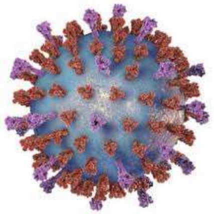
La Fisica della Materia Soffice
...a Perugia

Corso: *Complementi di Fisica della Materia*

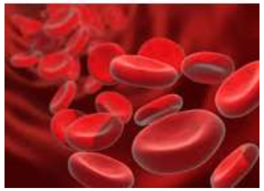
Prof.ssa: *Silvia Corezzi*

Cos’è la Materia Soffice?

Materia facilmente deformabile sotto l’azione di una perturbazione.
Ad esempio: liquidi, polimeri, colloidi, surfattanti, cristalli liquidi, materia granulare
(materia biologica e sintetica, gel, vetri)



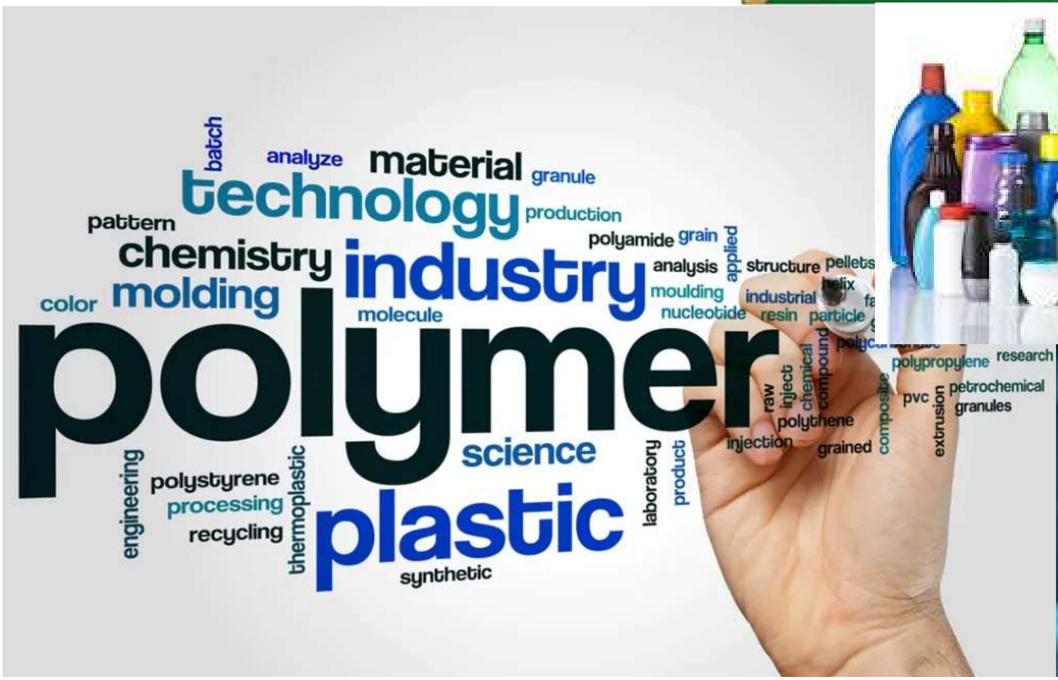
virus



blood

foam

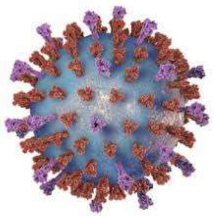
colloid



glass

Perché è soffice?

1. Maggiore scala spaziale delle unità strutturali di base
2. Più deboli interazioni



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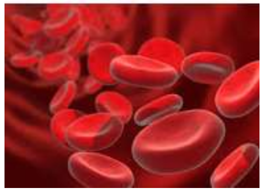

