaboration partners in this project are from NTNU, IFE-Kjeller, Giamag Technologies (magnetic technology), Borregaard AS (nanocellulose technology), Snøhetta AS (architecture and design), NOVA Universidade Lisboa Portugal (Materials science, Prof. Maria Helena Godinho), and from Instituto Superior Técnico for Research and Development in Lisboa Portugal (Physics, Prof. Carlos Manuel dos Santos Rodrigues da Cruz).

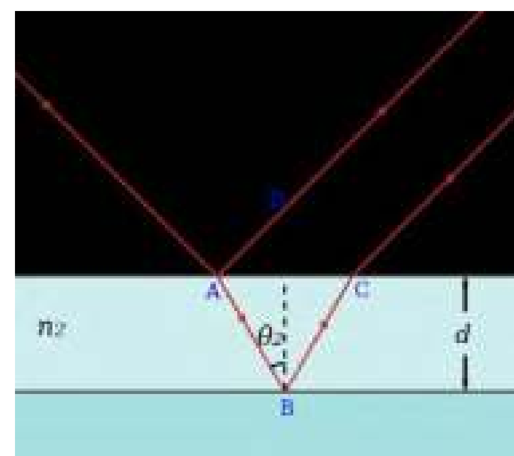


Schematics of wetting of four different surfaces. The largest contact area between the droplet and the surface is given in flat and micro-structured surfaces, is reduced in nano-structured surfaces, and is minimized in hierarchical (nano-micro) structured surfaces. This contains the principle of the so-called self-cleaning Lotus leaf effect, depicted to the left.

Natural and biomimetic artificial surfaces for super-hydrophobicity, self-cleaning, low adhesion, and drag reduction, B. Bhushan, Y. C. Jung, Progress in Materials Science 56, 1-108 (2011)

Peacock feathers: Brown pigment + nanostructures

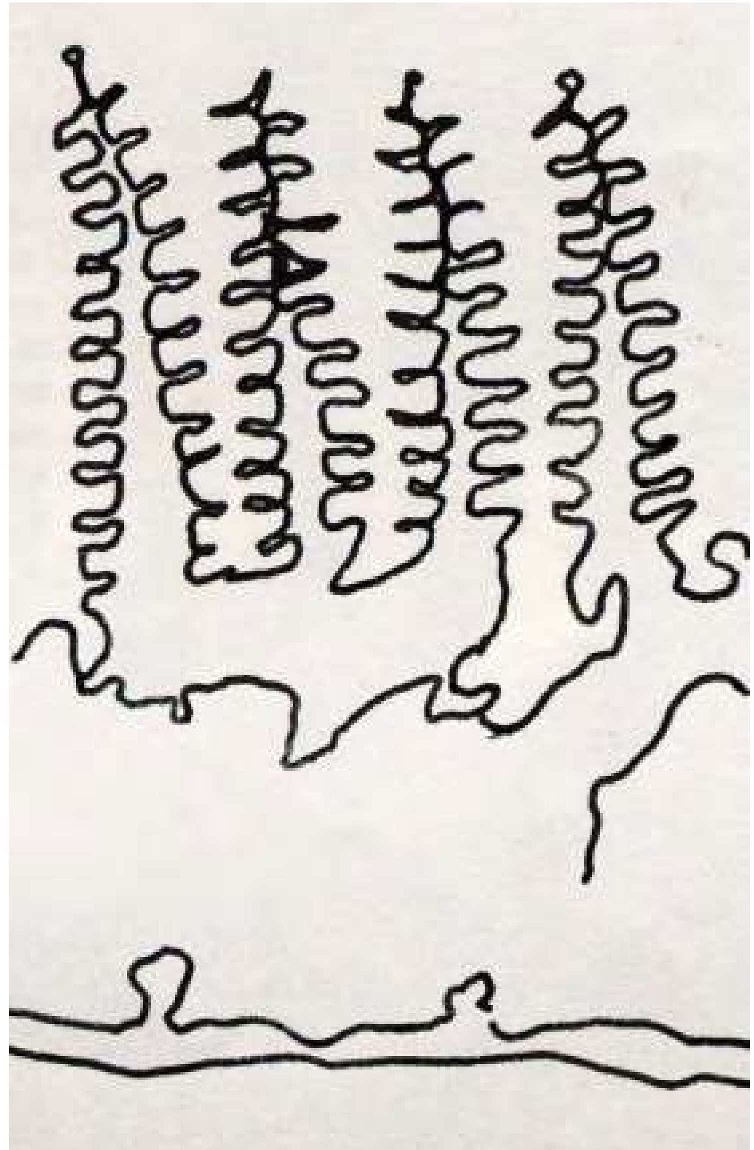




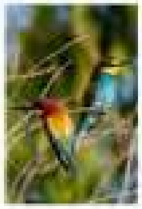
When light falls on a thin film, the waves reflected from the upper and lower surfaces travel different distances depending on the angle, so they interfere.

The plum throated Continga bird gets its vibrant colors from a nanoscale network of keratin.

Butterfly wing at different magnifications reveals mesostructured chitin acting as a diffraction grating



Examples from wikipedia:

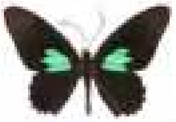


European bee-eaters owe their brilliant colours partly to diffraction grating microstructures in their feathers

In Morpho butterflies such as *Morpho helena* the brilliant colours are produced by intricate firtree-shaped microstructures too small for optical microscopes.

The male *Parotia lawesii* bird of paradise signals to the female with his breast feathers that switch from blue to yellow.

Brilliant green of emerald swallowtail, *Papilio palinurus*, is created by arrays of microscopic bowls that reflect yellow directly and blue from the sides.



Emerald-patched cattleheart butterfly, *Parides sesostris*, creates its brilliant green using photonic crystals.

Iridescent scales of *Lamprocyphus augustus* weevil contain diamond-based crystal lattices oriented in all directions to give almost uniform green.

Hollow nanofibre bristles of *Aphrodita aculeata* (a species of sea mouse) reflect light in yellows, reds and greens to warn off predators.

Longfin inshore squid, *Doryteuthis pealeii*, has been studied for its ability to change colour.

Thin-film interference in a soap bubble. Colour varies with film thickness.

Smoked pork loin showing iridescence due to the fine arrangement of the muscle fibrils.

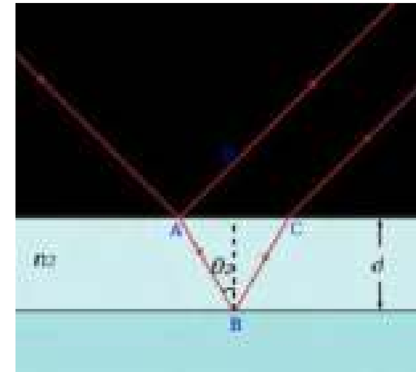
Article | OPEN

Full-Color Biomimetic Photonic Materials with Iridescent and Non-Iridescent Structural Colors

Ayaka Kawamura, Michinari Kohri, Gen Morimoto, Yuri Nannichi, Tatsuo Taniguchi & Keiki Kishikawa

Scientific Reports 6, Article number: 33984 (2016)
doi:10.1038/srep33984
Download Citation
Materials for optics
Optical materials

Received: 04 August 2016
Accepted: 06 September 2016
Published online: 23 September 2016



Polydopamine (PDA) shell layers
+ core polystyrene (PSt) particles

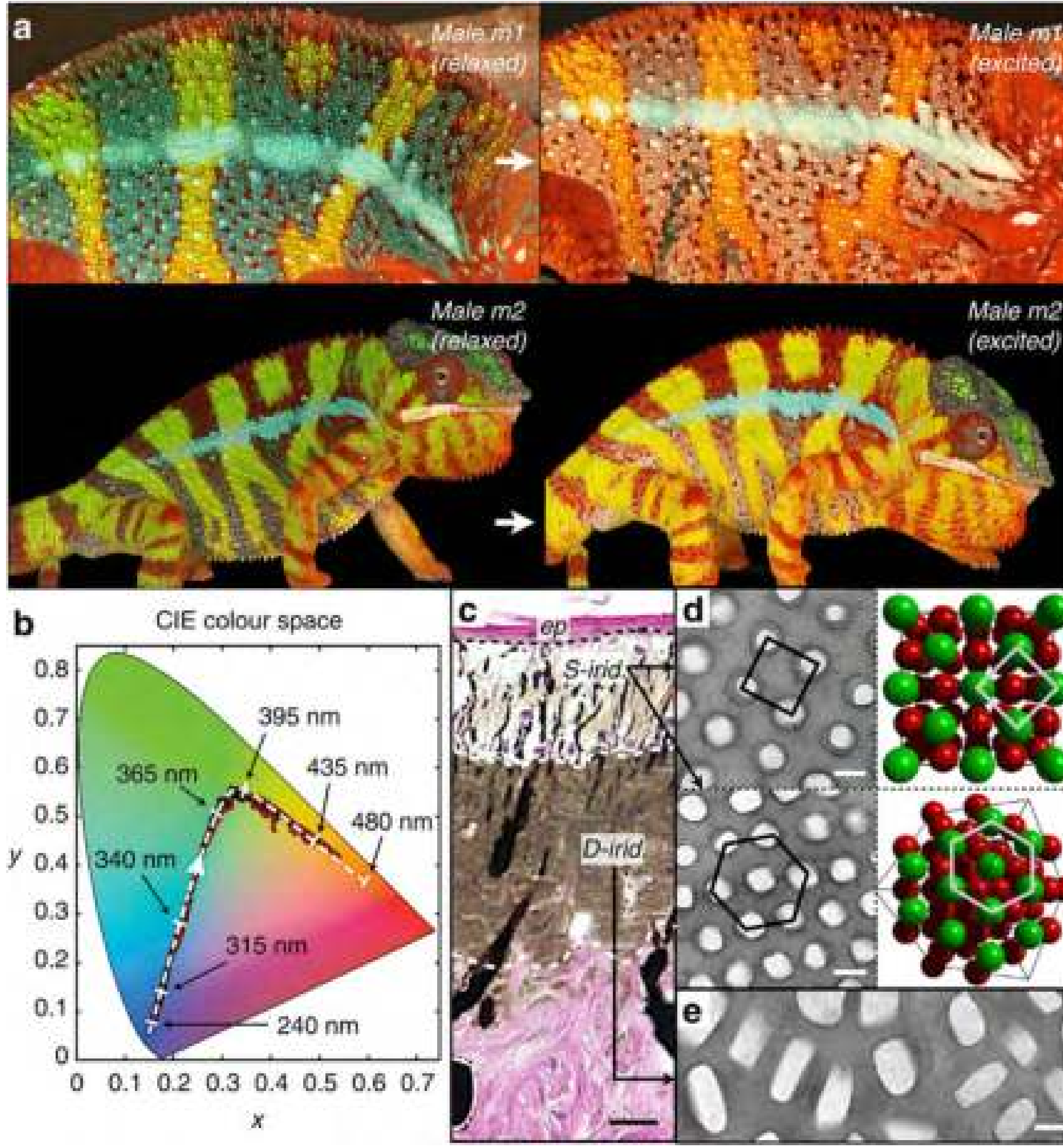
Article | OPEN

Photonic crystals cause active colour change in chameleons

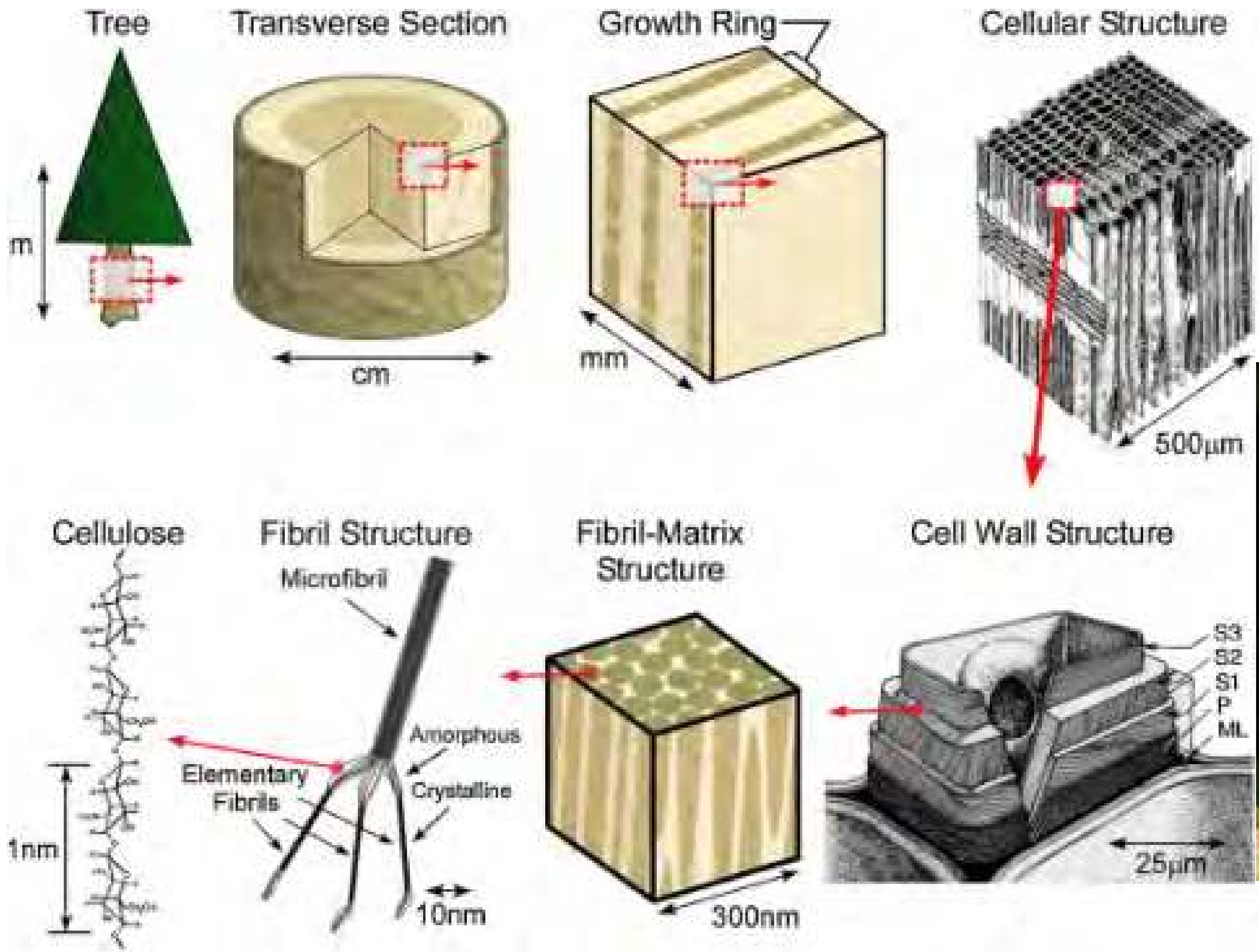
Jérémie Teyssier, Suzanne V. Saenko, Dirk van der Marel & Michel C. Milinkovitch

