

Complex Liquids and Soft Condensed Matter

Renato Torre e Eleonora Guarini

Lesson 01

torre@lens.unifi.it

Tel 055-4572495

LENS stanza 62

<https://sites.google.com/a/lens.unifi.it/torre/>

R.A.L. Jones, *Soft Condensed Matter*, Oxford Univ. Press 2002

What is Soft Matter ??

Materials in states of matter that are:

«...neither simple liquids nor cristalline solids...»

... better to give some examples

Single component systems:

Complex liquids, Glasses, Liquid Crystals, Polymers, ... , Proteins, ...

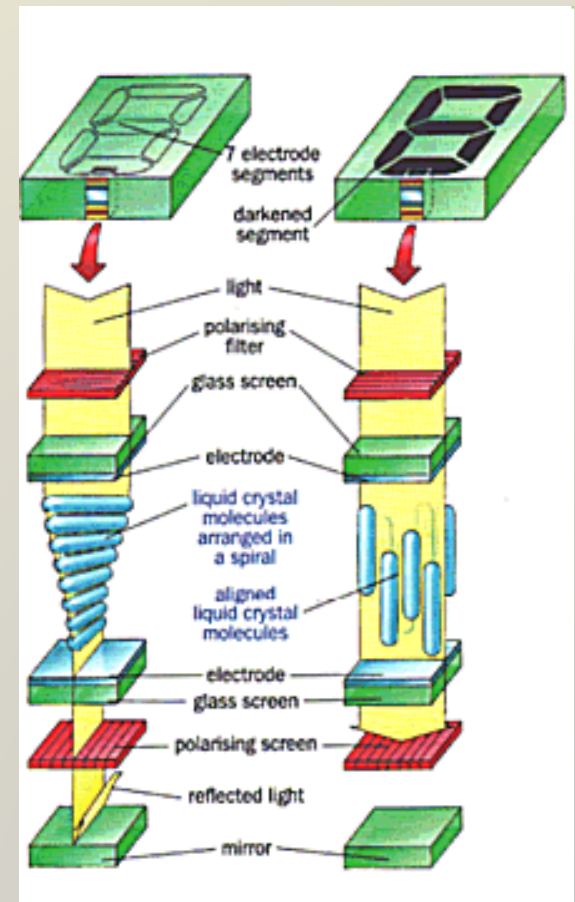
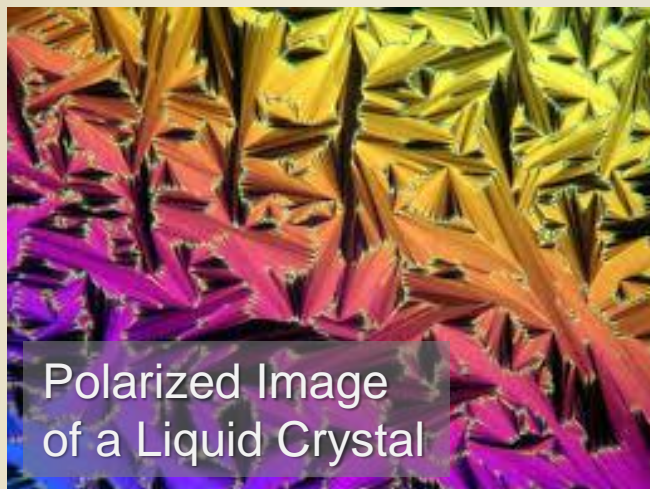
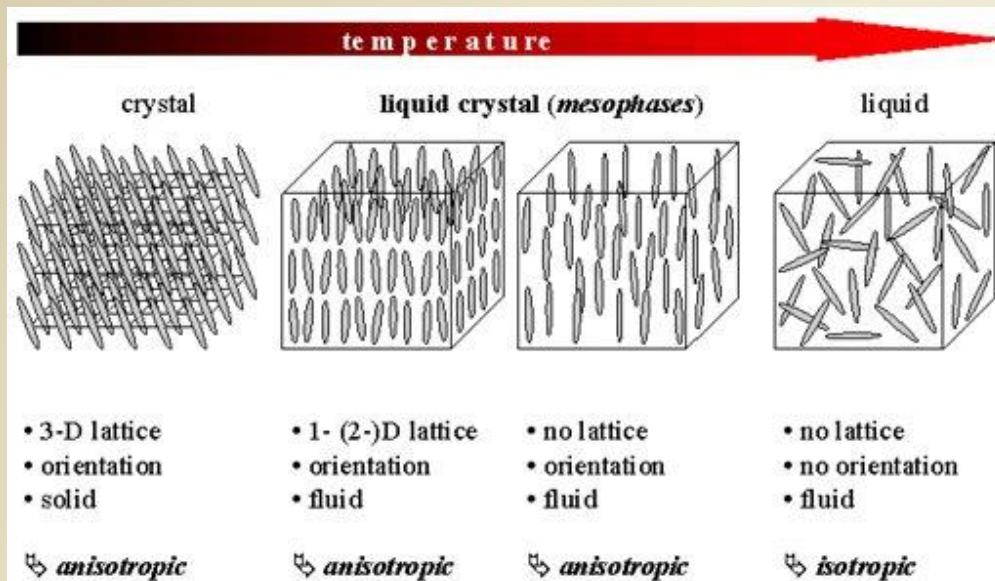
Multiple component systems:

Colloids, Gels, Micelles, ..., Liquid in Nano-Pore, NanoTube Composites, ...

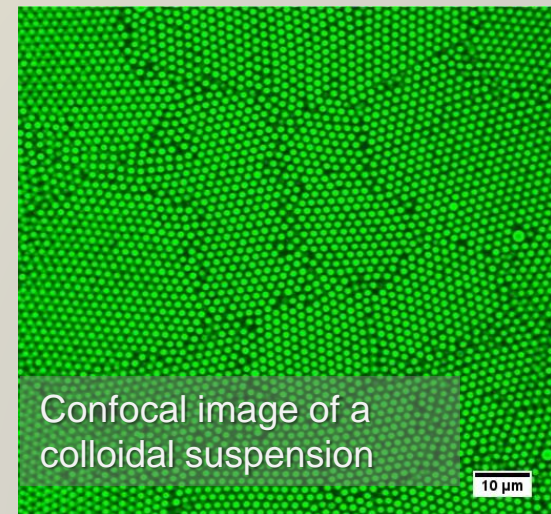
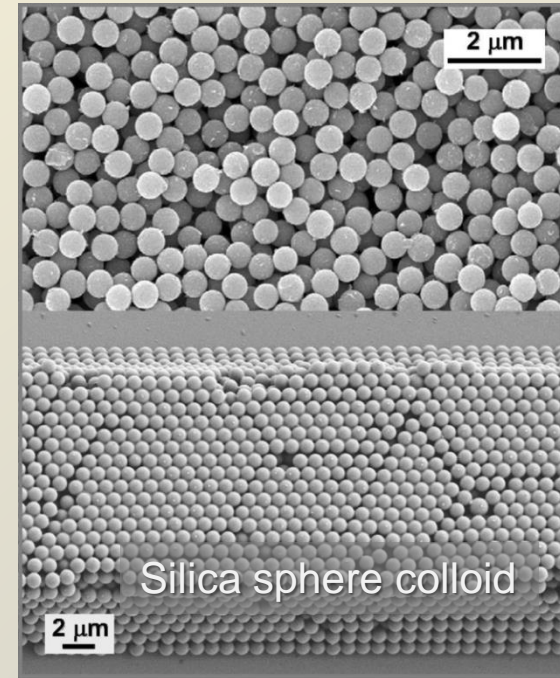
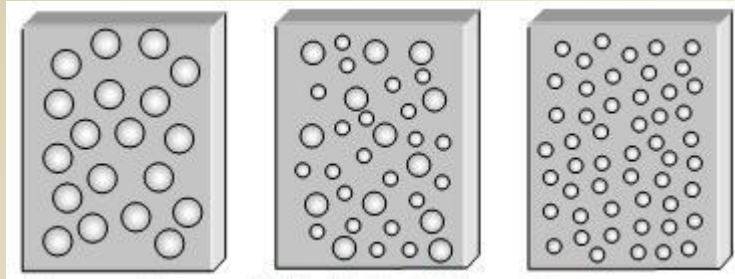
Very complex systems:

Biological Structures, Food and natural structures, ... ,

Liquid Crystals



Colloids



Some Research Groups

<http://www.softmatterworld.org>

Oxford Centre for Soft and Biological Matter
Physical and Colloid Chemistry, Utrecht University
Soft Condensed Matter group, Utrecht University
AMOLF Institute, Amsterdam, Netherlands
New England Complex Fluids Workgroup
Brandeis Complex Fluids Group
Polymer and Soft Matter Dynamics Lab, Université Libre de Bruxelles, Brussels, Belgium
Damien Baigl Laboratory, ENS Paris, France
Soft Matter Physics Group at University of Leipzig (Humboldt) Germany
Shock Waves in Soft Matter, Institute for the Physics of Soft Matter, Leibniz Universität Hannover, Germany
Computational Physics Group, University of Central Lancashire, UK
Theory and Computational Physics, Department of Physics, University of Cambridge, UK
Dynamics of Complex Fluids department at the Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany
Soft Matter Group at van der Waals-Zeeman Institute, University of Amsterdam, NL
Soft Matter Chemistry Group, University of Leiden, NL
Freiburg Institute for Advanced Studies (FRIAS), School of Soft Matter Research, University of Freiburg, D
Physics of Soft and Partially Ordered Matter Faculty of Mathematics and Physics University of Augsburg, Germany
Soft Matter and Molecular Biophysics Group, Department of Applied Physics, University of Santiago de Compostela, Spain
Soft Matter Team, Laboratoire Charles Coulomb, CNRS and University Montpellier 2, Montpellier, France
Matière et Systèmes Complexes, CNRS, Université Paris Diderot, France
Laboratoire de Physique des Solides, CNRS, Université Paris 11, Orsay, France
Matière molle et chimie, CNRS, ESPCI, Paris, France
Physique et Mécanique des Milieux Hétérogènes, CNRS, ESPCI, Paris, France
Physico-chimie des Polymères et Milieux Dispersés Sciences et Ingénierie de la Matière Molle, ESPCI Paris, France
Laboratoire Colloïdes et Matériaux Divisés, CNRS, ESPCI, Paris
Group of Microfluidics, Chemical Organisation and Nanotechnology, ENS Paris, France
Physicochimie Curie, Institut Curie Paris, France
Laboratoire Interdisciplinaire sur l'Organisation Nanométrique et Supramoléculaire, CEA Saclay
Service de Physique de l'État Condensé, CEA Saclay
Institut de Physique de Rennes, équipe matière molle, CNRS, Université de Rennes 1, France
Institut Charles Sadron, CNRS, Université de Strasbourg, France
Centre de Recherche Paul Pascal, Bordeaux, Paris, France
Laboratoire du Futur, CNRS, Rhodia, Bordeaux, France
LPMCN, équipe Liquides aux interfaces, CNRS, Université de Lyon 1, France
Polymer and Soft Matter Team, Department of Physics, Université Libre de Bruxelles, Brussels, Belgium
Interface and complex fluids laboratory, Université de Mons, Belgium
Laboratoire de Physique, CNRS, ENS Lyon, Lyon, France
Groups of Prof. Fuchs and Maret, University of Konstanz, Germany
Groups of Prof. Hinrichs and Weiss, University of Hohenheim, Stuttgart, Germany

Center for Soft Matter Research New York University, US
Soft Matter Physics Group (Weitzlab), Harvard University, US
Chicago Soft Matter Collective
The Institute for Soft Matter Synthesis and Metrology at Georgetown University
Nagel Group, University of Chicago, US
Yang Zhang's Group, University of Illinois at Urbana-Champaign, US
David Grier's Group, New York University, US
Eric Weeks' Group, Emory University, US
Soft Matter Lab, Memorial University of Newfoundland, Canada
Polymer and Condensed Matter Physics Group, Greg McKenna's Labs, Texas Tech University, US
Prof. Linda Hirst's soft matter physics group, University of California, Merced, US
Losert Lab, University of Maryland, US

Google, 92.700.000 hits on web

Google scholar, 2.460.000 publications, about 60.000 in last 2 years

Nature and Nature Materials, Science and PNAS

Soft Matter

Physical Review E

The European Physical Journal E

PCCP and many other....

Without Asia-China

.... and ITALY

What's the Physic point of view ??