blood

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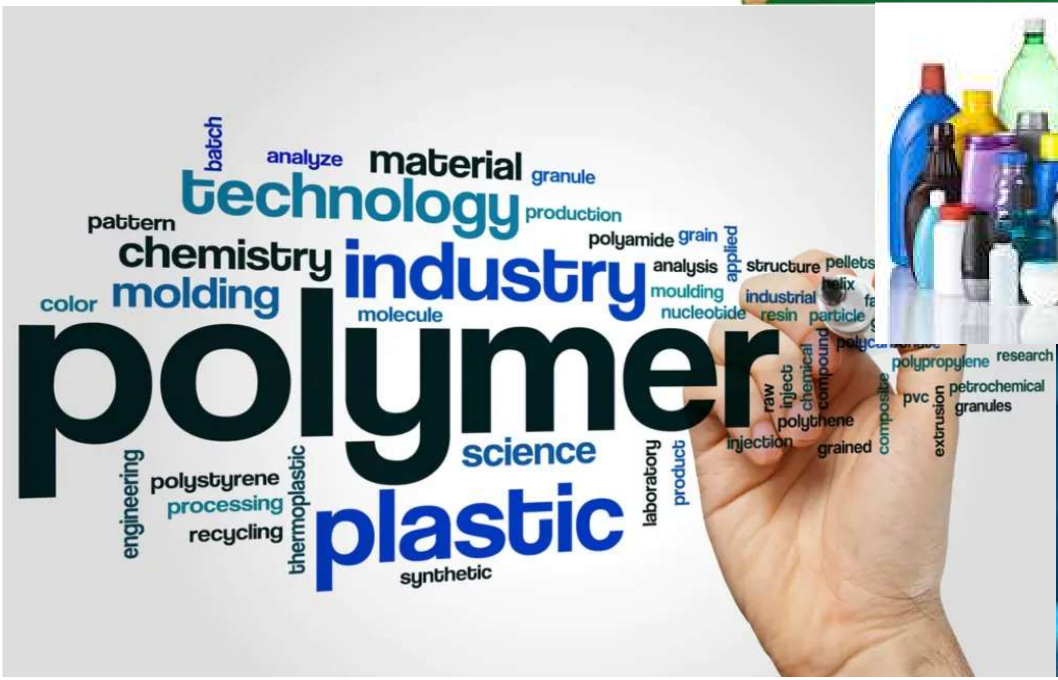

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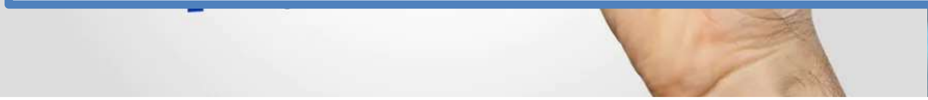
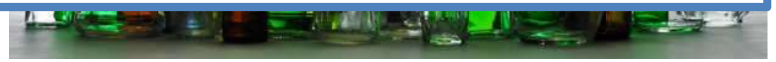
Quali tratti distintivi?

Fluidi complessi, ovvero strutturati su **scale di lunghezza mesoscopiche**, che mostrano **proprietà emergenti** indipendenti dal (e spesso non riconducibili al) dettaglio atomico, e che esibiscono **dinamiche lente**.

Soggetti a **fluttuazioni**, per es. a moto Browniano, con **energie** di 'interazione tra strutture' e di 'deformazione di una struttura' **dell'ordine di $k_B T$**.

Ricchi diagrammi di fase, dove la **competizione tra entalpia ed entropia** può portare all'**auto-assemblaggio** delle molecole. L'auto-assemblaggio può avvenire gerarchicamente, dando luogo a **strutture sovramolecolari** su scale crescenti.





Perché è soffice?