Nature Communications 6, Article number: 6368 (2015)
doi:10.1038/ncomms7368
Download Citation
Photonic crystals

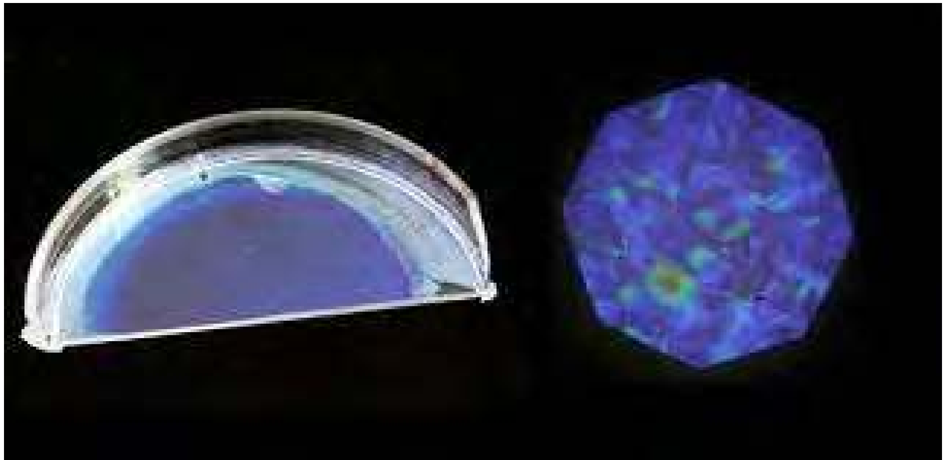
Received: 16 June 2014
Accepted: 22 January 2015
Published online: 10 March 2015



Chameleons can change their color in less than 1 second



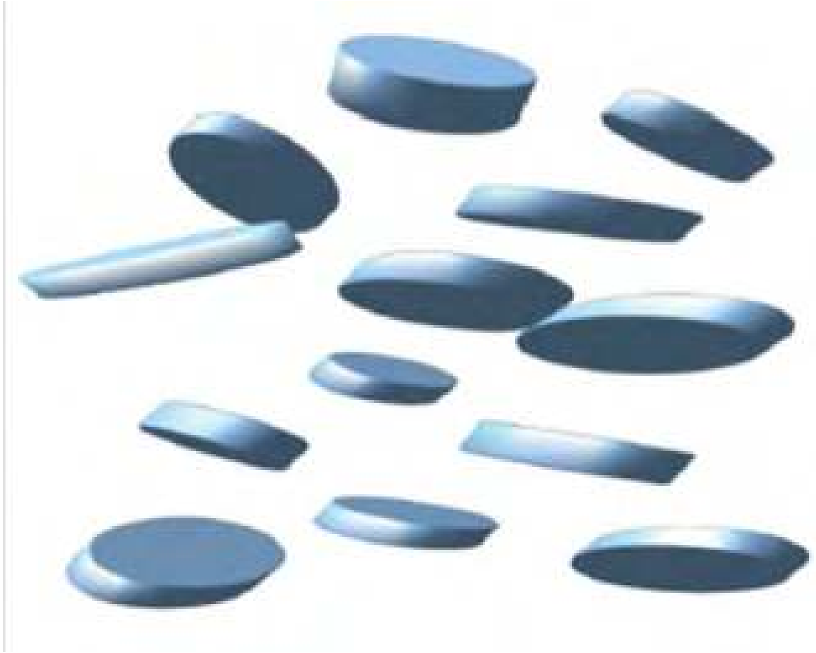
The most intense blue known in nature: African Pollia condensata berries



Dumanli, A. G., Kamita, G., Landman, J., van der Kooij, H., Glover, B. J., Baumberg, J. J., Steiner, U. and Vignolini, S. (2014), "Controlled, Bio-inspired Self-Assembly of Cellulose-Based Chiral Reflectors." Advanced Optical Materials. doi: 10.1002/adom.201400112

Self-assembly:

Making a macroscopic sample (i.e. about 10^{20} nanoparticles) by physically picking up and moving nanoparticles into place, one by one, would take about 300 million years, even if the time for moving individual particles could be made as short as 1 millisecond.



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Self-assembly:
Emergent patterns, more is different

NTNU

Human made design:
Top-down Self-assembly

How nature works:
Bottom-up Self-assembly

Scientific challenge of nanostructured self-assembly:
Combination of Top-down and Bottom-up:

Another pile of rocks

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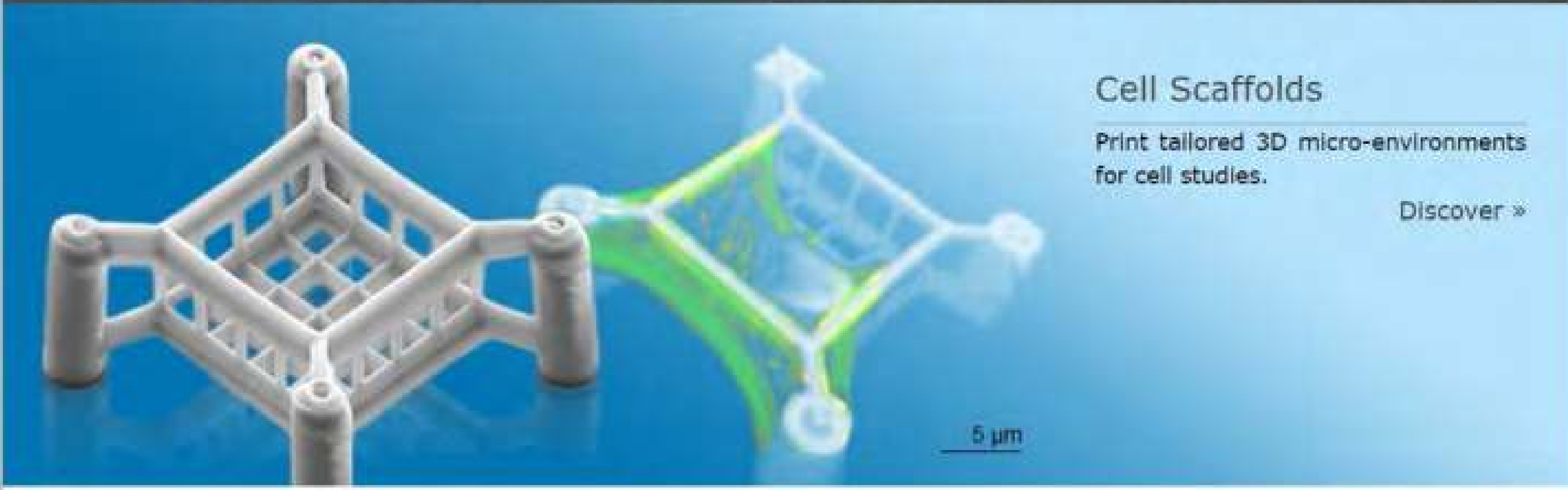

High Precision 3D Printing Solutions

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Liquid Crystalline Phases Characterization

Order Parameter = O.P.
= Angular distribution function
= $S_2 = \frac{1}{2}\langle 3\cos^2\theta - 1 \rangle$

Isotropic
Phase (O.P. = 0)

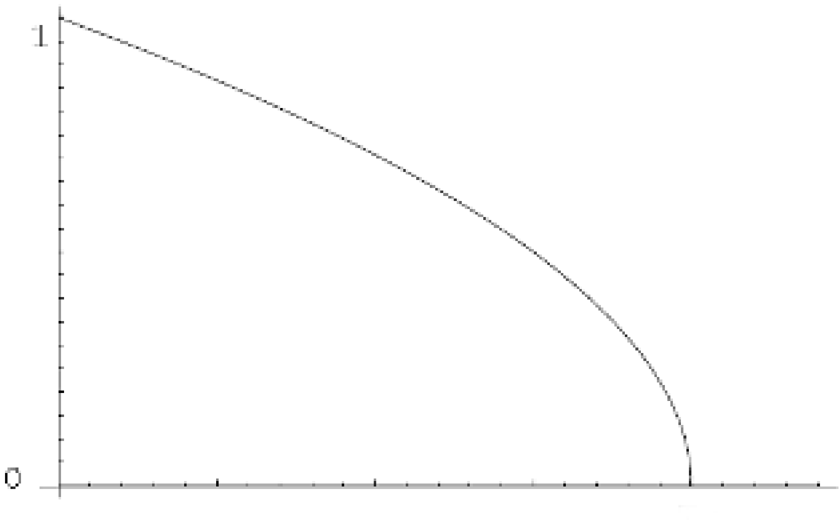
Nematic
Phase (O.P. ≠ 0)

Irving Langmuir (Nobel Prize in Chemistry 1932): 1st experimental work in 1938 on liquid crystal structures in a clay suspension.

J. Chem Phys. 6, 873 (1938)

LCPC = Liquid Crystalline Phases Characterization

Order Parameter (0<O.P.<1) =
Angular distribution function



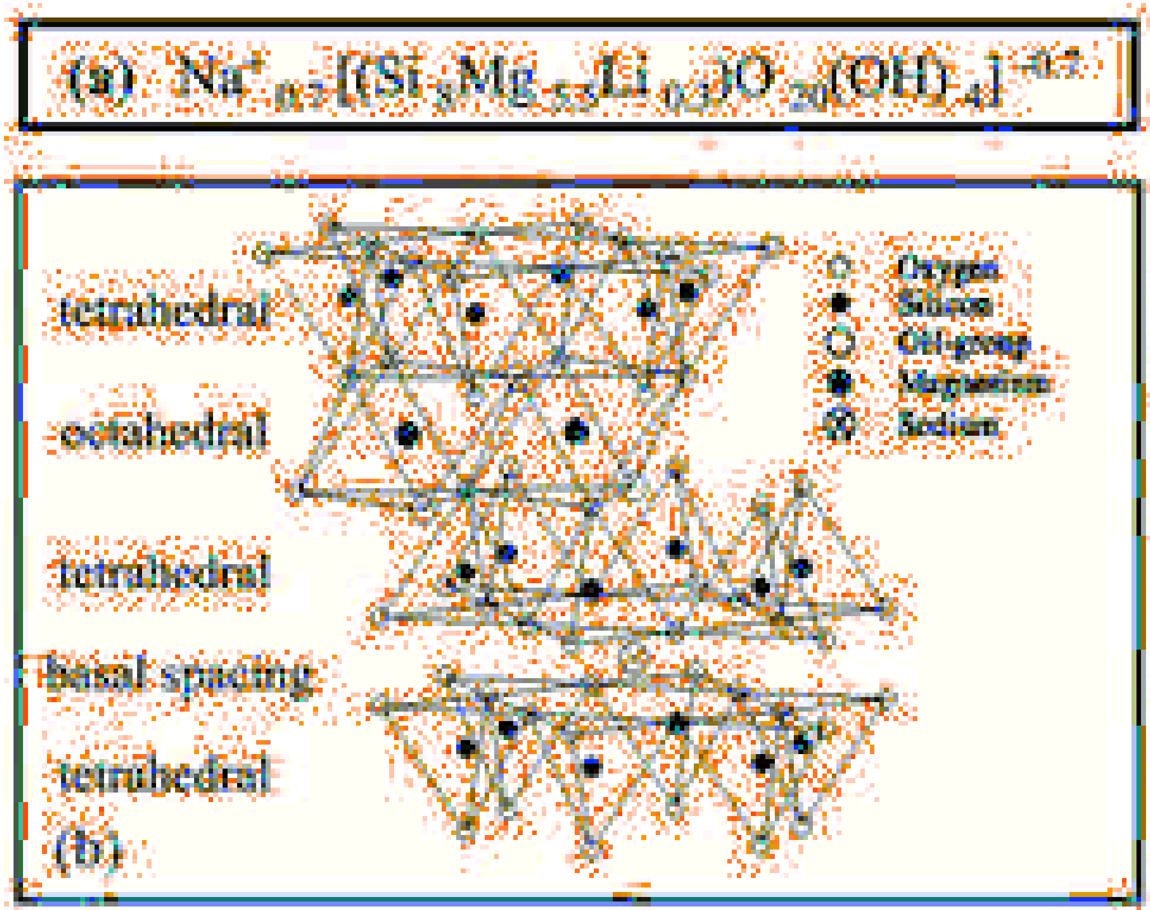
Particle concentration
Electric fields
Magnetic fields
Etc.

