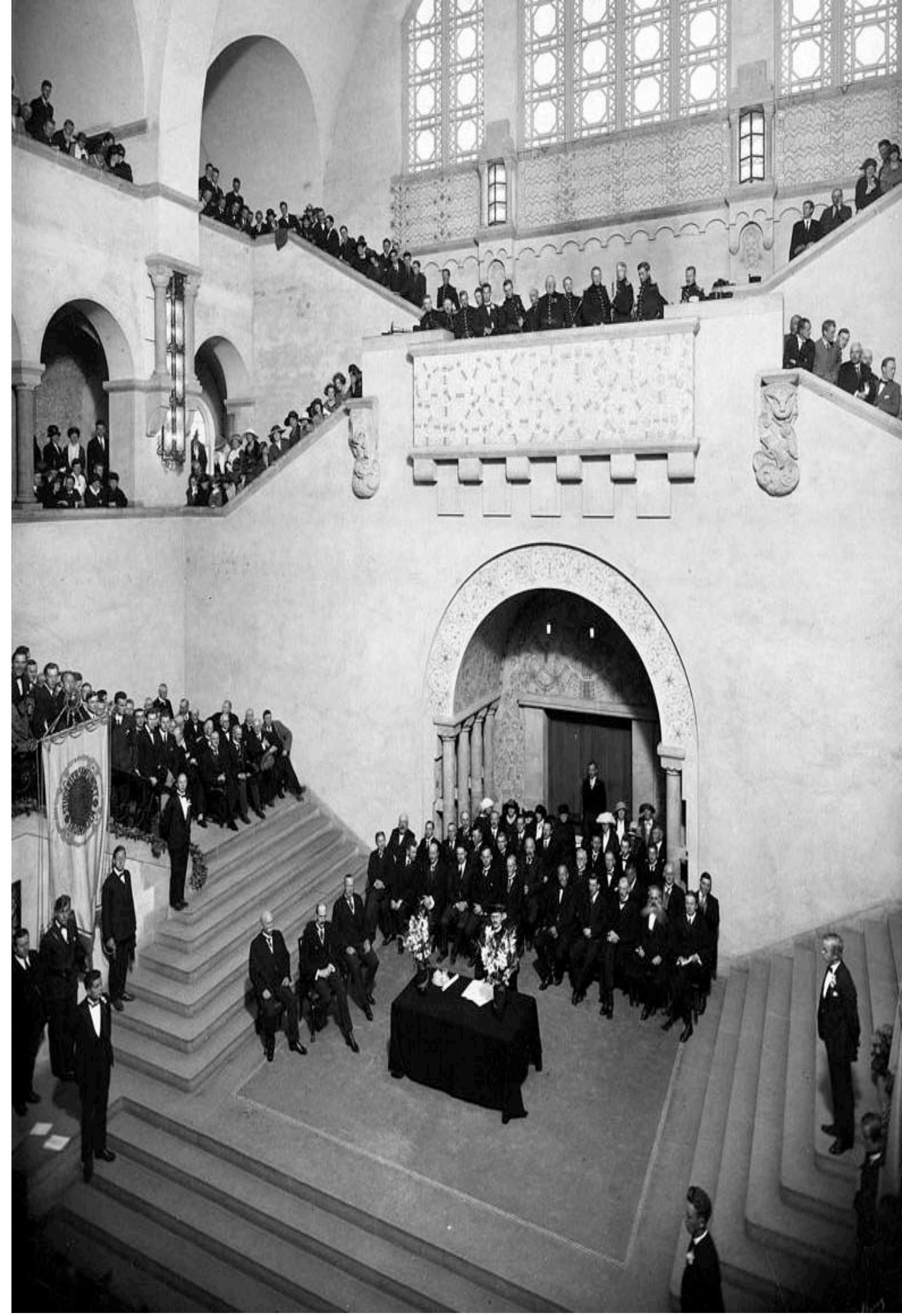
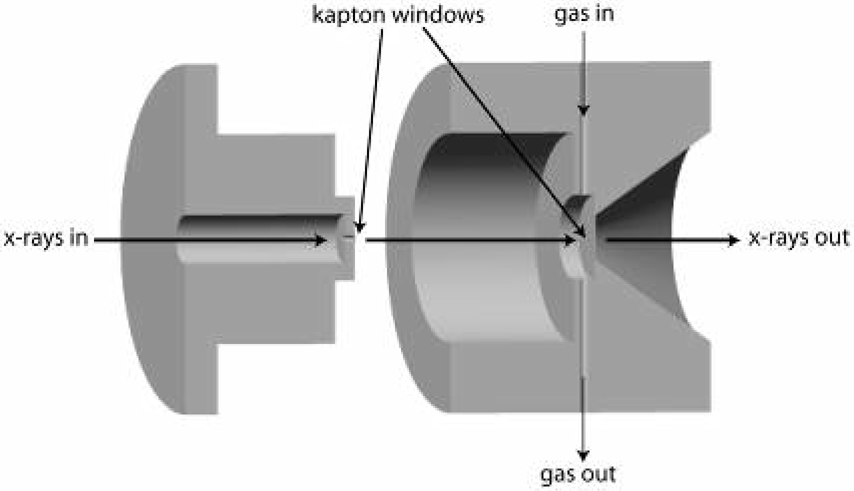



Laboratory for Soft and Complex Matter Studies at NTNU,
Trondheim, Norway:

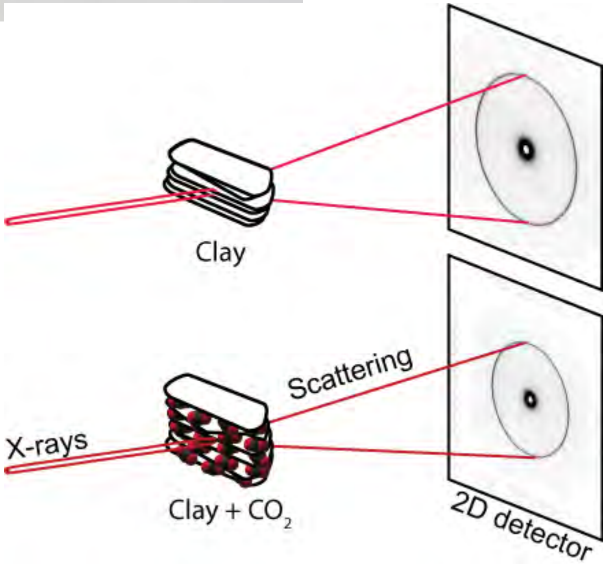
http://folk.ntnu.no/fossumj/lab

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.

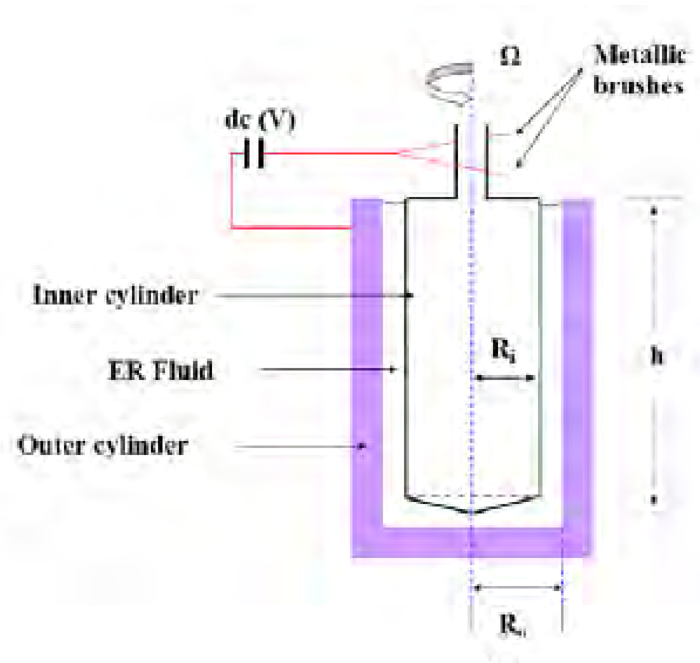
Nano-scale tools:
AFM, Small-Angle X-ray Scattering: SAXS, etc.



Home made sample cell



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

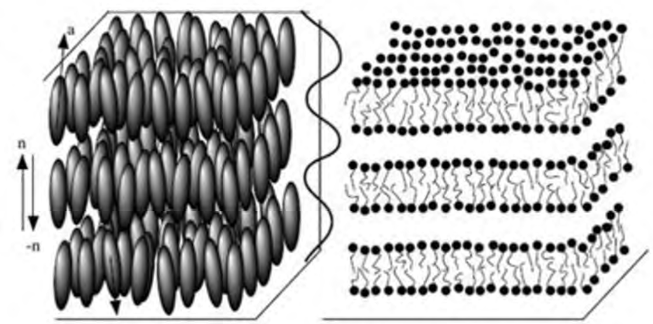


Soft condensed matter:

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.