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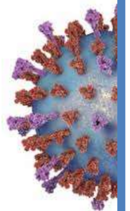
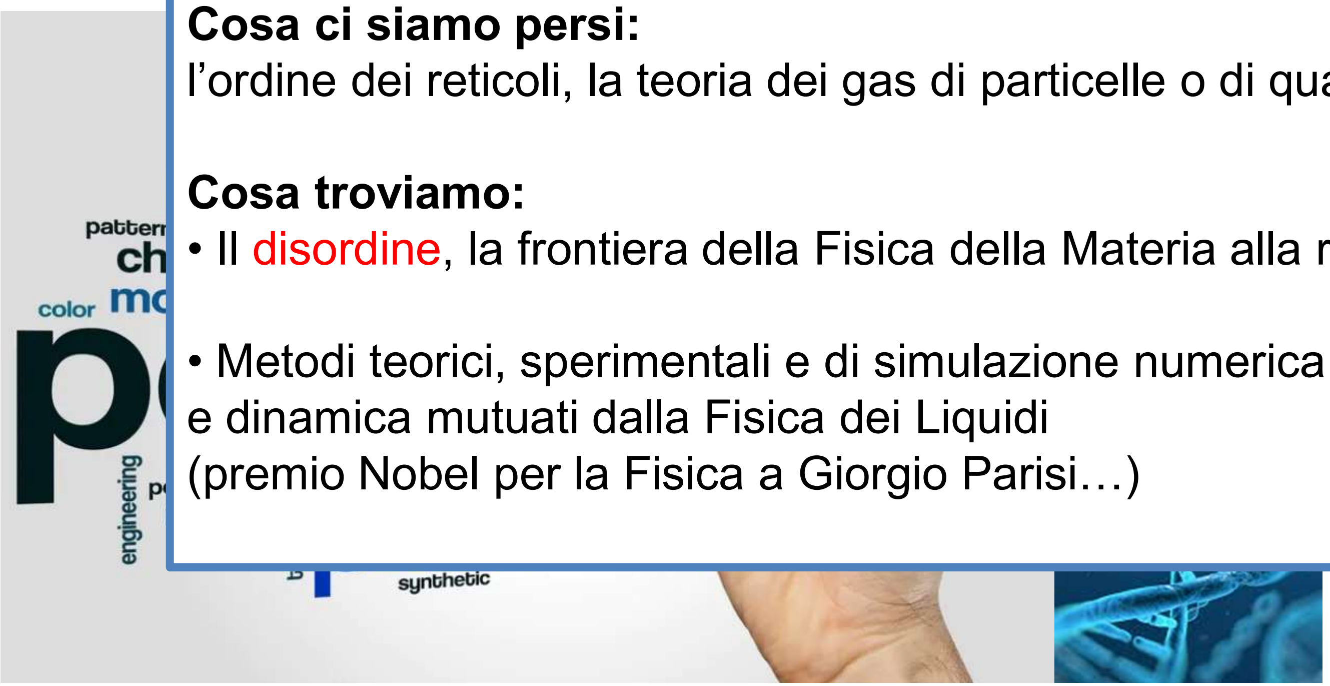
2. Più deboli interazioni






Dallo studio dei cristalli o dei gas a quello della materia soffice:

Cosa ci siamo persi:
l'ordine dei reticoli, la teoria dei gas di particelle o di quasi-particelle, …

Cosa troviamo:

- Il disordine, la frontiera della Fisica della Materia alla ricerca di modelli interpretativi efficaci

- Metodi teorici, sperimentali e di simulazione numerica per lo studio di struttura, termodinamica e dinamica mutuati dalla Fisica dei Liquidi
(premio Nobel per la Fisica a Giorgio Parisi…)