Isotropic
Phase (O.P. = 0)

Nematic
Phase (O.P. > 0)

Self-organization

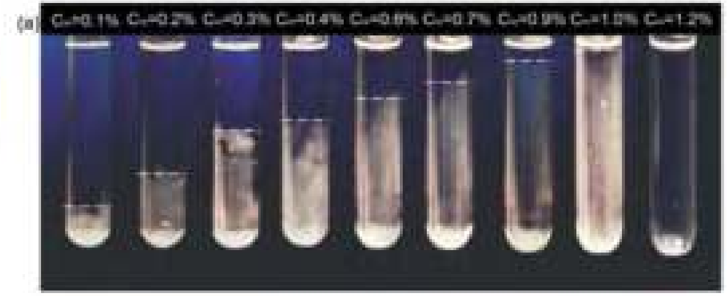
The most common and most used synthetic clay: Laponite



Colloidal gels: **Clay goes patchy**,
W. K. Kegel & H. N. W. Lekkerkerker,
Nature Materials 10, 5–6 (2011)

Observation of empty liquids and **equilibrium gels in a colloidal clay**,
B. Ruzicka, E. Zaccarelli, L. Zulian, R. Angelini, M. Sztucki, A. Moussaïd,
T. Narayanan and F. Sciortino, **Nature Materials 10, 56-60 (2011)**

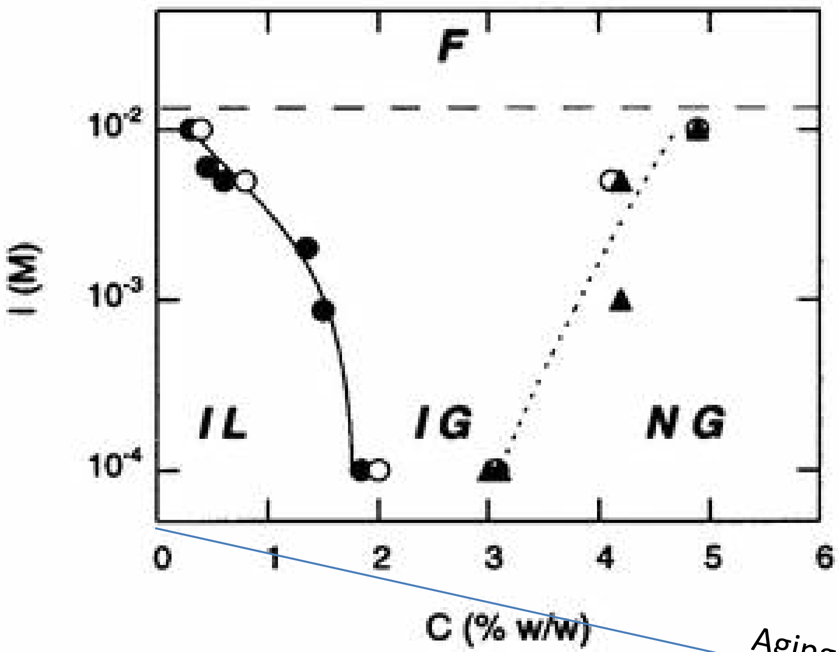
One sample for each point



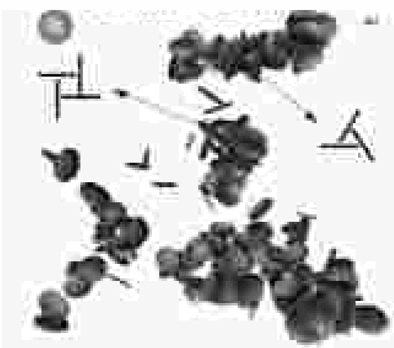
Langmuir 1998, *14*, 4718–4723

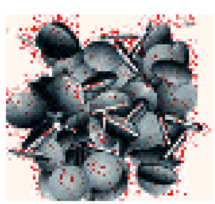
On Viscoelastic, Birefringent, and Swelling Properties of Laponite Clay Suspensions: Revisited Phase Diagram

A. Mourchid,* E. Lécolier, H. Van Damme, and P. Levitz*



Aging time





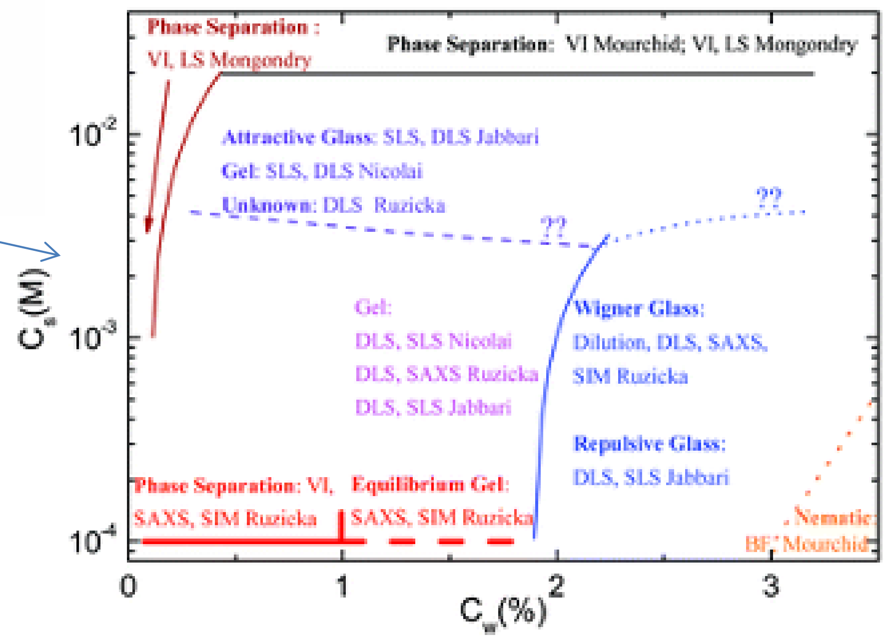
Soft Matter

Cite this: *Soft Matter*, 2011, **7**, 1268

www.rsc.org/softmatter

A fresh look at the Laponite phase diagram

Barbara Ruzicka*[ab] and Emanuela Zaccarelli*[ab]



Soft Matter

RSCPublishing

PAPER

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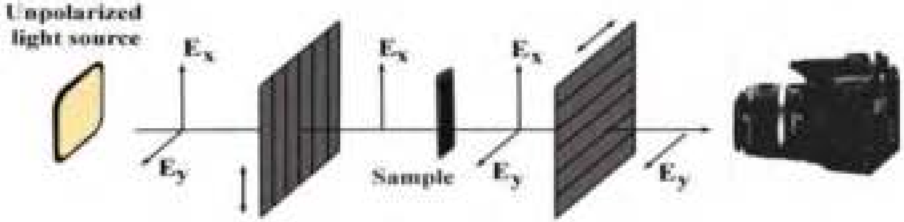
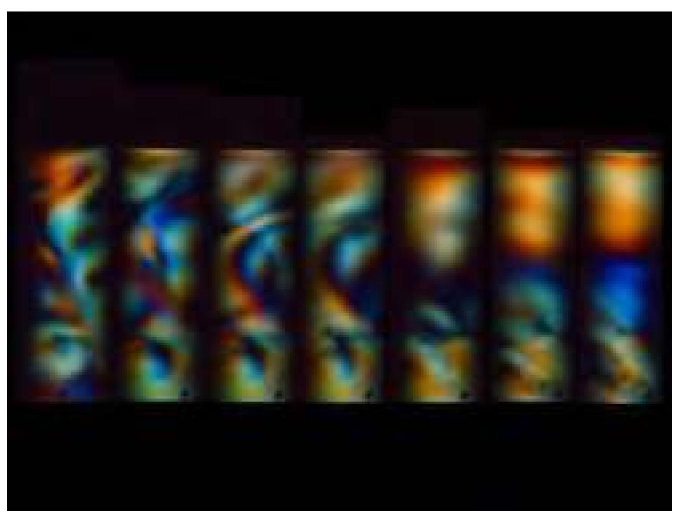
View Journal | View Issue

Orientational order in a glass of charged platelets with a concentration gradient

Cite this: Soft Matter, 2013, 9, 9999

Elisabeth Lindbo Hansen,[*a] Sara Jabbari-Farouji,[b] Henrik Mauroy,[c] Tomás S. Plivelic,[d] Daniel Bonn[e] and Jon Otto Fossum[a]





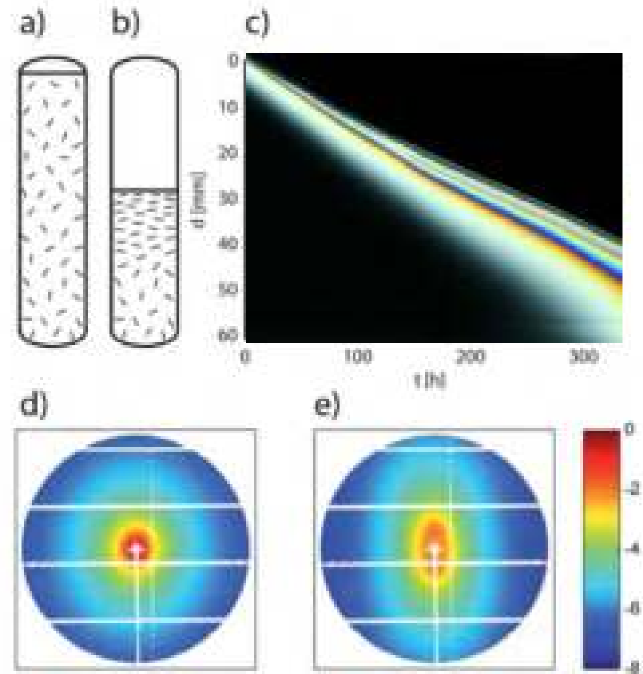
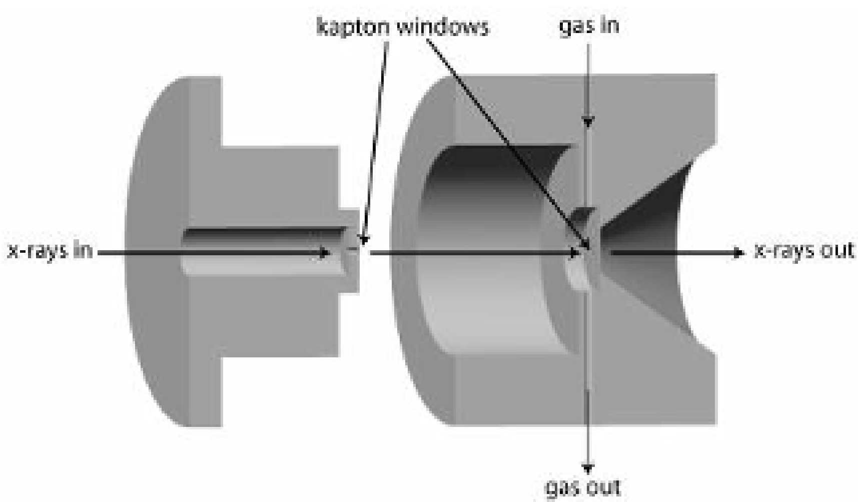
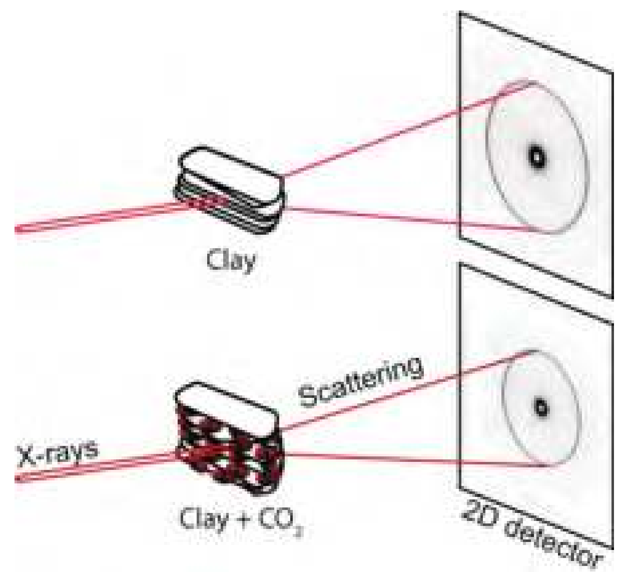


Fig. 2 a) Schematic of the structure of an isotropic Laponite glass and (b) of a Laponite glass with evaporation-induced orientational order. (c) A spatio-temporal plot of developing birefringence in an evaporating C_w = 3.0 wt% LRD sample, showing the central part of a capillary imaged at successive waiting times. Crossed linear polarizers were oriented at 45 deg with the vertical capillary axis. The thickness of the sample was l = 2.65 nm, so that 4[th] order magenta, appearing at the interface near the end of this time series, implies a $\Delta n = 8.3 \times 10^{-4}$. (d) SAXS pattern collected from the sample imaged in (c) at a distance of 10 mm from the interface, at the end of the time series, and (e) just below the interface.

Nano-scale tools:
AFM, Small-Angle X-ray Scattering: SAXS, etc.