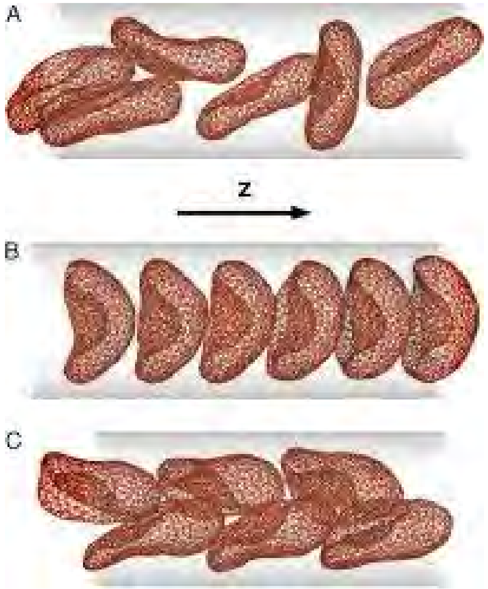
The founder of soft matter science:

Pierre-Gilles de Gennes

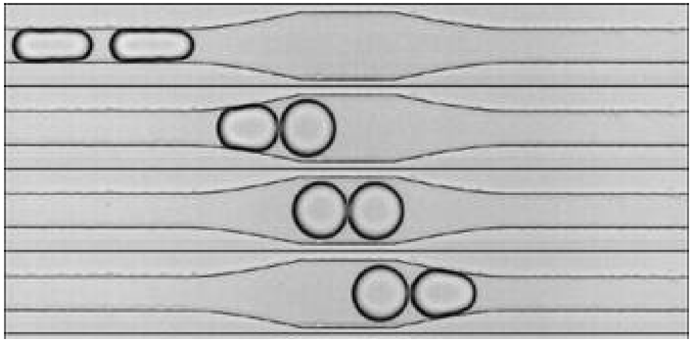
French physicist : 1932 –2007,
Nobel Prize laureate in physics in 1991

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.

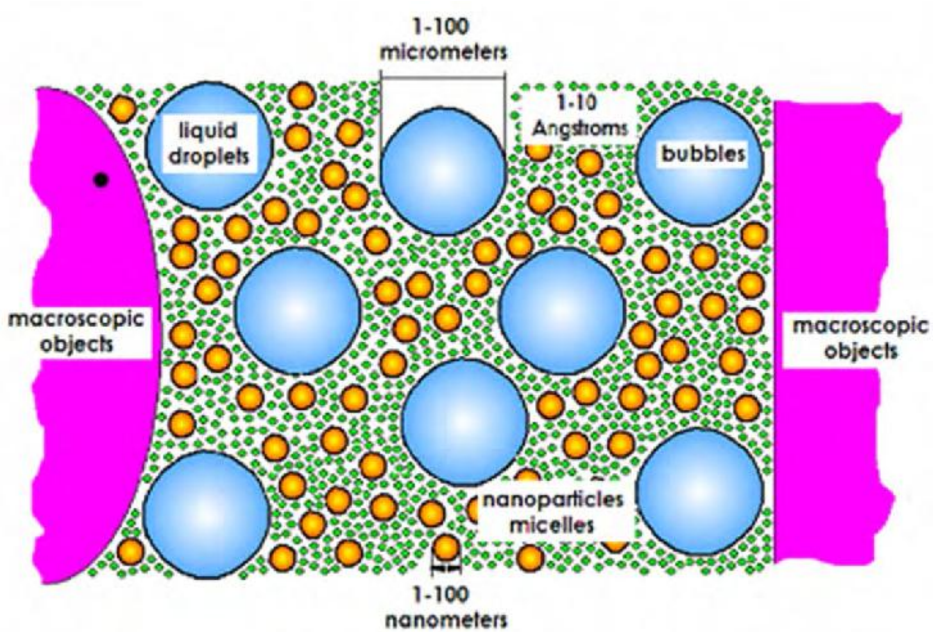
Self-assembly, including Janus and «patchy» particles:

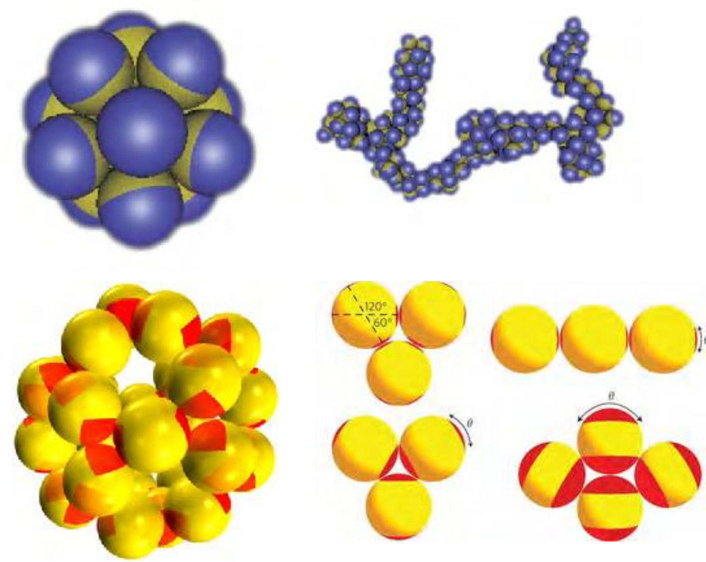
Guided interactions on nano-/meso-scale («Colloids with valence»).

Soft Matter in Confined Environments:

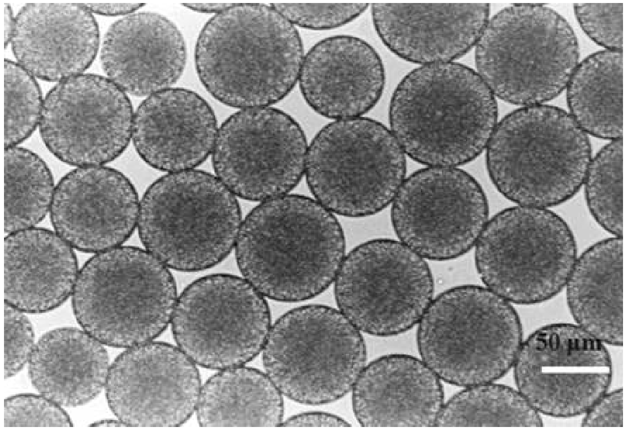
Soft and/or active matter inside porous structures. Microfluidics. Drops.

Etc.





Monodisperse emulsions



18 materialstoday APRIL 2008 | VOLUME 11 | NUMB

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]*

[a]*School of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138, USA*
[b]*School of Chemical Engineering, Sichuan University, Chengdu, Sichuan, 610065, China*
[c]*Amore-Pacific R&D Center, 314-1, Bora-dong, Giheung-gu, Yongin-si, Gyeonggi-Do, 446-729, Korea*
[d]*School of Physics, Georgia Institute of Technology, Atlanta, GA 30332, USA*
[e]*School of Materials Engineering, Purdue University, West Lafayette, IN 47907, USA*
[f]*Department of Physics, Harvard University, Cambridge, MA 02138, USA*
*E-mail: weitz@seas.harvard.edu