Proposte di Tesi

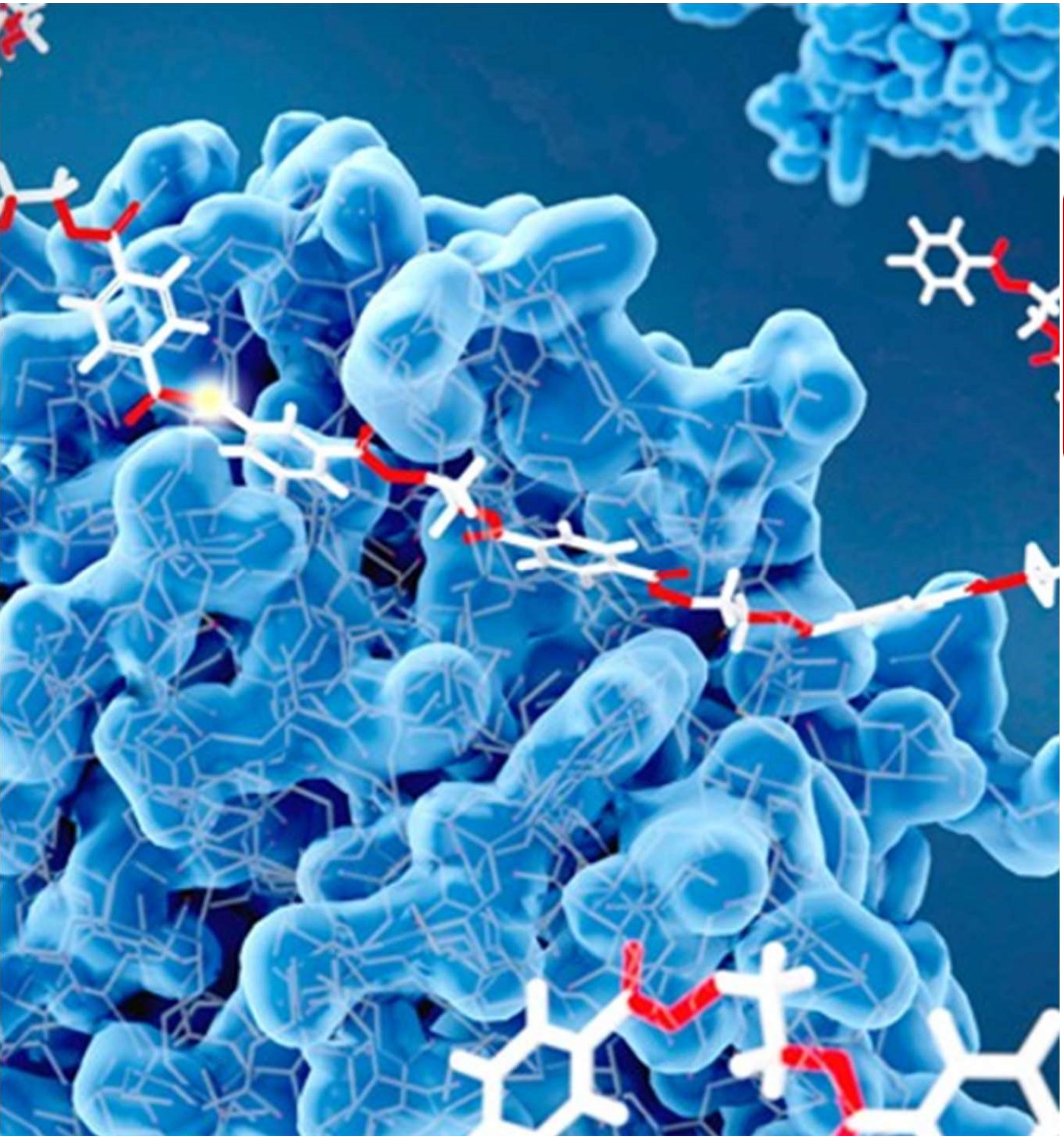
Proposta PLASTICA

1. Studio del processo di degradazione enzimatica del PET ad elevato indice di cristallinità in ambiente di reazione solido-umido

Proposta VETRO

2. Caratterizzazione elastica mediante spettroscopia Brillouin di nuovi materiali di rivestimento degli specchi nei rivelatori di onde gravitazionali

Please contact: ***silvia.corezzi@unipg.it***



Proposta PLASTICA

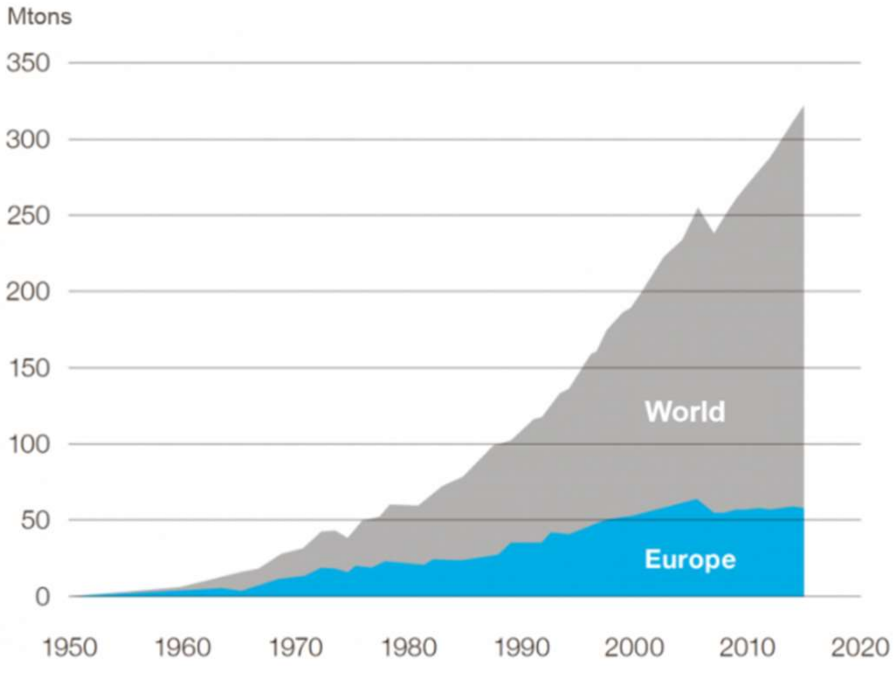
1. Studio del processo di degradazione enzimatica del PET ad elevato indice di cristallinità in ambiente di reazione solido-umido