Home made sample cell



X-ray synchrotron sources that we have used recently:

ESRF – Grenoble, France
LNLS – Campinas, Brasil
MaxIV Lab. – Lund, Sweden
PLS – Pohang, S-Korea
(In the past: BNL; APS – USA)
++++++++++++

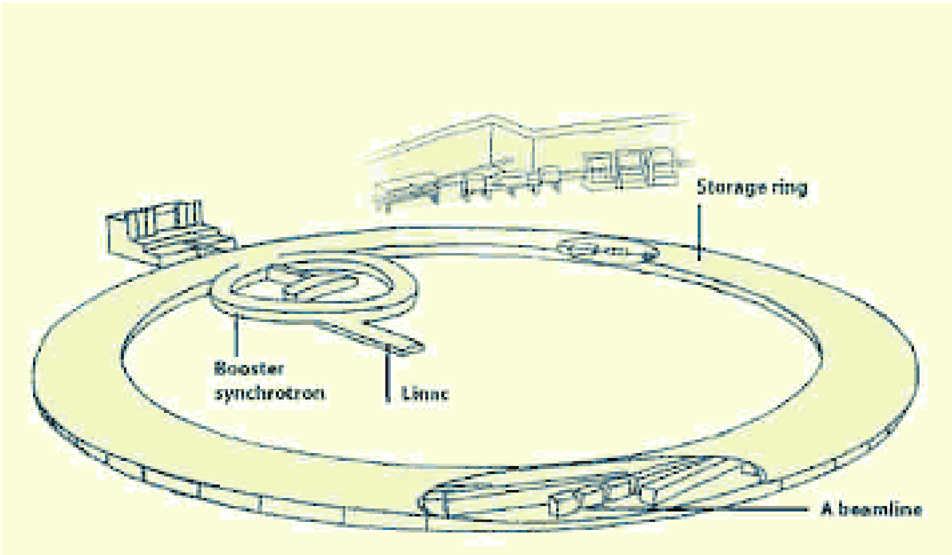
Neutrons in Norway:

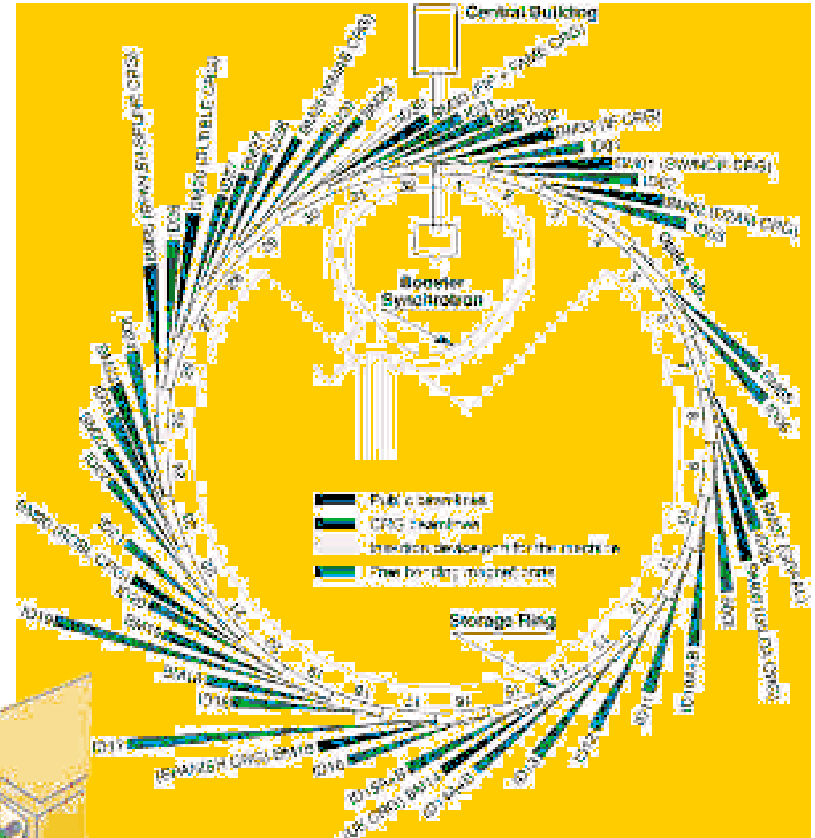
IFE – Kjeller, Norway

Jeep II reactor:

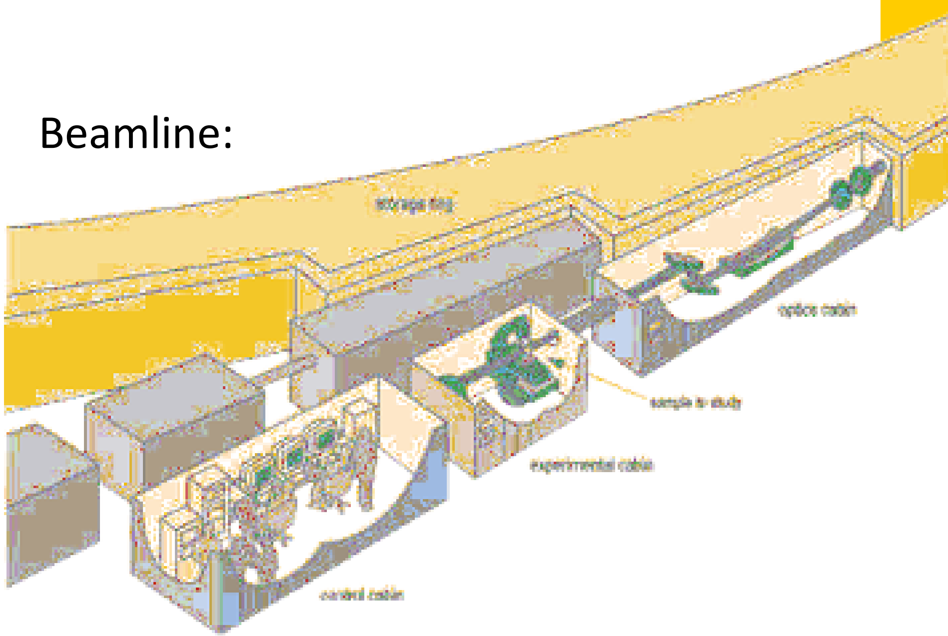
SANS at IFE:

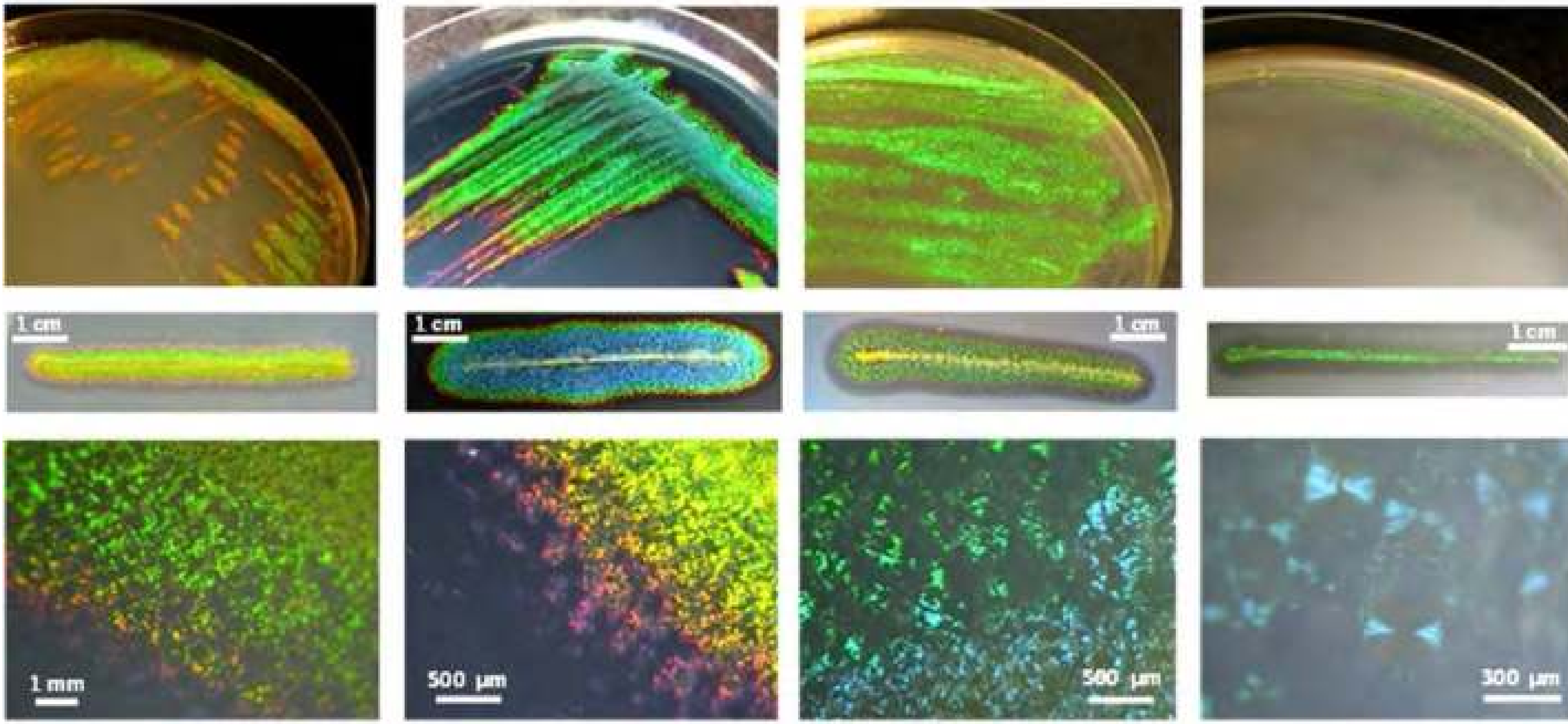
X-ray synchrotron sources:





Beamline:





SCIENTIFIC REPORTS

OPEN

A unique self-organization of bacterial sub-communities creates iridescence in *Cellulophaga lytica* colony biofilms

Received: 30 July 2015
Accepted: 17 December 2015
Published: 28 January 2016

Betty Kientz[1,*], Stephen Luke[2], Peter Vukusic[2,*], Renaud Péteri[3,*], Cyrille Beaudry[3], Tristan Renault[4], David Simon[3], Tâm Mignot[5] & Eric Rosenfeld[1,*]

Flocking and swarming

Selected for a Viewpoint in *Physics*
PRL **110,** 228102 (2013) PHYSICAL REVIEW LETTERS week ending 31 MAY 2013

Fluid Dynamics of Bacterial Turbulence

Jörn Dunkel,[1] Sebastian Heidenreich,[2] Knut Drescher,[3] Henricus H. Wensink,[4] Markus Bär,[2] and Raymond E. Goldstein[1]

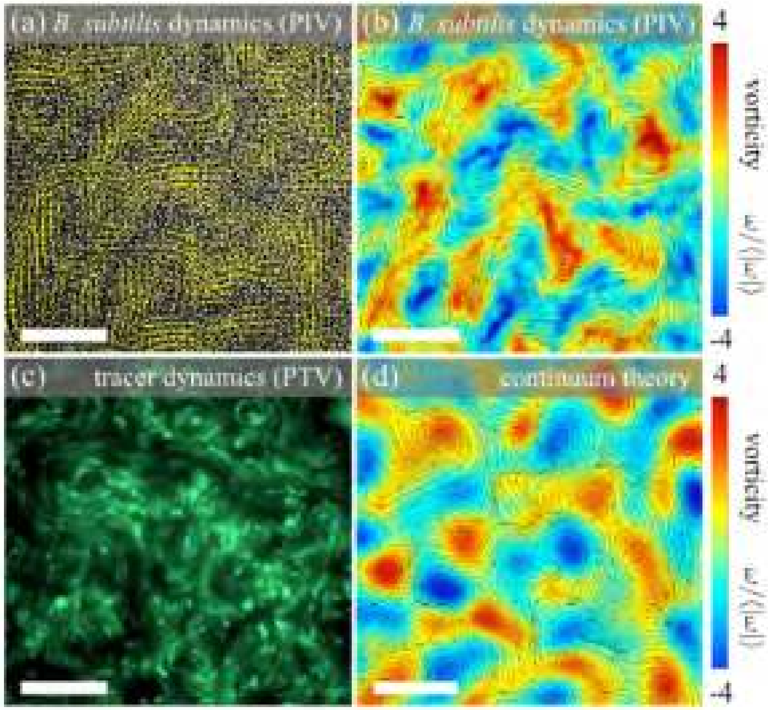


FIG. 1 (color online). Flow fields from experiments and simulations [38]. (a) Very dense homogeneous suspension of *B. subtilis* overlaid with the PIV flow field showing collective bacterial dynamics. Longest arrows correspond to velocity of 30 μm/s. (b) Streamlines and normalized vorticity field determined from PIV data in (a). (c) Turbulent "Lagrangian" flow of fluorescent tracer particles (false-color) in the same suspension, obtained by integrating emission signals over 1.5 s. (d) Partial snapshot of a 2D slice from a 3D simulation of the continuum model (parameters in Table I). Scale bars 70 μm.