Understanding and modeling of:

« ... *Universal and Common Properties...* »

... either from experiments and theories

Thermodynamics:

Equilibrium vs Non-Equilibrium, Phase Transition , Entropy vs Energy, ... ,

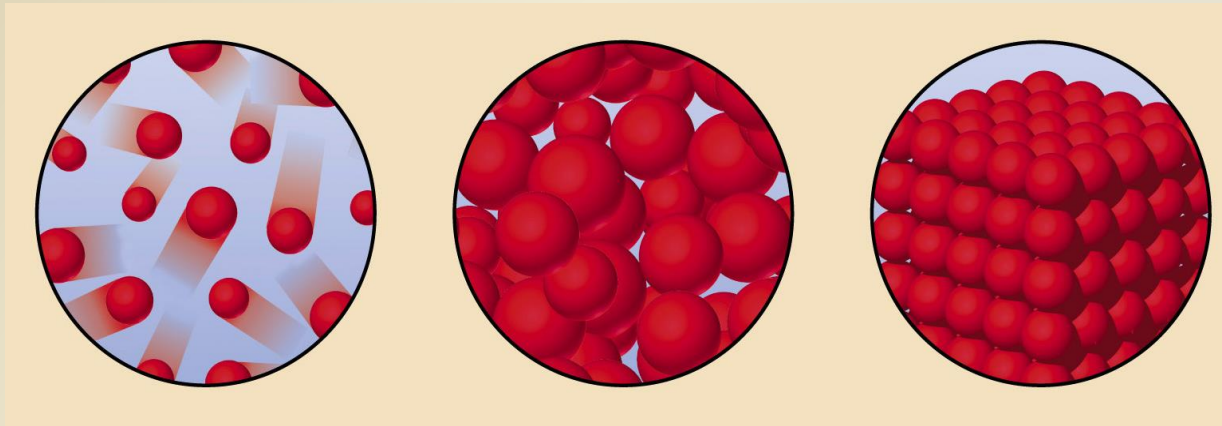
Structure and Topology:

Length Scales, Correlation and Distribution, Assembling, ... ,

Dynamics :

Viscosity vs Elasticity, Transport and Diffusion, Vibrations , ...

Energy vs Potential



Kinetic Energy
 $E_c = \frac{1}{2} m v^2$

vs

Potential Energy
 $E_p = V(r_g)$

High Temperature

$$E_c \gg E_p$$

Gas phase

Low Temperature

$$E_c \ll E_p$$

Crystal/Solid phase

Intermediate Temp.

$$E_c \sim E_p$$

Liquid and Soft Matter

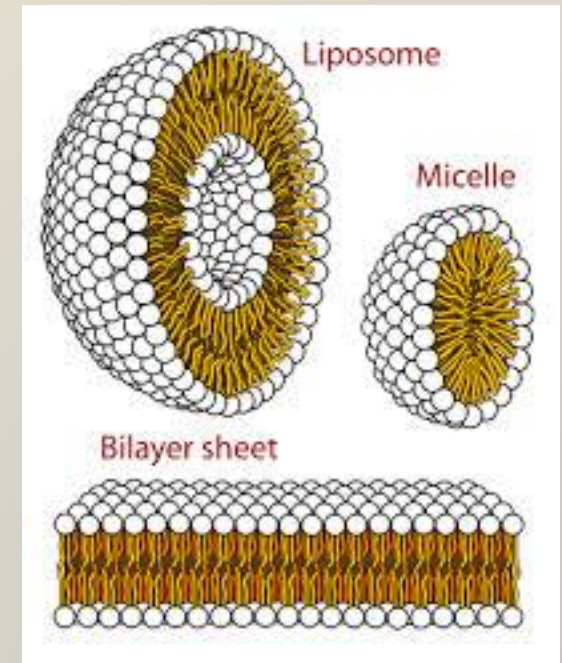
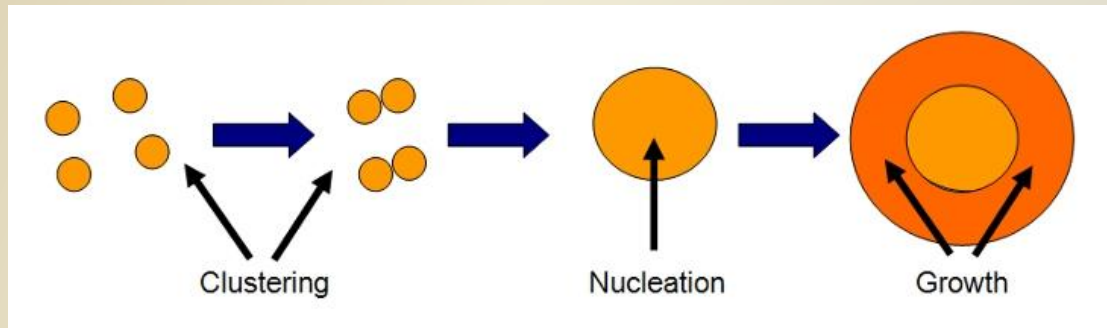
$$E_c \sim E_p$$