Monodisperse emulsions

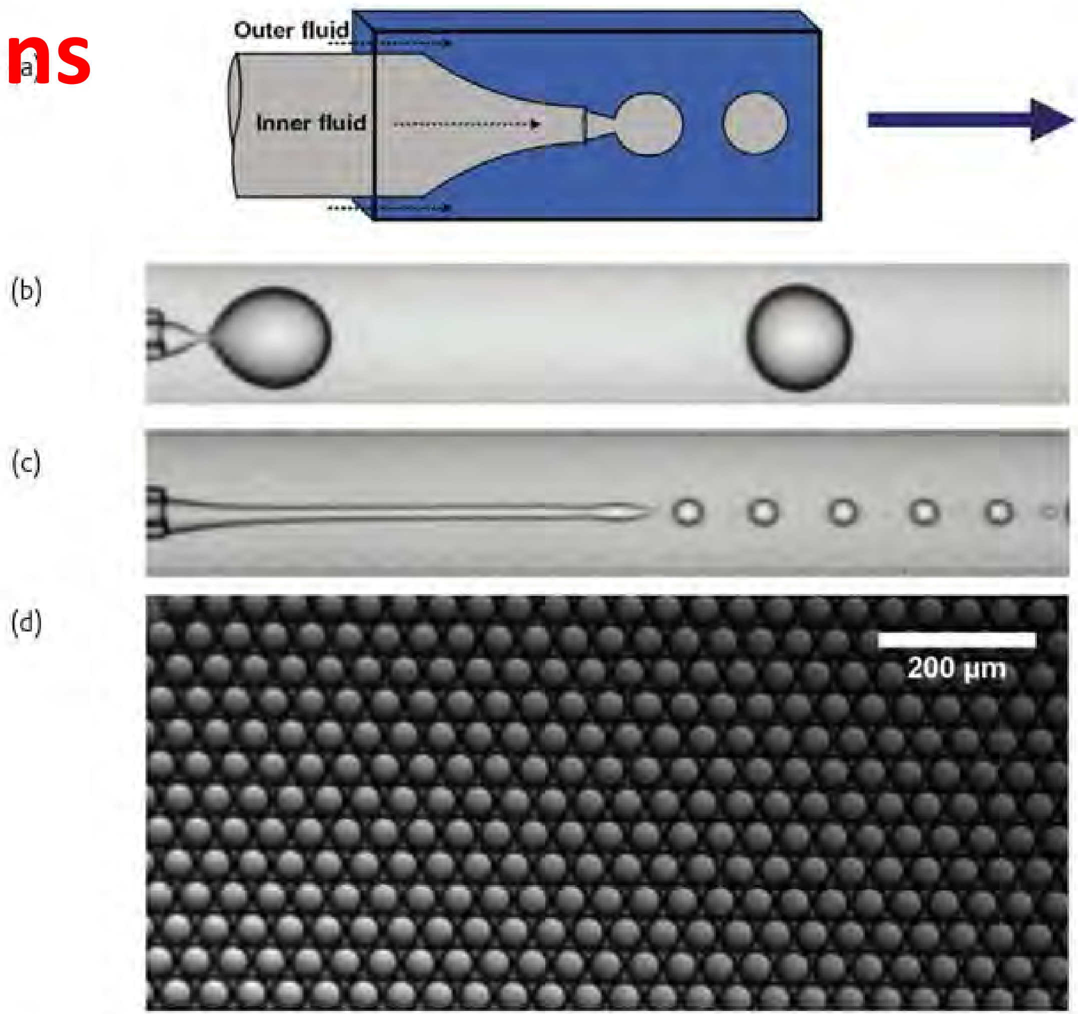
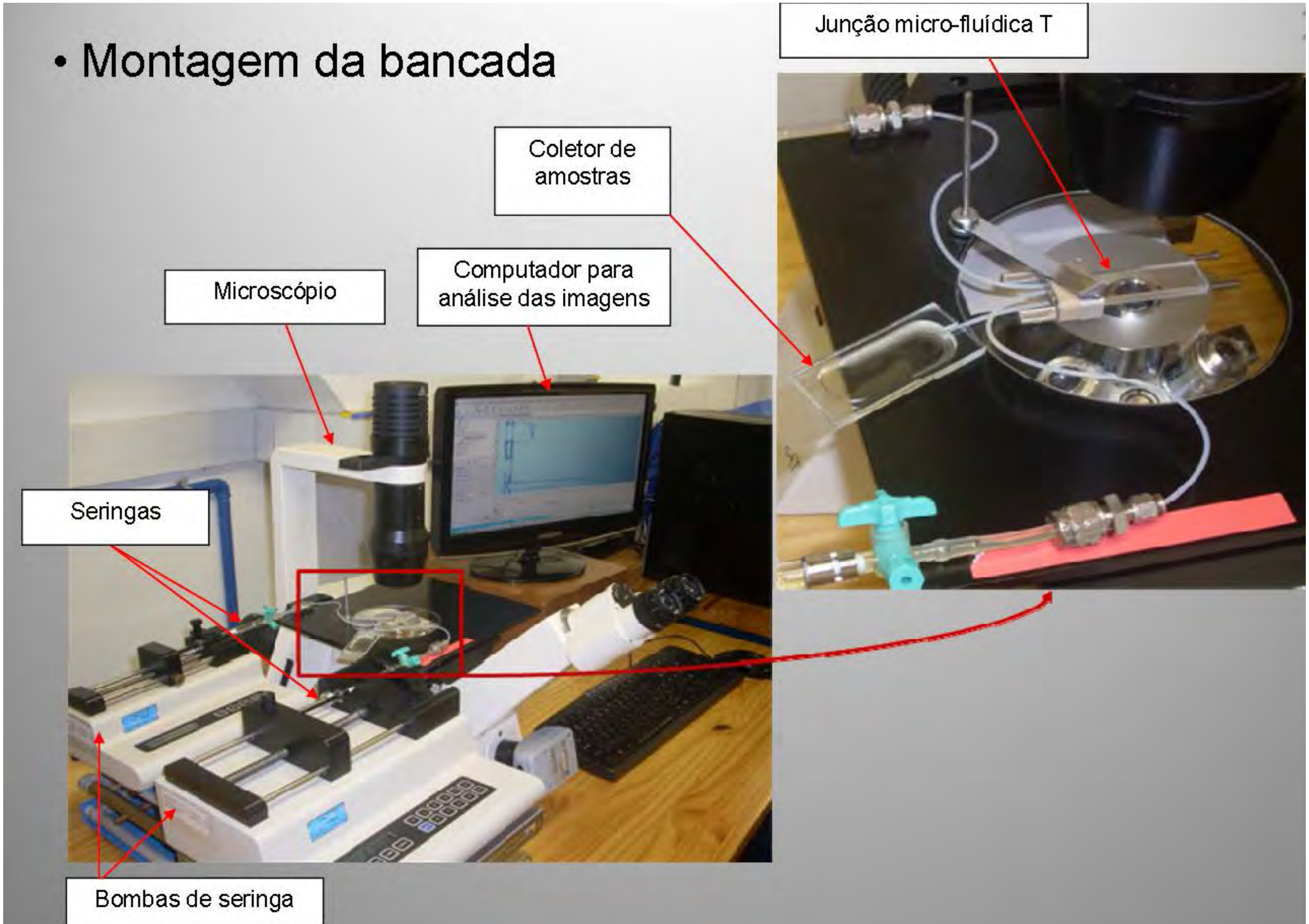


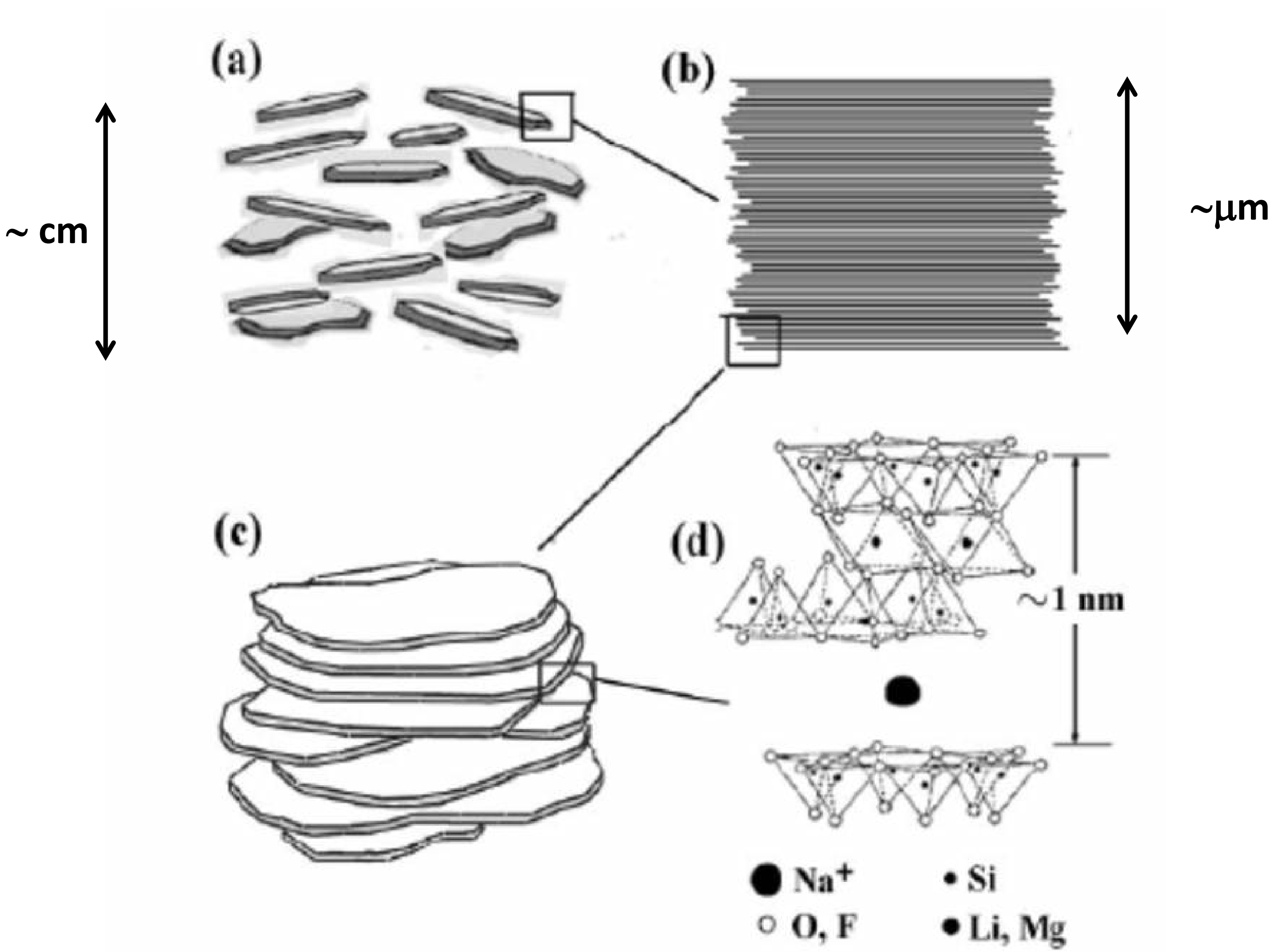
Fig. 2 Single emulsions in a co-flow microfluidic device. (a) Schematic of a co-flow microcapillary device for making droplets. Arrows indicate the flow direction of fluids and drops. (b) Image of drop formation at low flow rates (dripping regime). (c) Image of a narrowing jet generated by increasing 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