Selected for a Viewpoint in *Physics*
PRL **110,** 228102 (2013) PHYSICAL REVIEW LETTERS week ending 31 MAY 2013

Fluid Dynamics of Bacterial Turbulence

Jörn Dunkel,[1] Sebastian Heidenreich,[2] Knut Drescher,[3] Henricus H. Wensink,[4] Markus Bär,[2] and Raymond E. Goldstein[1]

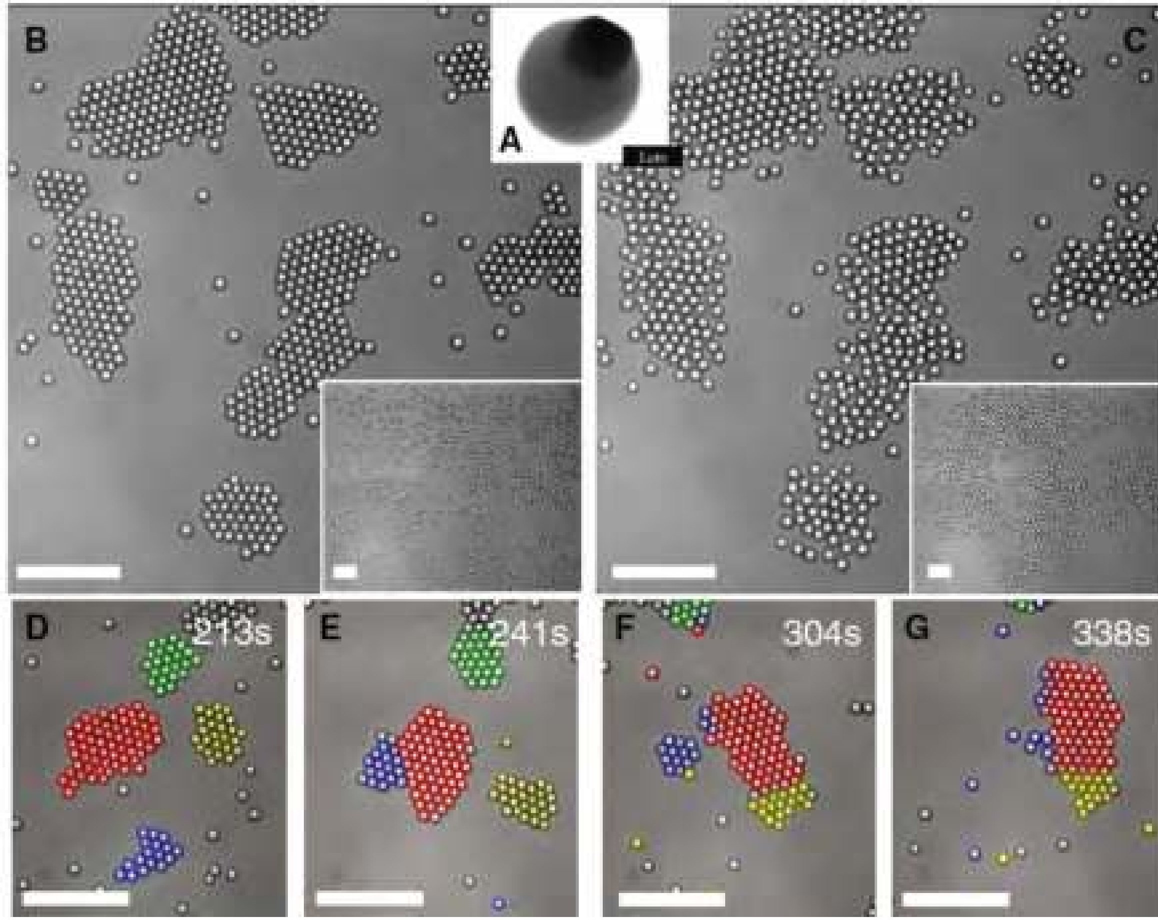
exp_03_40xoil_40fps_fluo.mov: Real-time low-resolution movie (duration 50 s) of tracer motion as used for the PTV analysis (see main text for imaging parameters).

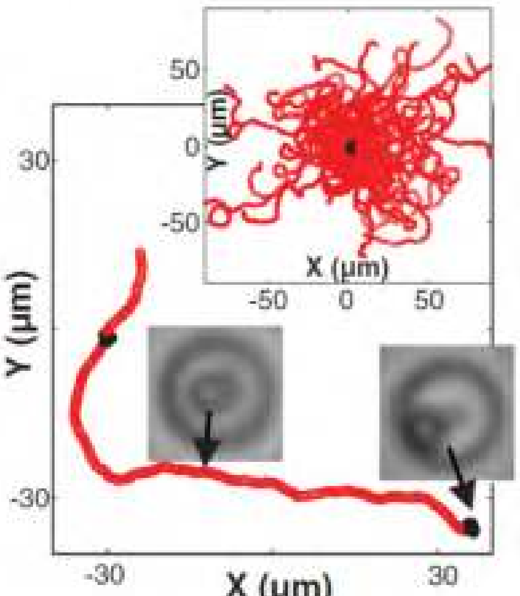
exp_03.mov: Real-time movie (duration 50 s) of the PIV flow field as extracted from "exp_03_40xoil_40fps_brightfield.mov"

Living Crystals of Light-Activated Colloidal Surfers

Jeremie Palacci *et al.*
Science **339**, 936 (2013);
DOI: 10.1126/science.1230020

Fig. 1. (**A**) Scanning electron microscopy (SEM) of the bimaterial colloid: a TPM polymer colloidal sphere with protruding hematite cube (dark). (**B**) Living crystals assembled from a homogeneous distribution (inset) under illumination by blue light. (**C**) Living crystals melt by thermal diffusion when light is extinguished: Image shows system 10 s after blue light is turned off (inset, after 100 s). (**D** to **G**) The false colors show the time evolution of particles belonging to different clusters. The clusters are not static but rearrange, exchange particles, merge (D→F), break apart (E→F), or become unstable and explode (blue cluster, F→G). For (B) to (G), the scale bars indicate 10 μm. The solid area fraction is $\Phi_s \approx 0.14$.





A hematite cube protruding from a TPM polymer spheremoves on fixed glass substrate when exposed to blue light (red part of trace) and diffuses when the light is off (black part of trace). Initially, with no light, the hematite cube is oriented randomly (image, right) but rotates and faces downward toward the glass substrate when the light is turned on (image, left). The particle then surfs on the osmotic flow it induces between the substrate and itself. (Inset) A superposition of the trajectories of many particles with their origins aligned.

Science AAAS

Living Crystals of Light-Activated Colloidal Surfers

Jeremie Palacci *et al.*

Science **339**, 936 (2013);
DOI: 10.1126/science.1230020

Phoretic and osmotic effects can conveniently be switched on and off by light.

1896. ANNALEN No 11.

der

PHYSIK UND CHEMIE.

NEUE FOLGE. BAND 59.

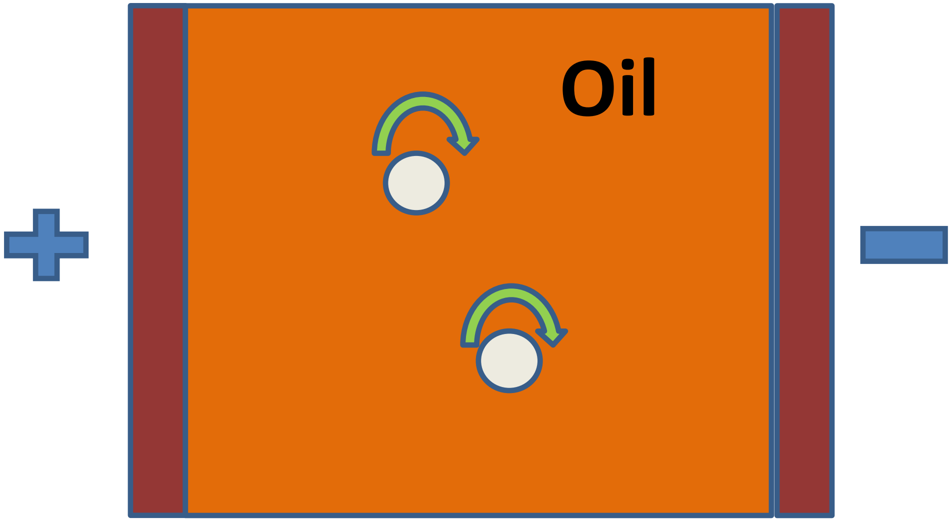
1. *Ueber Rotationen im constanten electrischen Felde; von G. Quincke.*

[illegible]

Georg Hermann Quincke

Born	19 November 1834 Frankfurt (Oder)
Died	13 January 1924 (aged 89) Heidelberg
Nationality	German
Fields	Physics
Doctoral advisor	H. G. Magnus, F. E. Neumann
Doctoral students	K. F. Braun, P. Lenard

Quincke rotation



Small glass beads rotate spontaneously when immersed in liquids and subject to an electrostatic field

1. Threshold electric field
2. Rotation axis normal to the applied E-field

Quincke rotation

Georg Hermann Quincke

Born	19 November 1834 Frankfurt (Oder)
Died	13 January 1924 (aged 89) Heidelberg
Nationality	German
Fields	Physics
Doctoral advisor	H. G. Magnus, F. E. Neumann
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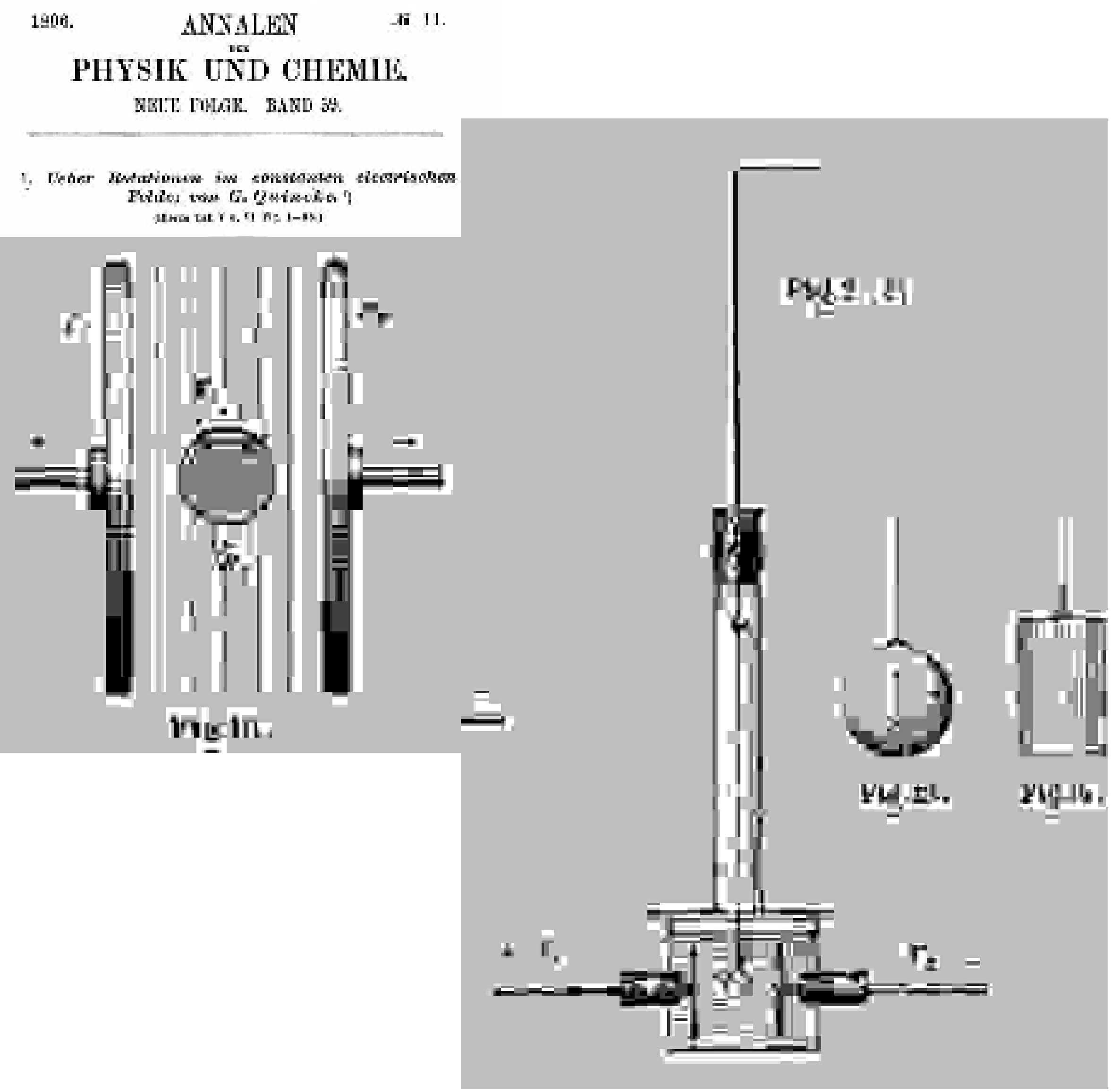

Quincke rotation

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Doctoral advisor	H. G. Magnus, F. E. Neumann
Doctoral students	K. F. Braun, P. Lenard

PHYSICAL REVIEW E 87, 043014 (2013)

Electrohydrodynamic interaction of spherical particles under Quincke rotation

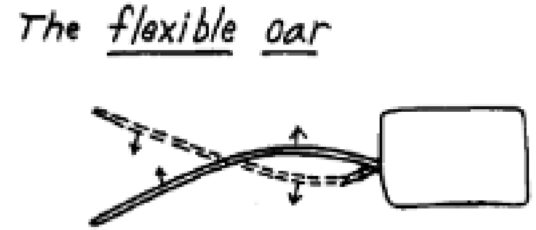
Debasish Das and David Saintillan*
Department of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801, USA
(Received 3 March 2013; published 29 April 2013)

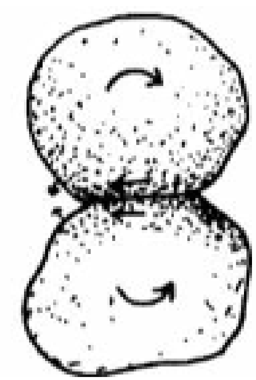
Interaction of Quincke rotating beads

Life at low Reynolds number American Journal of Physics, Vol. 45, No. 1, January 1977

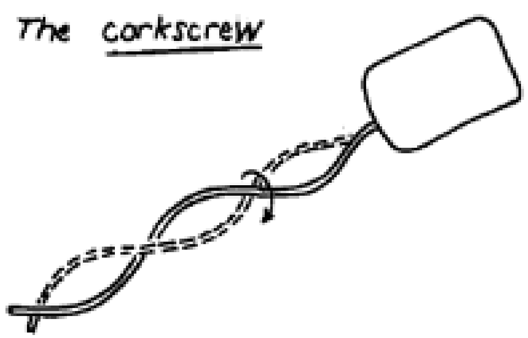
E. M. Purcell
Lyman Laboratory, Harvard University, Cambridge, Massachusetts 02138
(Received 12 June 1976)

Another animal might consist of two cells which were stuck together and were able to roll on one another by having some kind of attraction here while releasing there. That thing will "roll" along.