Structure and Dynamics

Intermolecular forces try to keep a stable structure.

The kinetic energy makes the molecules moving.

The balance between these generates a plethora of meso-phases and soft matter systems, as well as it regulates Nucleation and Self-Assembly



The time-scale of structure modifications is a key parameter, named the Relaxation Time.

Strange Phenomena in Soft Matter

Non-Newtonian Fluids: Shear Thickening



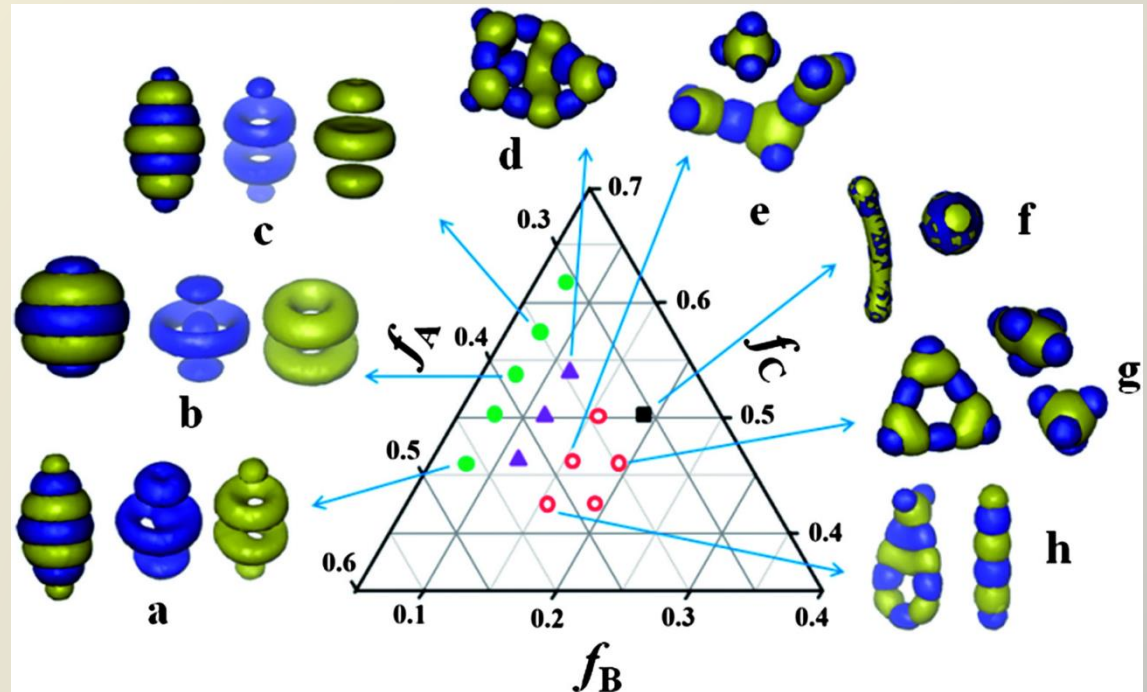
www.youtube.com/watch?v=bLiNHqwgWaQ

$$E_c \sim E_p$$

Equilibrium vs Non-Equilibrium

Soft matter systems are presenting complex equilibrium phase diagrams reach of phase transitions.

They are prone to show long lived a relatively stable non-equilibrium state.



micelle formation by self-assembly of star polymer in dilute solution