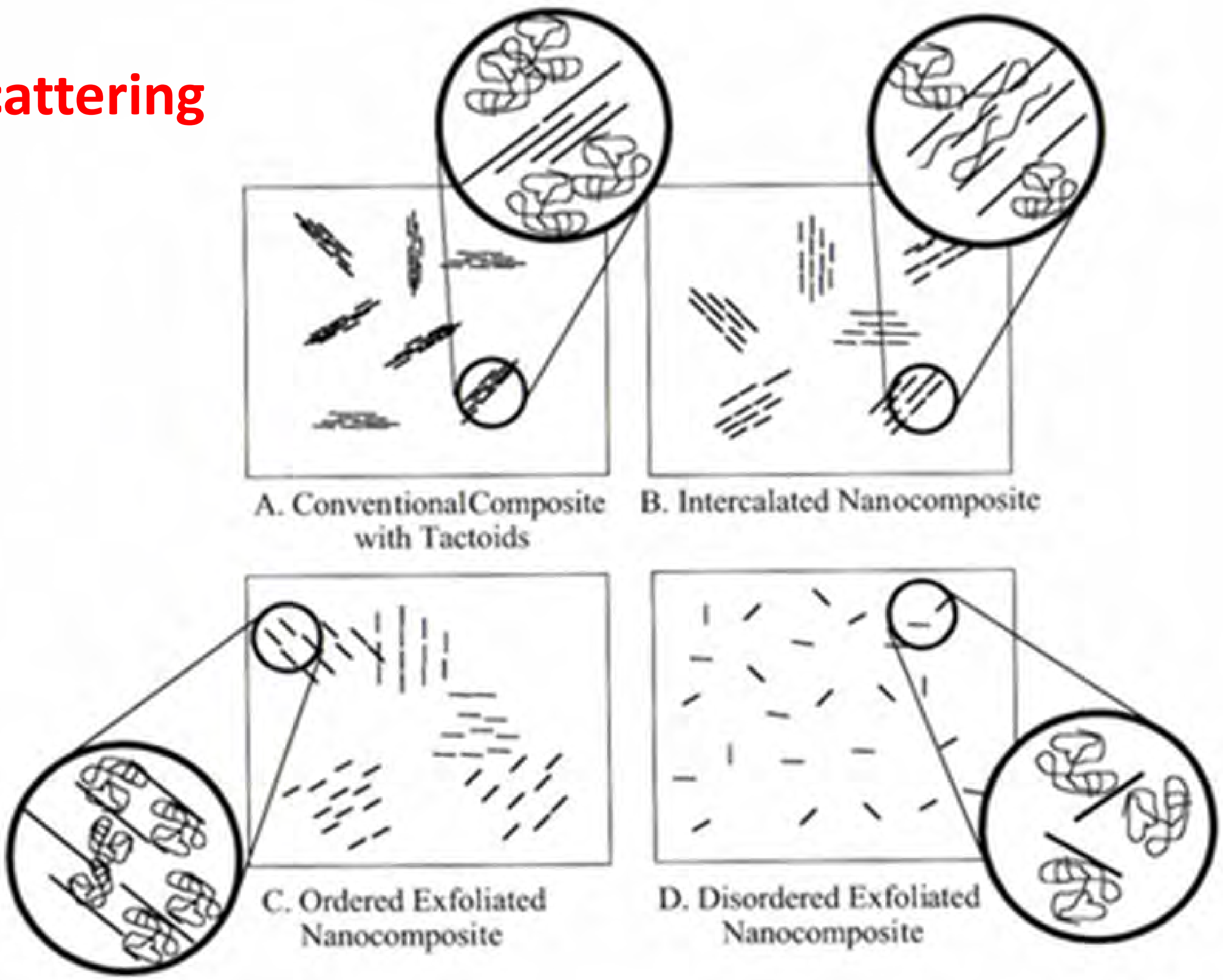
Plastics

Chocolate

Polymer-nano-composite materials

Nano-structures

Tools:
(Synchrotron) X-ray scattering
Neutron scattering

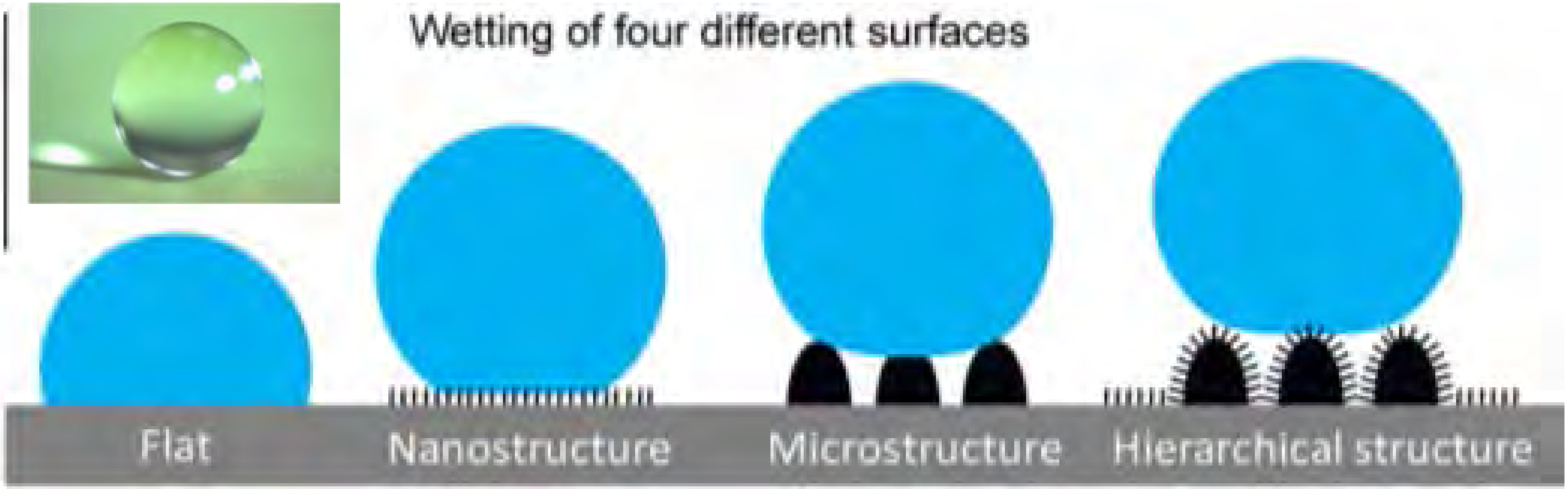


Running projects in the lab:

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).