Counter-rotating rotors



Swimmers

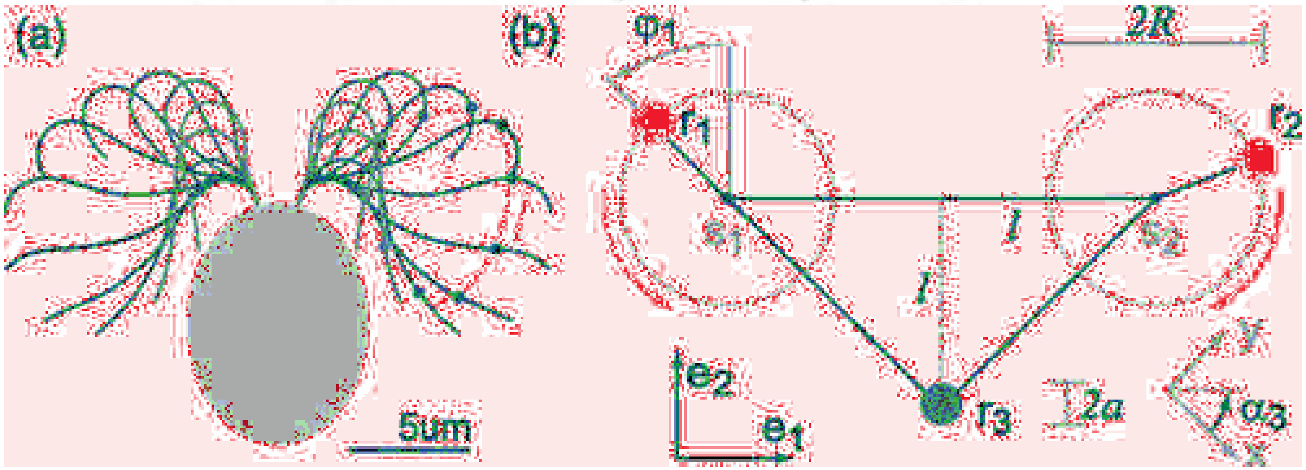
Chlamydomonas is a single-cell green alga about 10 micrometres in diameter that swims with two flagella.

Two-rotor bifilament swimmer: Chlamydomonas

Selected for a Viewpoint in *Physics*
PRL **109**, 138102 (2012) PHYSICAL REVIEW LETTERS week ending 28 SEPTEMBER 2012

Flagellar Synchronization Independent of Hydrodynamic Interactions

Benjamin M. Friedrich* and Frank Jülicher
Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany
(Received 7 June 2012; published 24 September 2012)



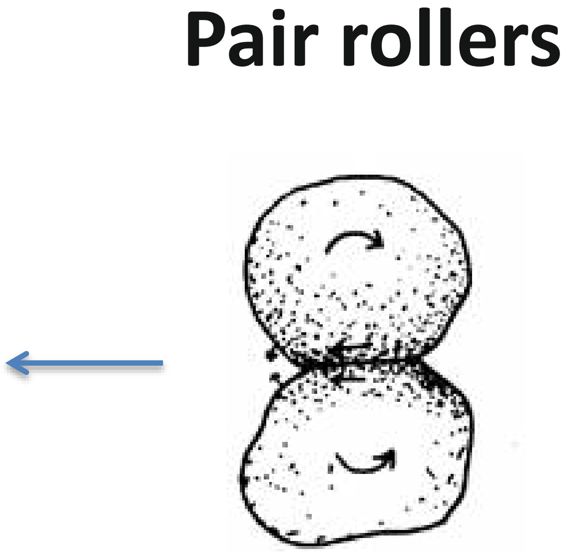
New Journal of Physics
The open access journal for physics

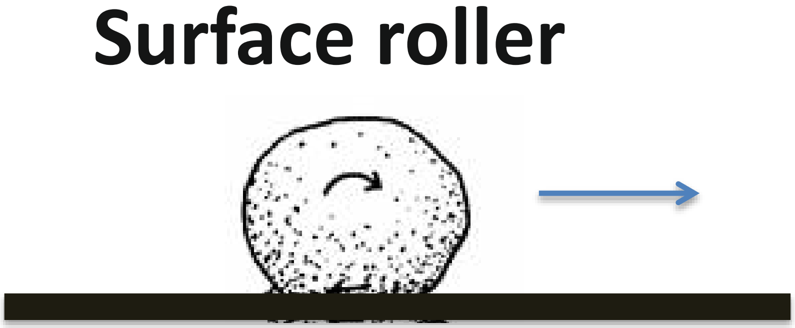
Phase-dependent forcing and synchronization in the three-sphere model of *Chlamydomonas*

Rachel R Bennett and Ramin Golestanian[1]
Rudolf Peierls Center for Theoretical Physics, University of Oxford, Oxford OX1 3NP, UK
E-mail: ramin.golestanian@physics.ox.ac.uk

New Journal of Physics **15** (2013) 075028 (17pp)
Received 10 April 2013
Published 30 July 2013
Online at http://www.njp.org/
doi:10.1088/1367-2630/15/7/075028

Two-rotor model of bifilament swimmer





Kicking off one another, or kicking of a surface

nature International weekly journal of science

NATURE | LETTER

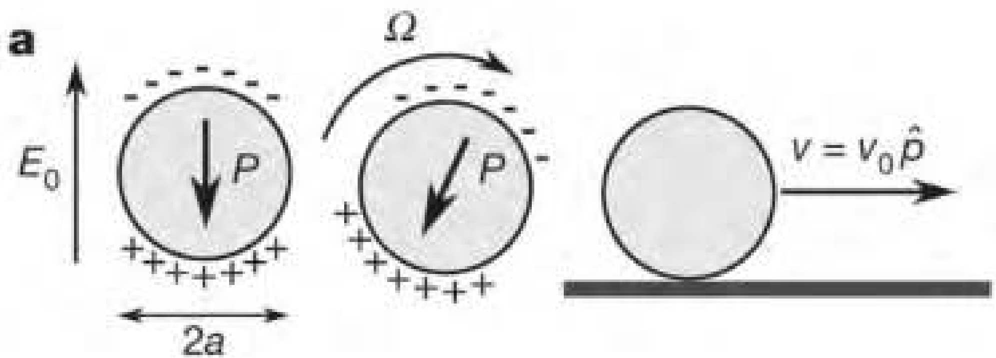
日本語要約

Emergence of macroscopic directed motion in populations of motile colloids

Antoine Bricard, Jean-Baptiste Caussin, Nicolas Desreumaux, Olivier Dauchot & Denis Bartolo

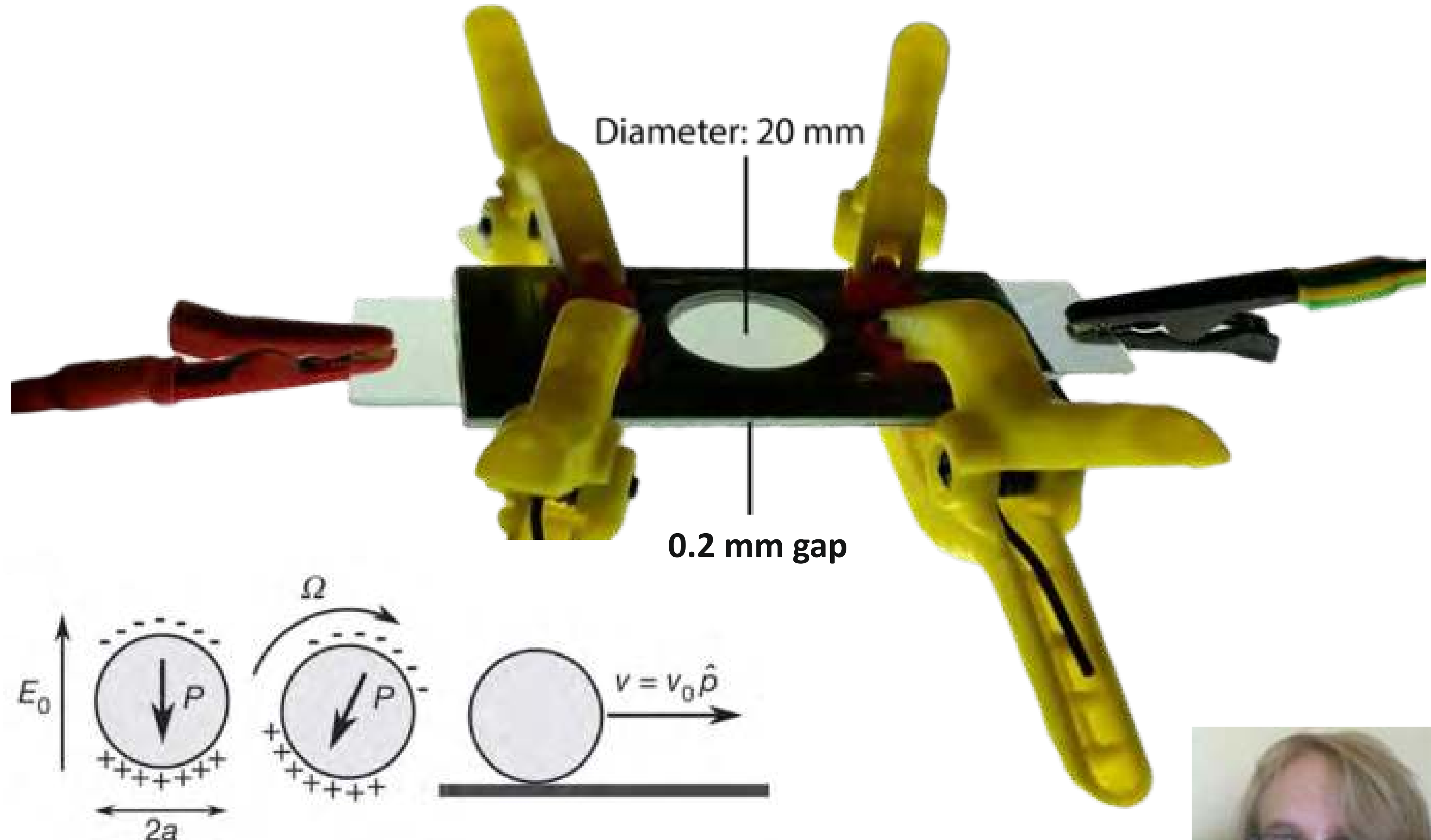
Affiliations | Contributions | Corresponding author

Nature **503**, 95–98 (07 November 2013) | doi:10.1038/nature12673
Received 17 May 2013 | Accepted 12 September 2013 | Published online 06 November 2013



Quincke rotating spheres interact and self-organize:

Hele-Shaw cell with ITO glass covers: suspension containg 30micron PS beads



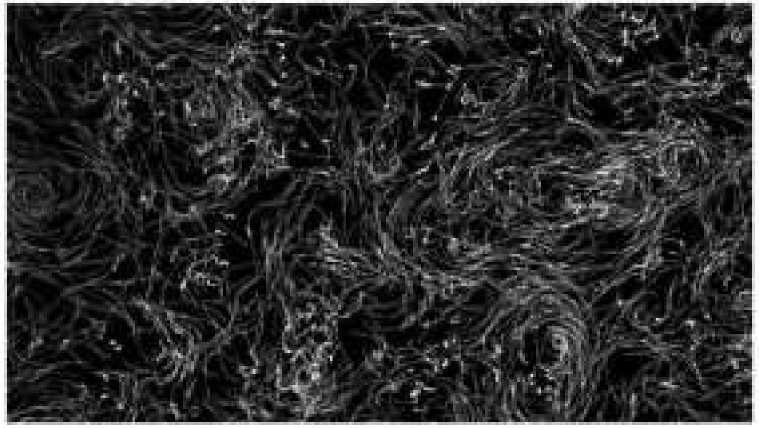
Experiments at NTNU Trondheim: Tommy Kristiansen

40μm   2250V/mm

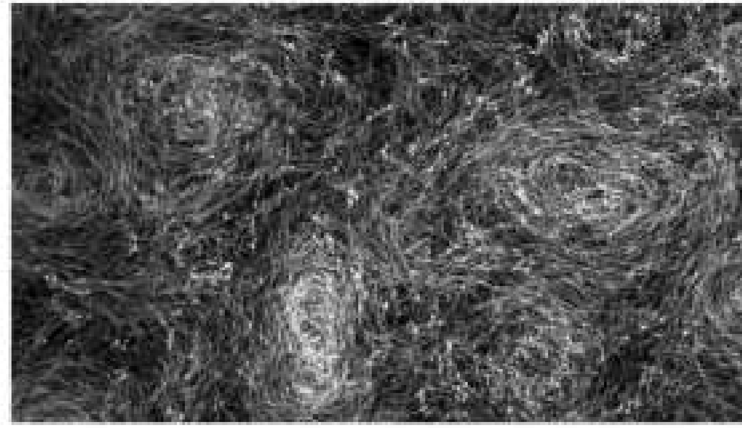
Fast moving quincke rollers

Experiments at NTNU Trondheim: Tommy Kristiansen

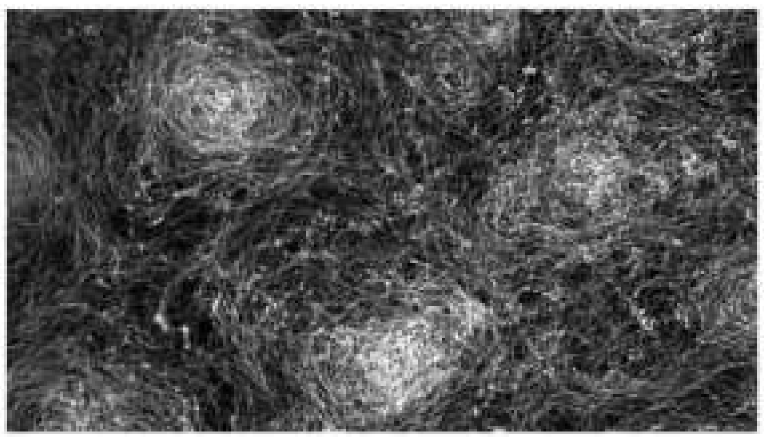
Streak photos of fast moving Quincke rollers: «Vortices»