Towards efficient PET biodegradation

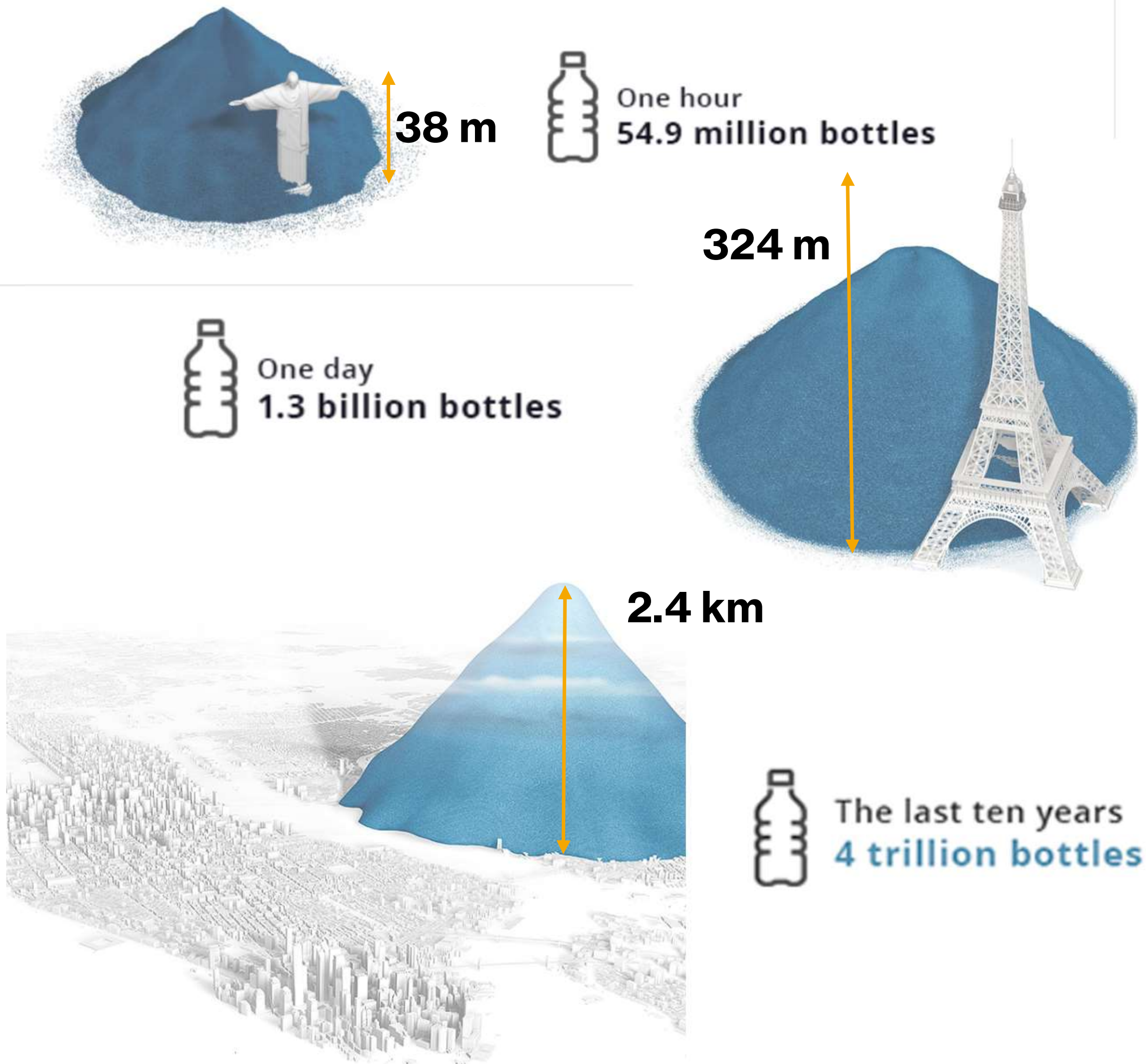
Funding:

PON "Research and Innovation" 2014-2020 / GREEN Topic

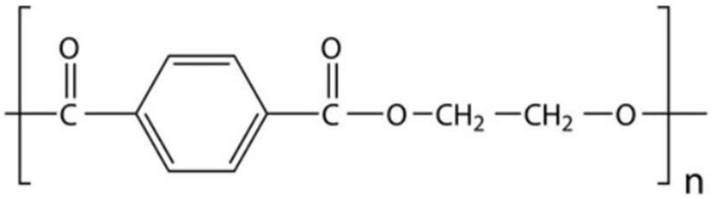
Annual plastic production worldwide (1950-2015)



Source: *Geyer et al.* (2017)



PET (polietilene tereftalato)



PET-$(C_{10}H_8O_4)_n$

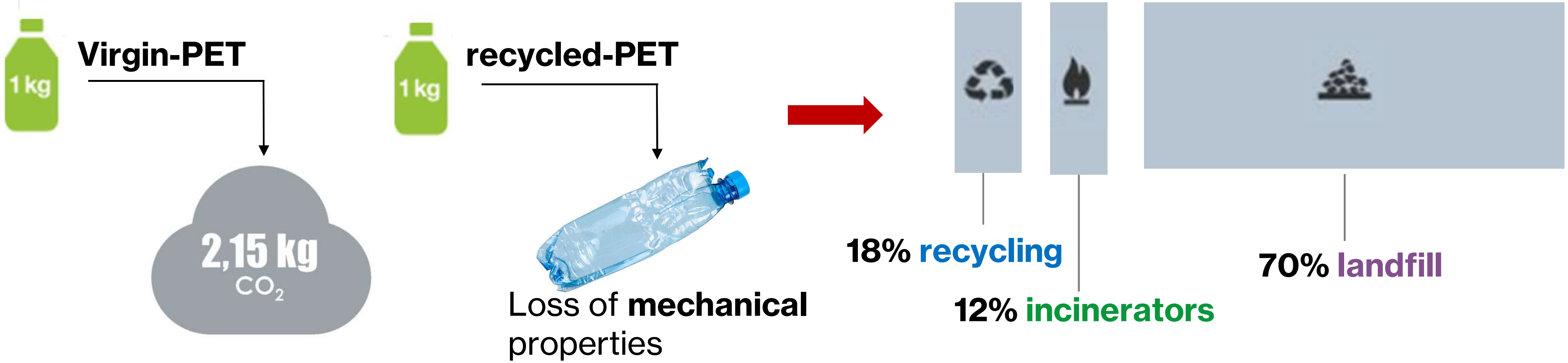
degradation time
~100 anni

micro/nanoplastics formation

1.

PET **stability** leads to high **resistance** to environmental degradation

PET (polietilene tereftalato)



2.