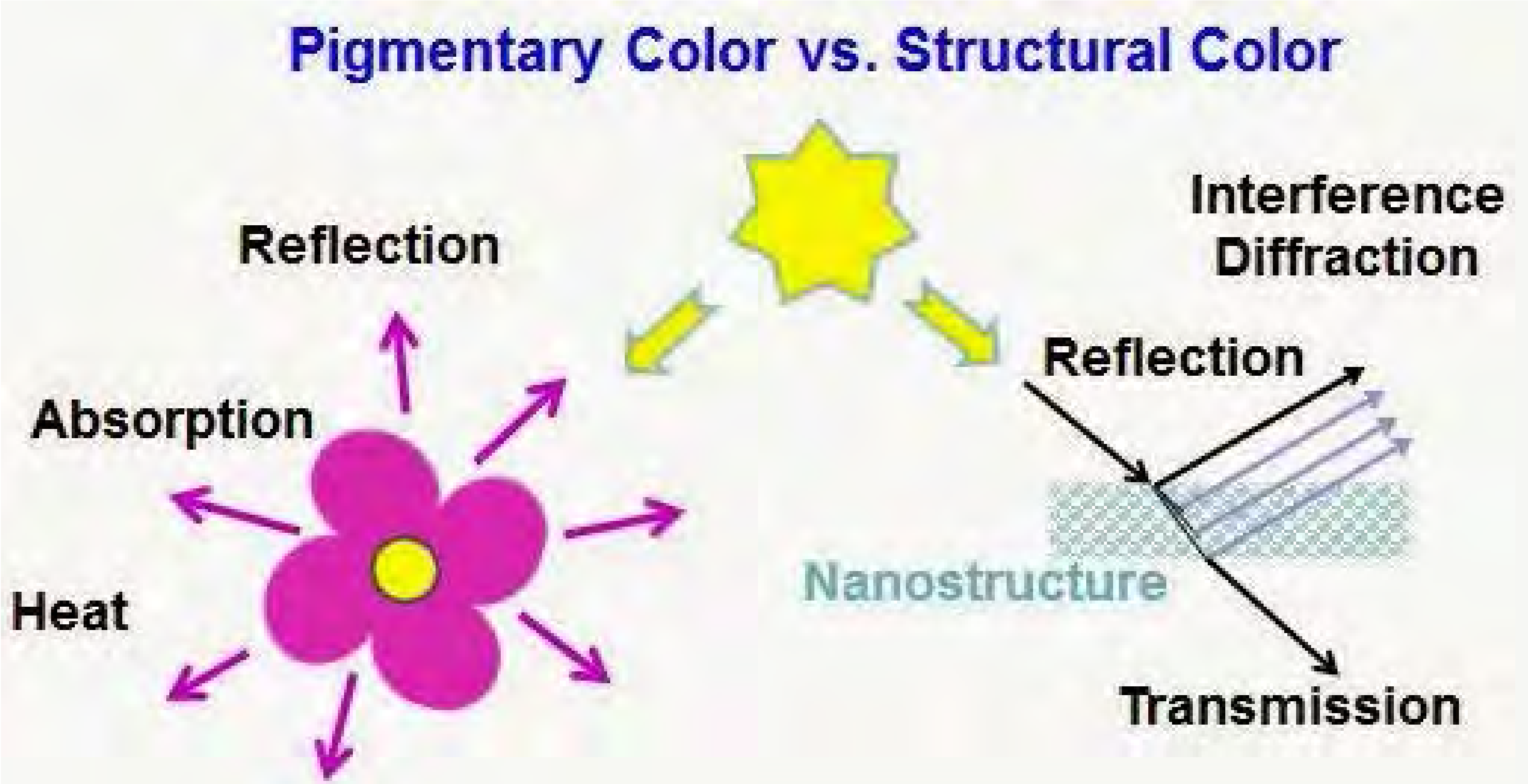
2017-2020: M-Era.Net (administrated by RCN NANO2021) project number 272919 "*Fabricating cellulose nanocomposites for structural coloration*" is a grant of 7 MNOK in total. 2 postdocs based at NTNU and 2 postdocs based in Lisboa are employed in this project. Project manager is Prof. J.O. Fossum from 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).



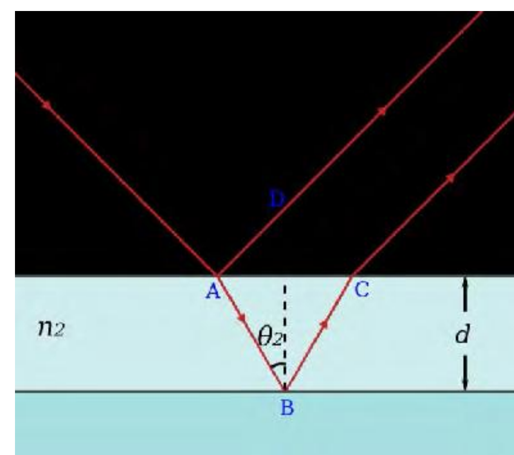
Schematics of wetting of four different surfaces. The largest contact area between the droplet and the surface is given in flat and micro-structured surfaces, is reduced in nano-structured surfaces, and is minimized in hierarchical (nano-micro) structured surfaces. This contains the principle of the 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

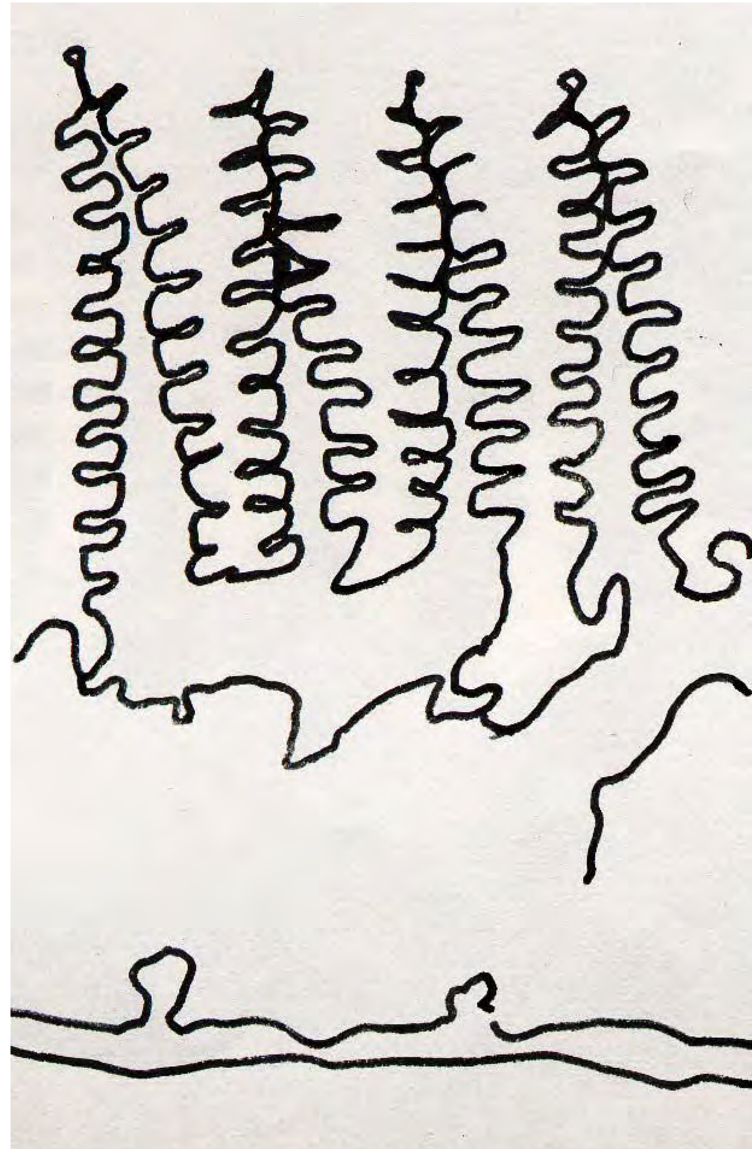


When light falls on a thin film, the waves reflected from the upper and lower surfaces travel different distances depending on the angle, so they interfere.



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.

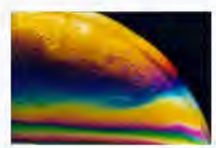
Brilliant green of emerald swallowtail, *Papilio palinurus*, is created by arrays of microscopic bowls that reflect yellow directly and blue from the sides.

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

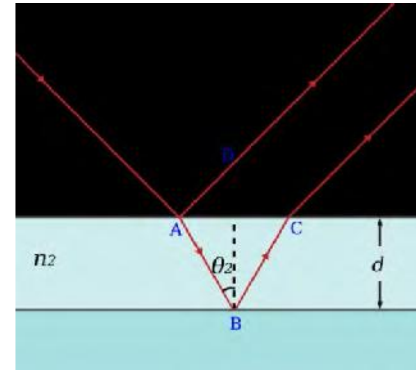
Full-Color Biomimetic Photonic Materials with Iridescent and Non-Iridescent Structural Colors