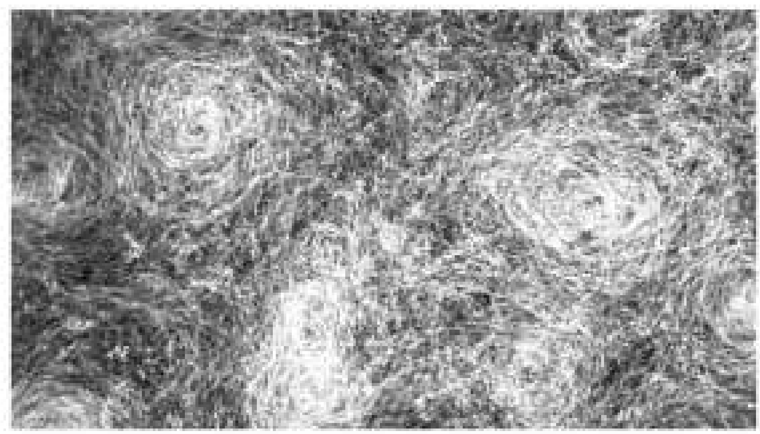
15 frames after 0 secs



100 frames after 3 secs



100 frames after 6 secs



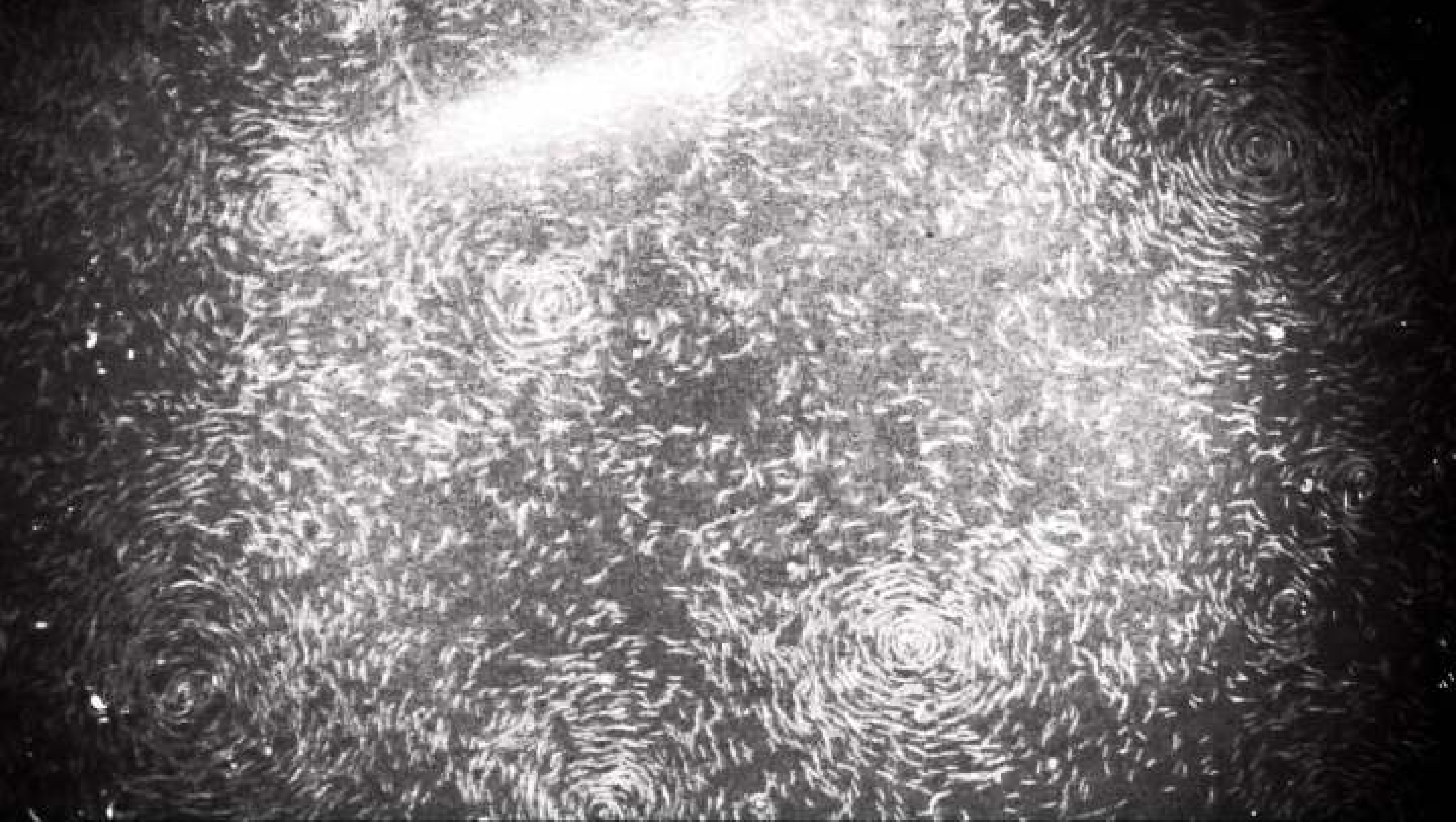
100 frames after 9 secs

Experiments at NTNU Trondheim: Tommy Kristiansen

30µm 1750V/mm

Zooming out: Fast moving quincke rollers

Experiments at NTNU Trondheim: Tommy Kristiansen



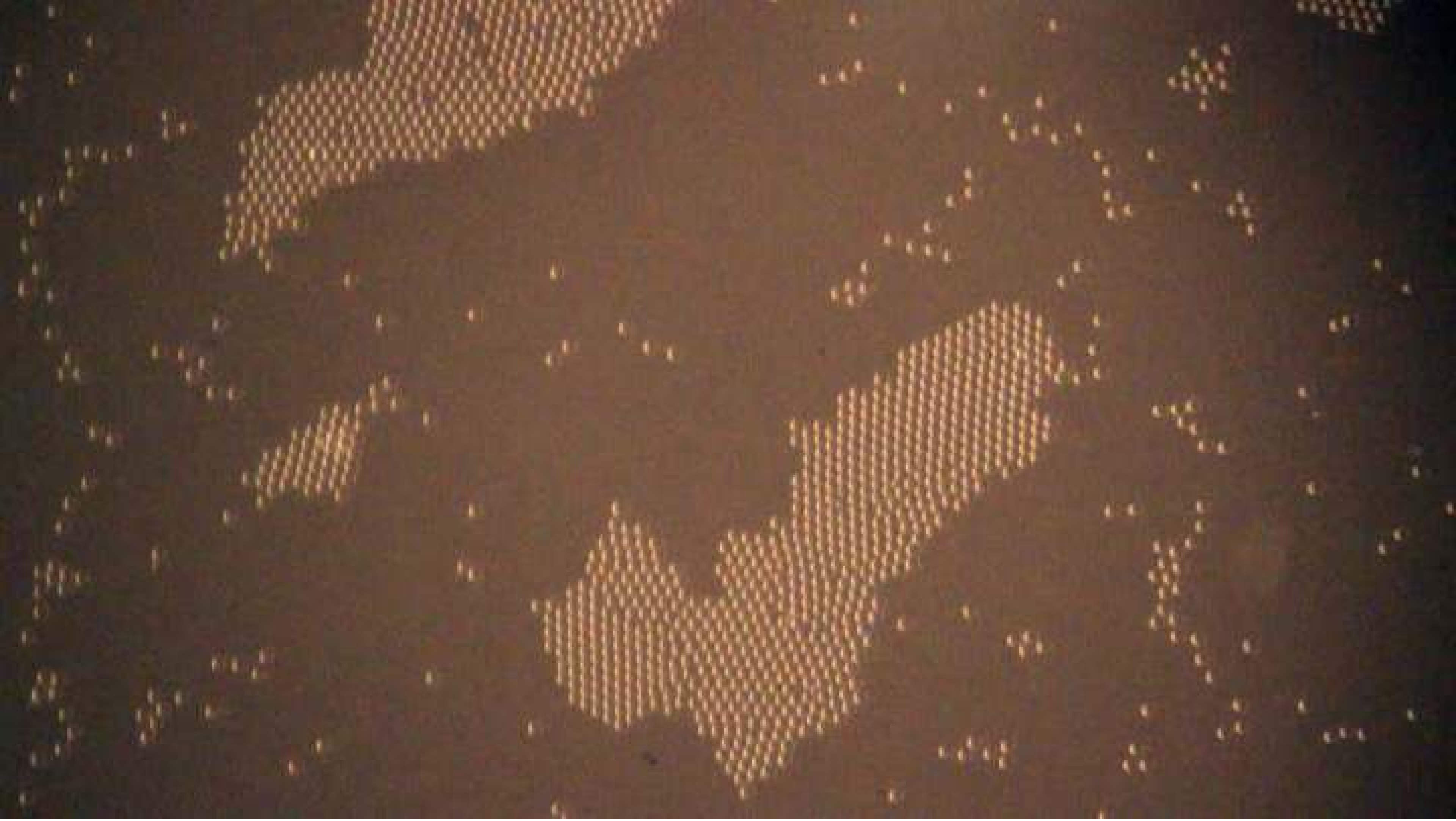
30μm   1750V/mm

Zooming out: Fast moving quincke rollers at half speed

Experiments at NTNU Trondheim: Tommy Kristiansen

30µm 1375V/mm 60fps «Living crystals «or active «entangled matter»

Experiments at NTNU Trondheim: Tommy Kristiansen



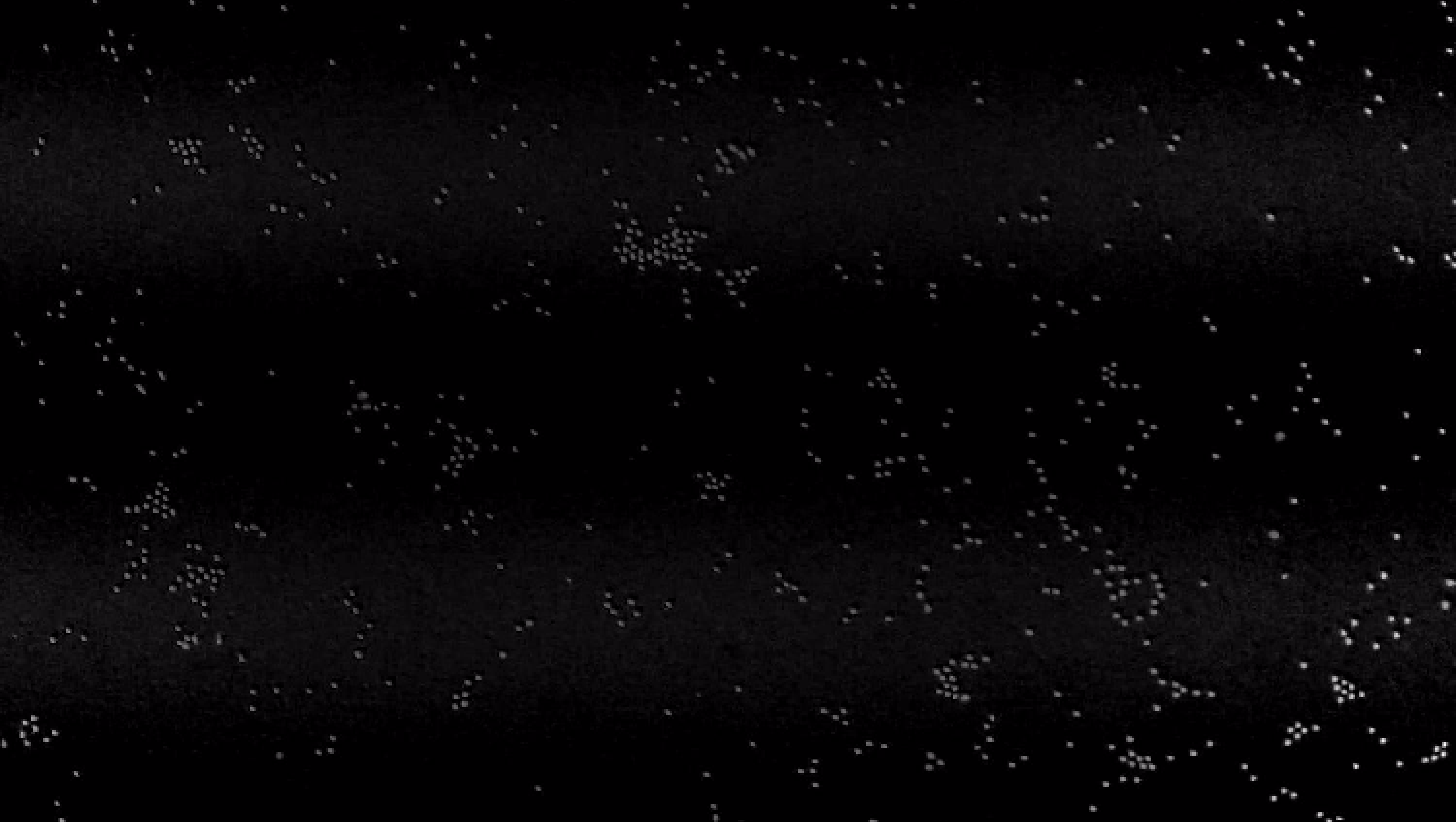
«Living crystals «or active «entangled matter»

Experiments at NTNU Trondheim: Tommy Kristiansen

40µm   1750V/mm

«Living crystals «or active «entangled matter»

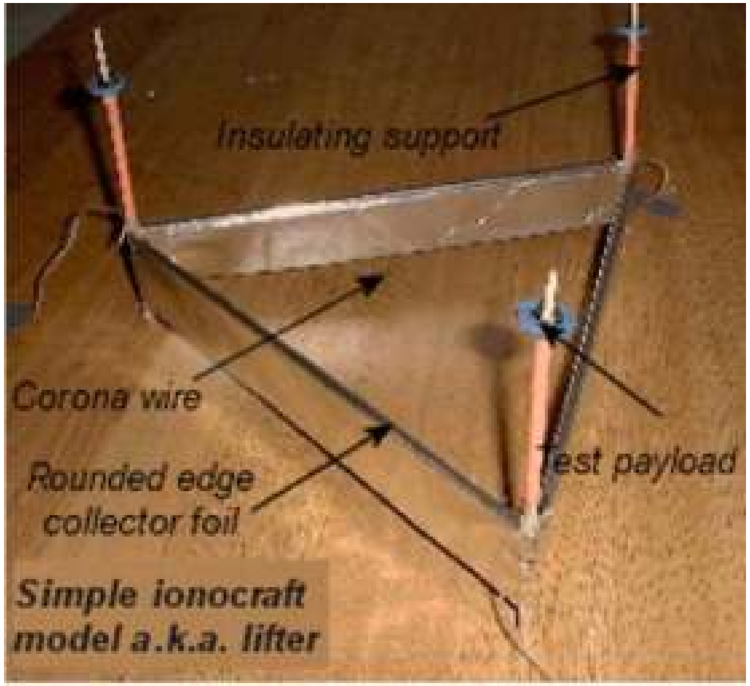
Experiments at NTNU Trondheim: Tommy Kristiansen

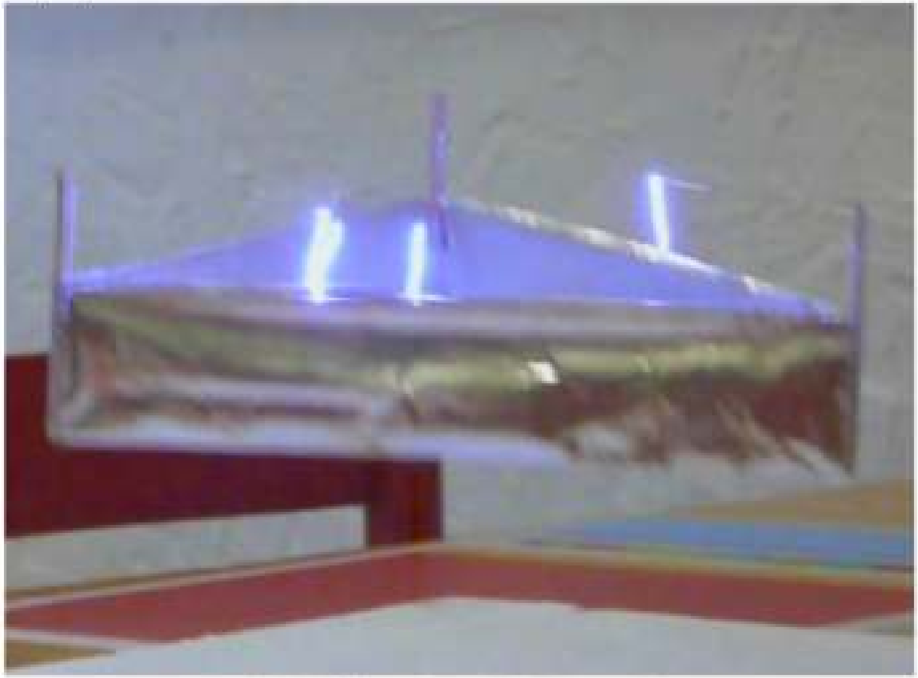


«Living crystals «or active «entangled matter»

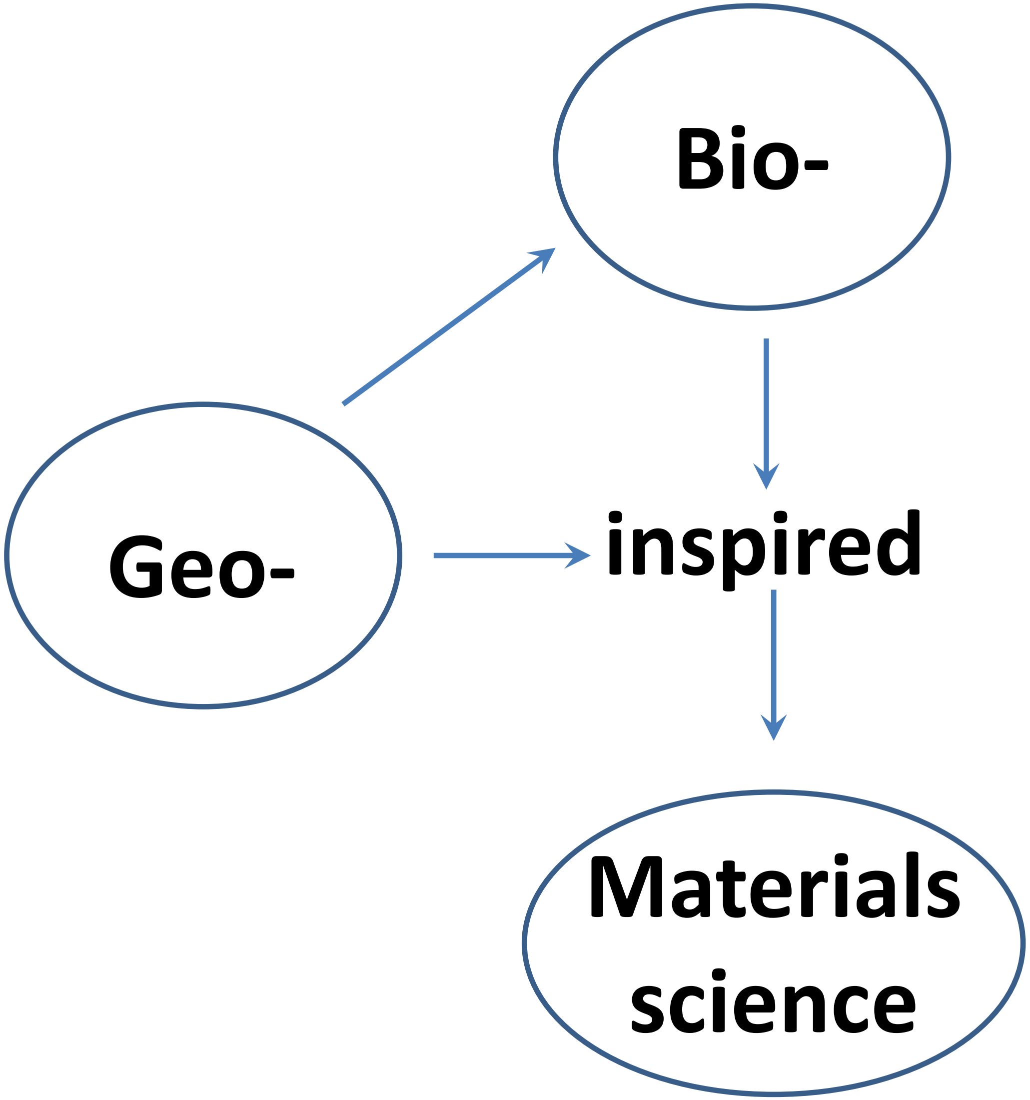
Experiments at NTNU Trondheim: Tommy Kristiansen

Elelctro-hydrodynamics at larger scale:
http://newatlas.com/mit-ionocraft/26908



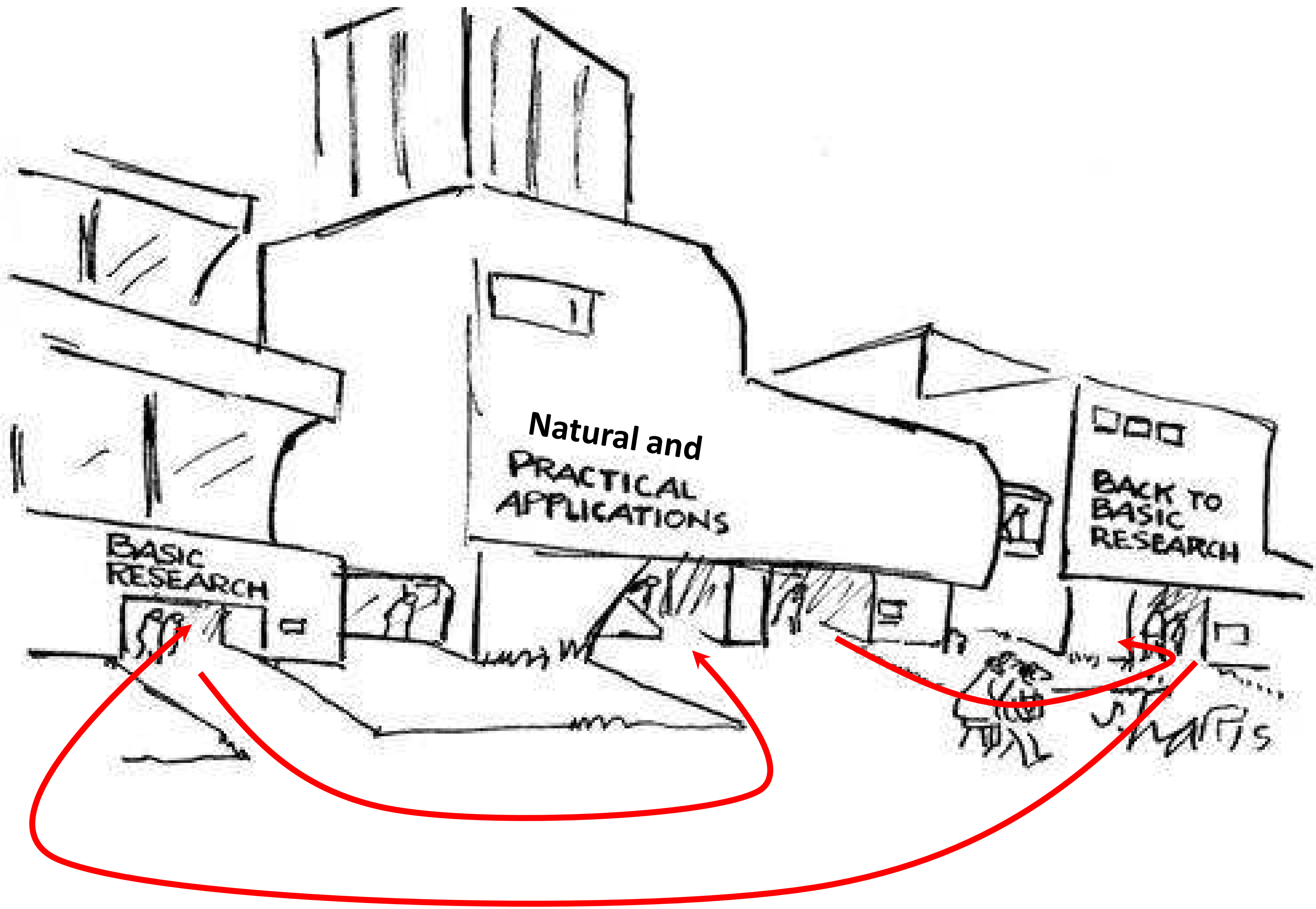


MIT researchers study electro-hydrodynamic thrust
David Szondy David Szondy April 8, 2013


Bio-
Geo-
inspired
Materials science

- Biomaterials and Soft Materials Expand
- Broader Impact Expand
- Electronics, Magnetics and Photonics Expand
- Energy and Sustainability Expand
- Nanomaterials Expand
- Processing and Manufacturing Expand
- Theory, Characterization and Modeling Expand

BM01—Multiscale Mechanobiology and Biomechanics—Theory, Experiments, Computations
BM02—Multiphase Fluids for Materials Science—Droplets, Bubbles and Emulsions
BM03—Biological and Bioinspired Materials for Photonics and Electronics—From Living Organisms to Devices
BM04—Biomaterials for Regenerative Engineering
BM05—Polymer Gels in Materials Science—3D/4D Printing, Fundamentals and Applications
BM06—2D Nanomaterials in Health Care
BM07—Emerging Materials and Devices for Engineering Biological Function and Dynamics
BM08—Materials Design for Neural Interfaces
BM09—Stretchable Bioelectronics—From Sensor Skins to Implants and Soft Robots
BM10—Bioinspired Interfacial Materials with Superwettability
BM11—Modeling, Characterization, Fabrication and Applications of Advanced Biopolymers—Where Form Meets Function
BM12—Biomolecular Self-Assembly for Materials Design



Natural and
PRACTICAL
APPLICATIONS
BASIC
RESEARCH
BACK TO
BASIC
RESEARCH

We are curiosity driven. Very little industrial funding.

«HEY, SAM, THE BIG ROUND YELLOW THING CAME UP AGAIN»

3 lectures:

4th July:

Nanoscience of soft materials

5th July:

The physics of clay minerals: From the nano-scale to the geo-scale, and everything in between

6th July:

Basic physics of drops/emulsions, in relation to applications in EOR, cosmetics, foods etc