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

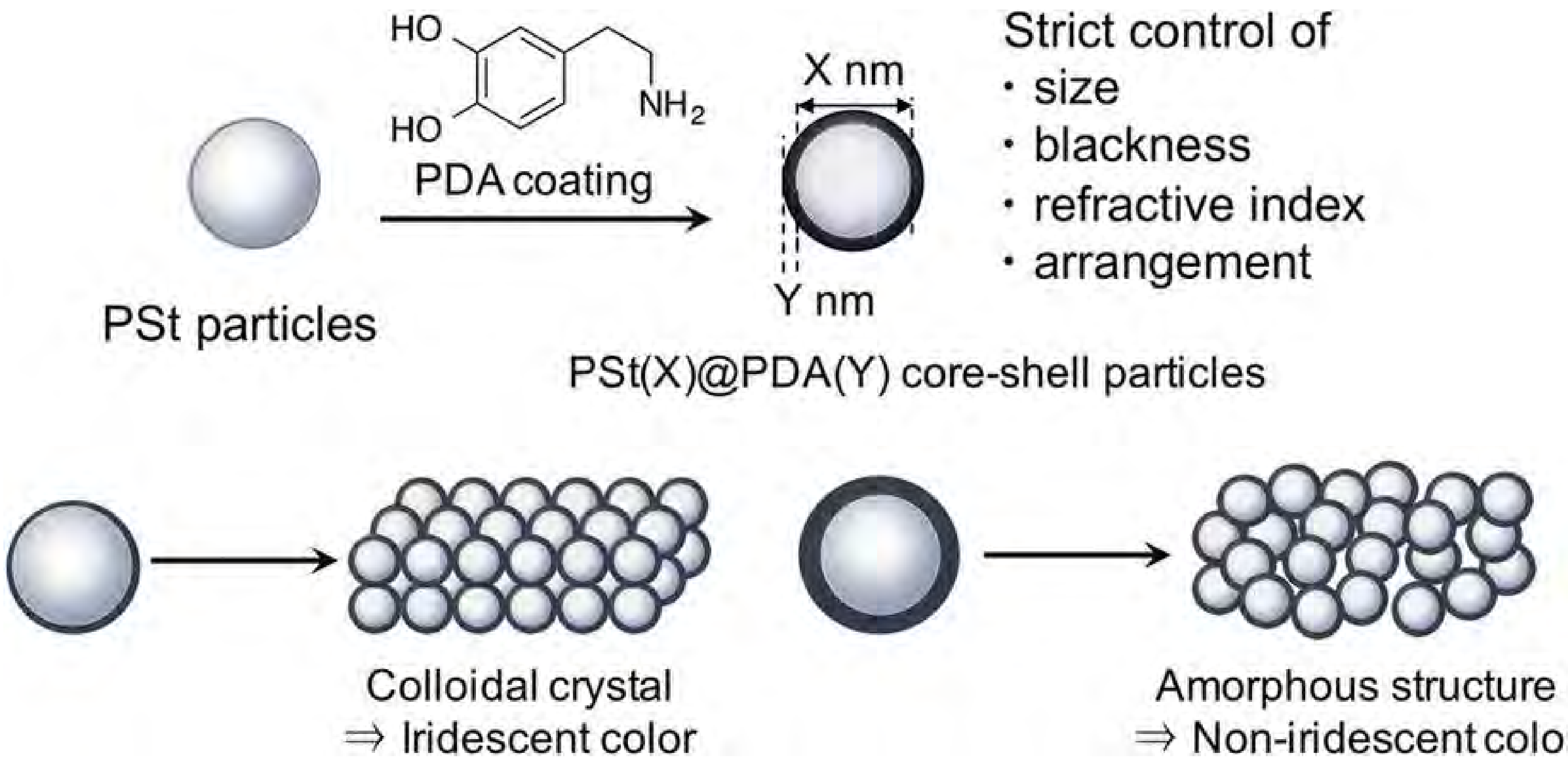
Scientific Reports **6**,
Article number: 33984 (2016)
doi:10.1038/srep33984
Download Citation

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



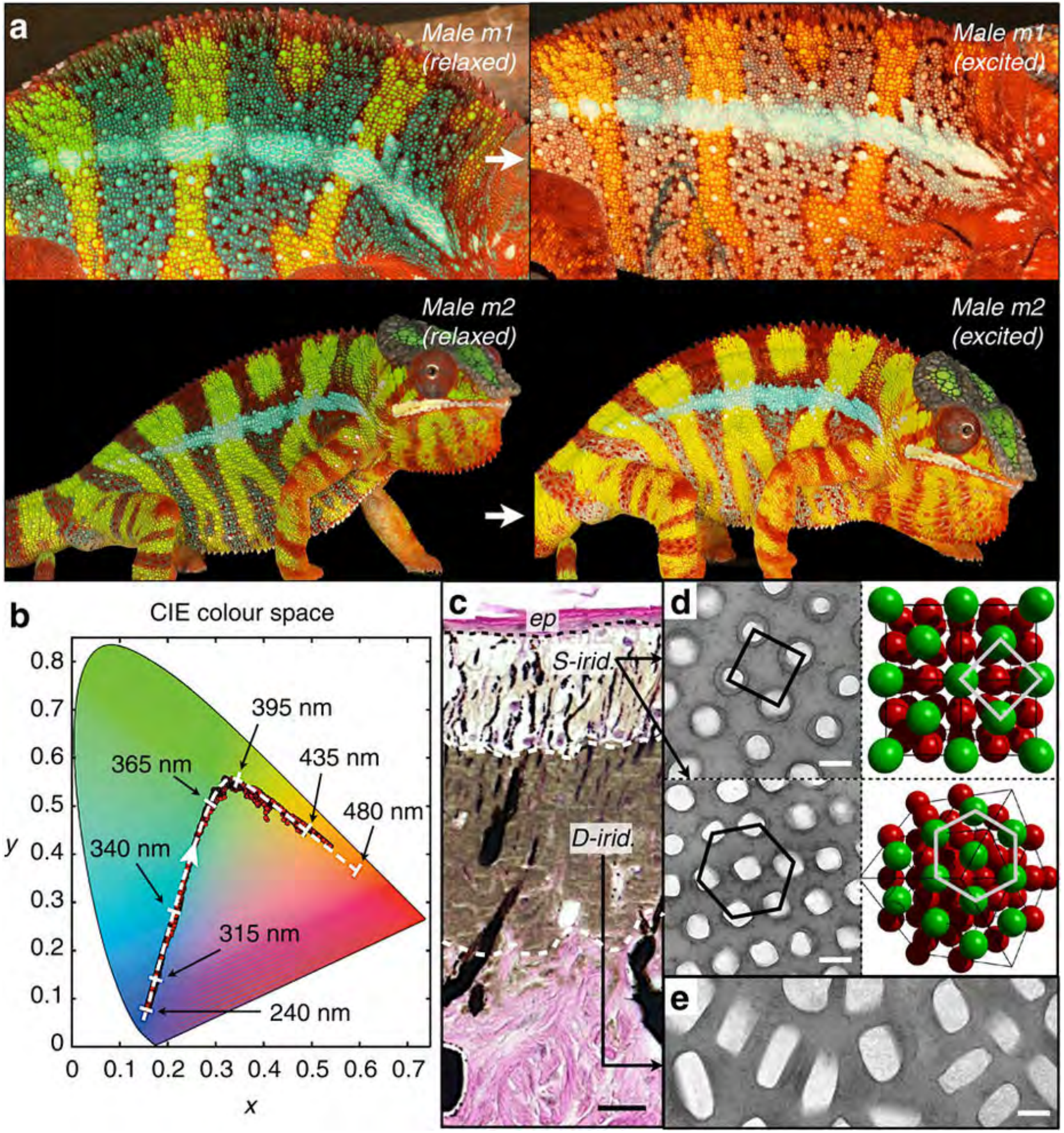
Article | OPEN

Photonic crystals cause active colour change in chameleons

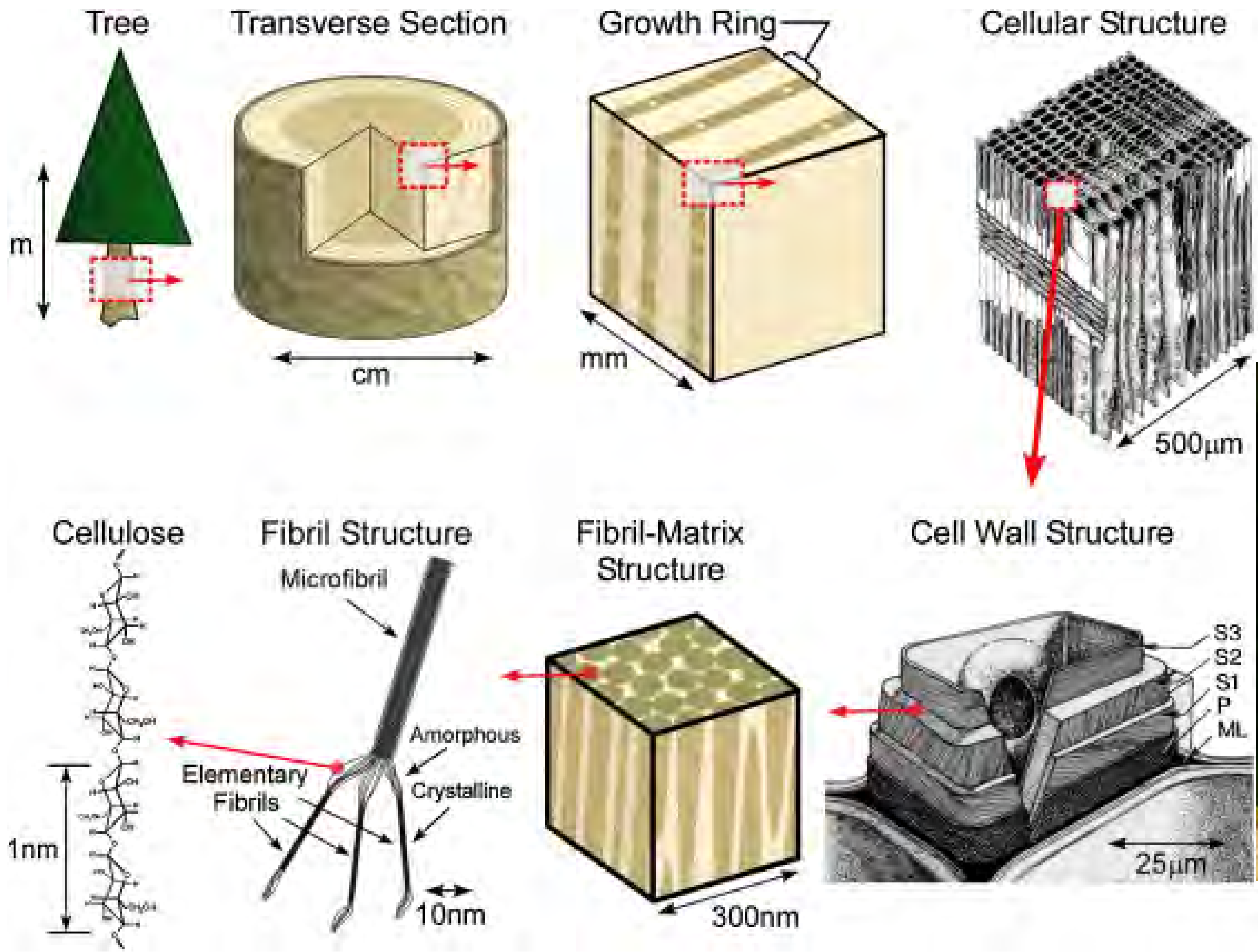
Jérémie Teyssier, Suzanne V. Saenko, Dirk van der Marel & Michel C. Milinkovitch

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

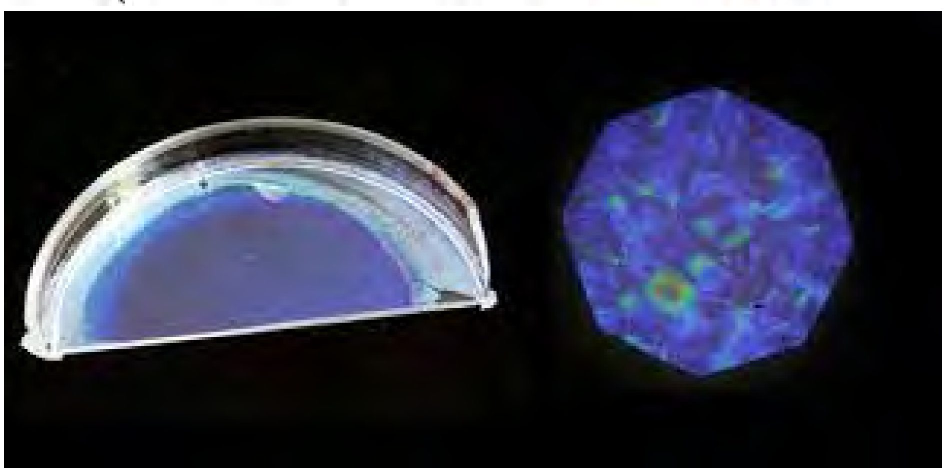
Received: 16 June 2014
Accepted: 22 January 2015
Published online: 10 March 2015



Chameleons can change their color in less than 1 second



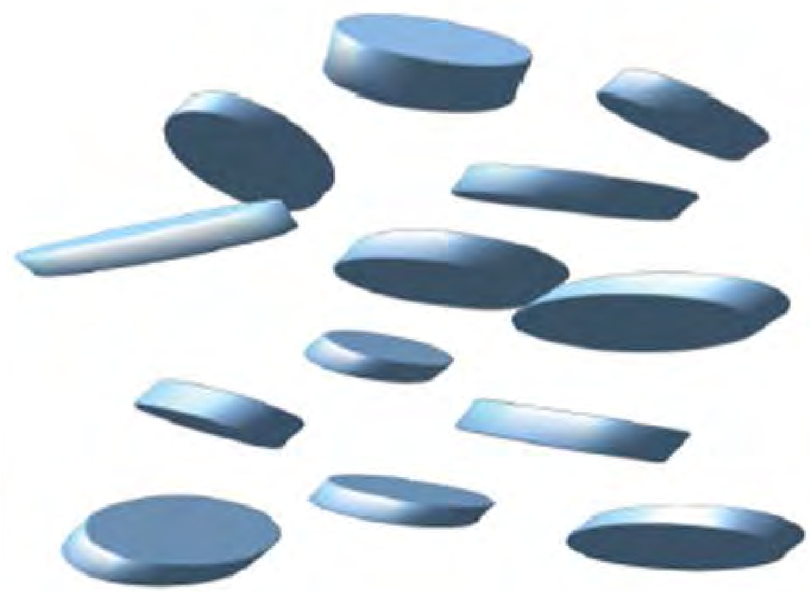
The most intense blue known in nature: African Pollia condensata berries



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.



NTNU – Trondheim
Norwegian University of
Science and Technology

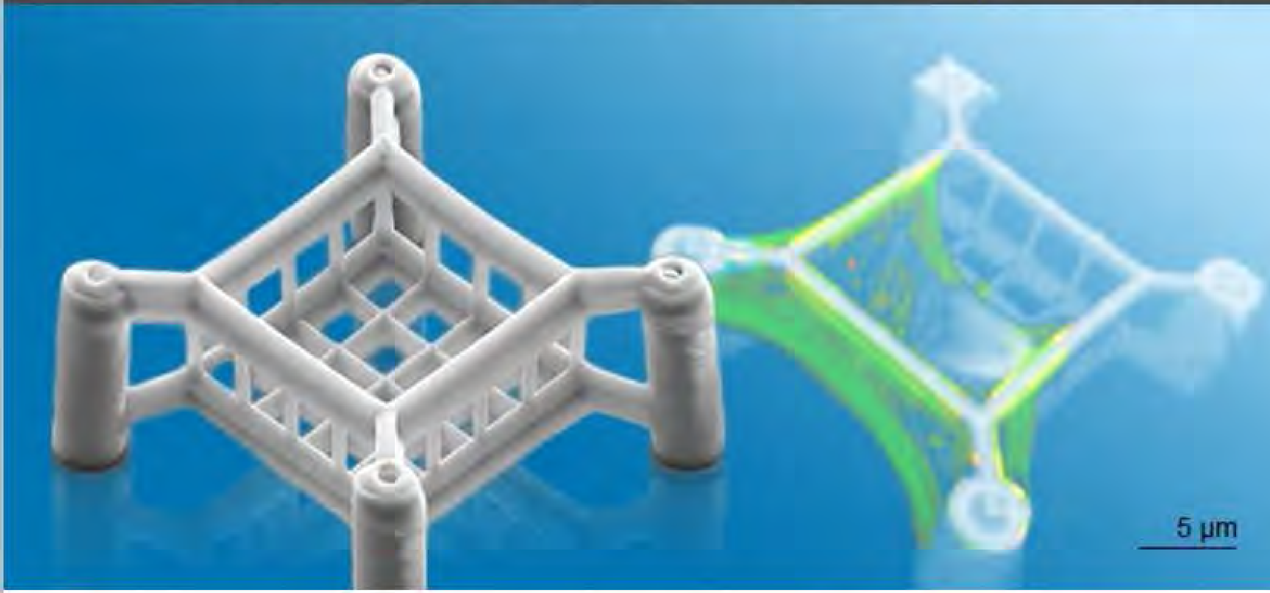
Self-assembly:
Emergent patterns, more is different

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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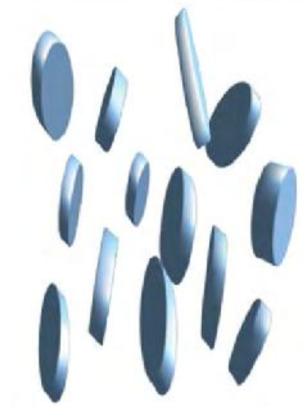
Liquid Crystalline Phases Characterization

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)

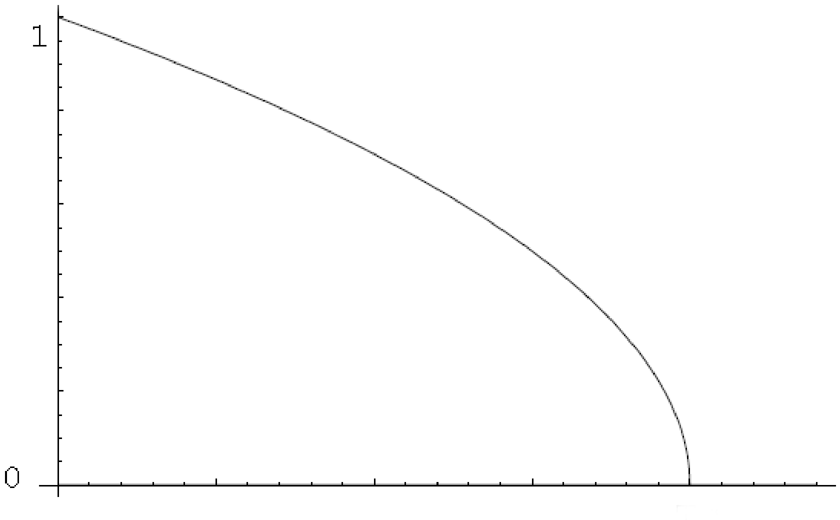


Irving Langmuir (Nobel Prize in Chemistry 1932): 1st experimental work in 1938 on liquid crystal structures in a clay suspension.

J. Chem Phys. 6, 873 (1938)

LCPC = Liquid Crystalline Phases Characterization

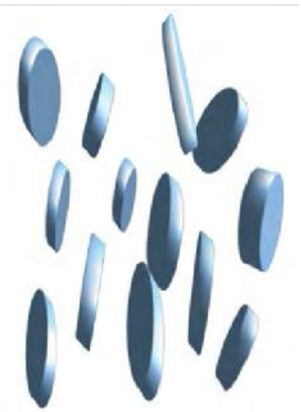
Order Parameter (0<O.P.<1) =
Angular distribution function



Particle concentration
Electric fields
Magnetic fields
Etc.

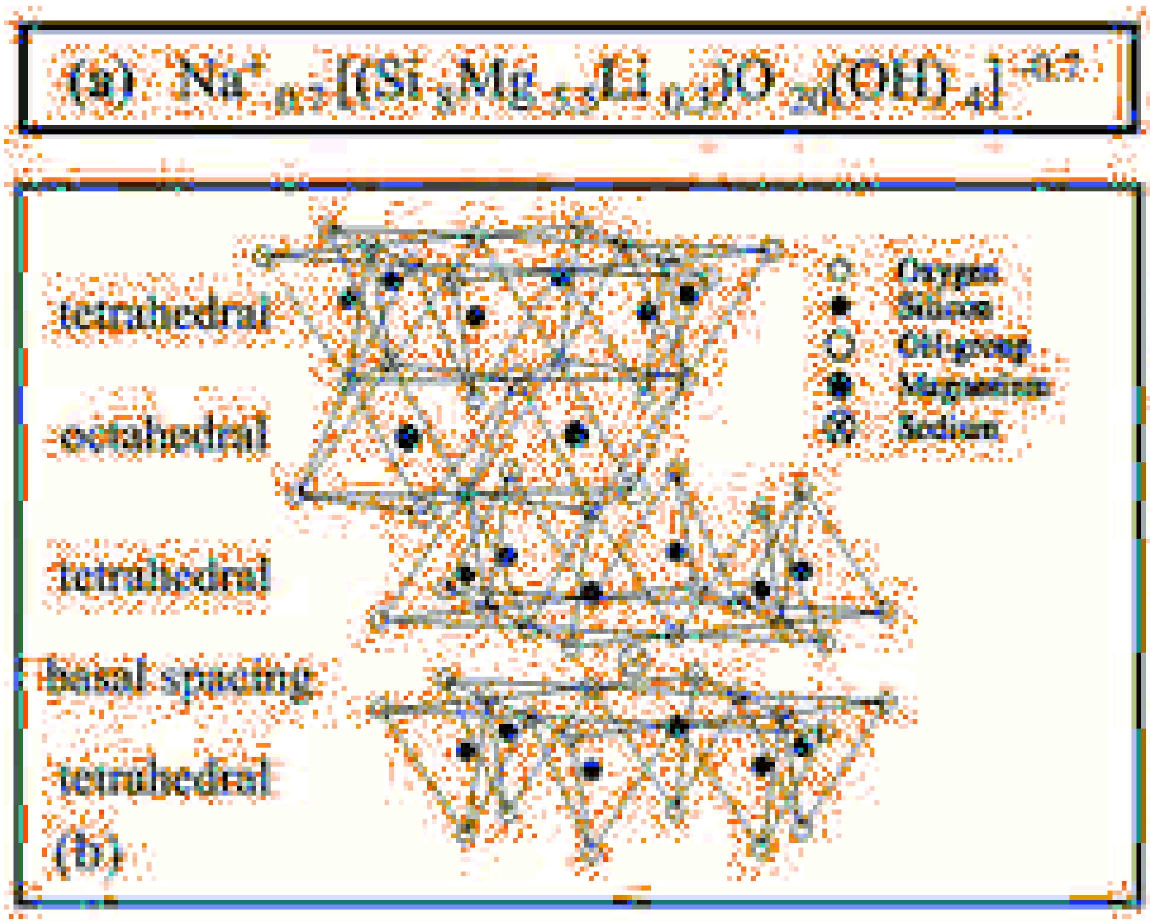
Isotropic
Phase (O.P. = 0)

Nematic
Phase (O.P. > 0)



Self-organization

The most common and most used synthetic clay: Laponite



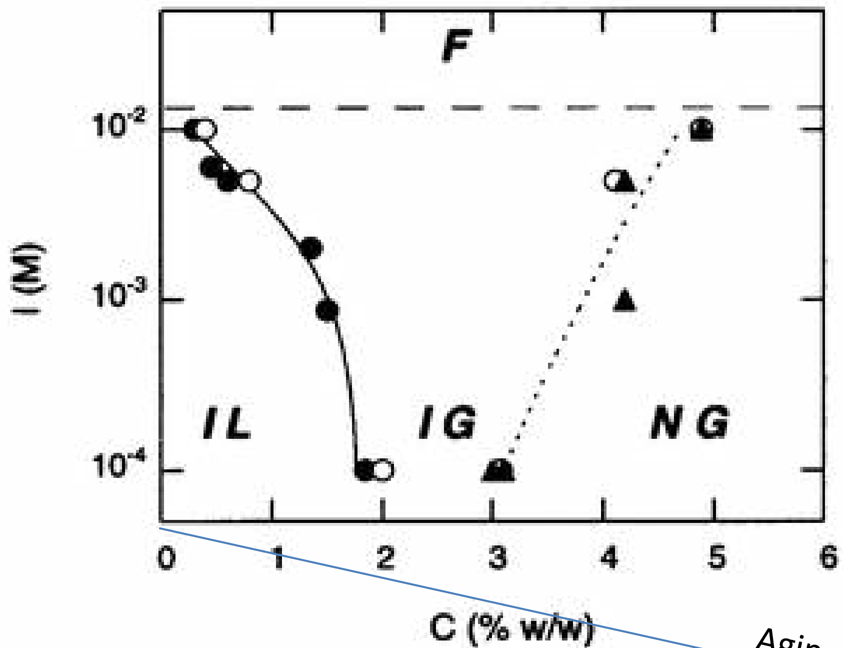
Colloidal gels: **Clay goes patchy**,
W. K. Kegel & H. N. W. Lekkerkerker,
Nature Materials 10, 5–6 (2011)

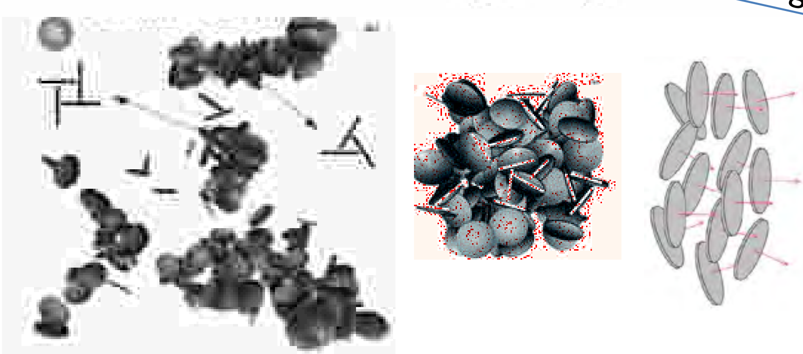
Observation of empty liquids and **equilibrium gels in a colloidal clay**,
B. Ruzicka, E. Zaccarelli, L. Zulian, R. Angelini, M. Sztucki, A. Moussaïd,
T. Narayanan and F. Sciortino, **Nature Materials 10, 56-60 (2011)**

Langmuir **1998**, *14*, 4718–4723

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

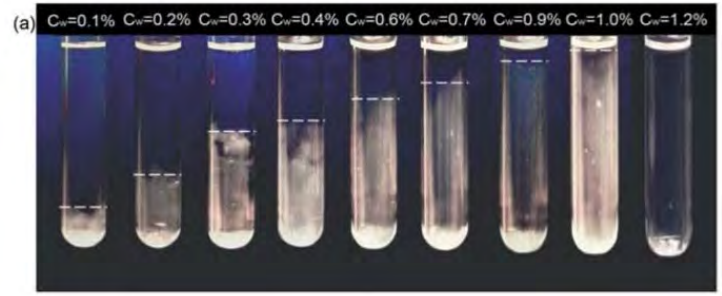
A. Mourchid,* E. Lécolier, H. Van Damme, and P. Levitz*





Aging time

One sample for each point



Soft Matter

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

www.rsc.org/softmatter

A fresh look at the Laponite phase diagram

Barbara Ruzicka*[a] and Emanuela Zaccarelli*[b]