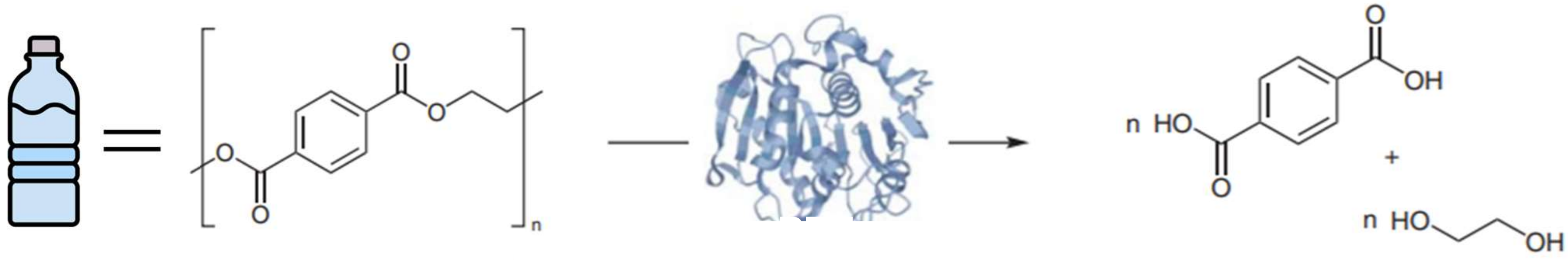
PET production, *ex-novo* or by recycling, and incineration both contribute to **greenhouse gas emission**

Source: *OECD-Improving plastic Management* (2020)

Article | Published: 08 April 2020

An engineered PET depolymerase to break down and recycle plastic bottles

V. Tournier et al.



PET
(polyethylene terephtalate)

Enzyme

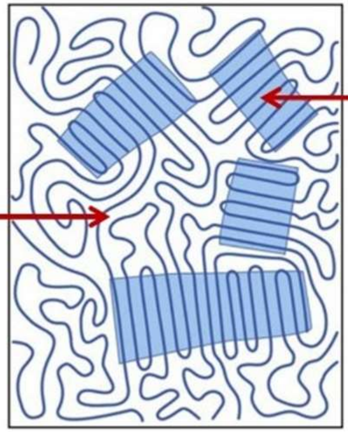
Terephtalic acid + Ethylene glycol

- **Synthesis of recycled-PET with unchanged properties**
- **Circular economy** (GREEN)

Reaction in dilute aqueous SOLUTION

Amorphous domains

accessible only above T_g (~70°C in H_2O)



Semicrystalline PET

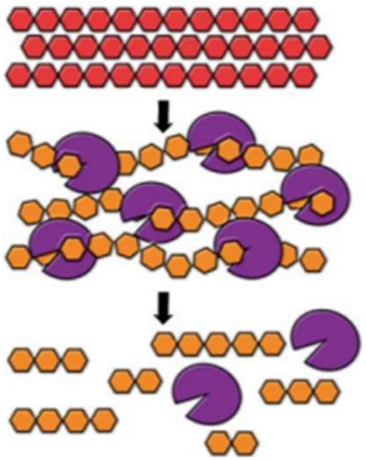
Crystalline domains

scarcely affected by enzymatic attack

DRAWBACKS

- **Accessibility**
- **Temperature of reaction**
- **Thermal stability of enzyme**

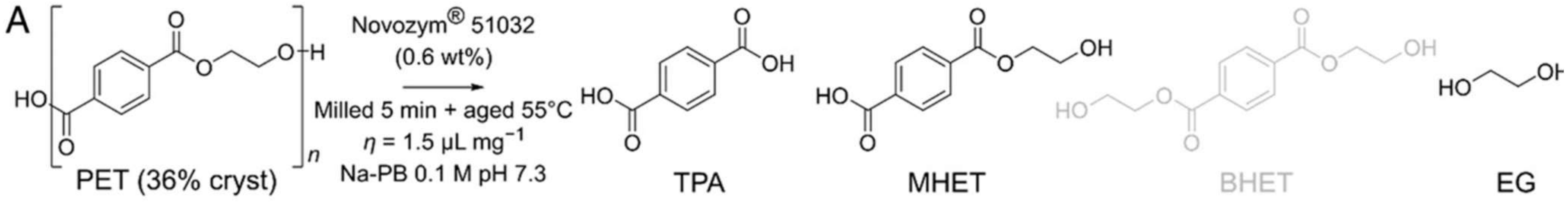
Amorphisation



PET **swelling** and disruption of **intermolecular forces** **increase accessibility**

Pretreatment

Enzymatic depolymerization of highly crystalline polyethylene terephthalate enabled in moist-solid reaction mixtures



EXPERIMENTAL TECHNIQUES:

- Circular Dichroism
- FTIR & Raman
- SAXS/SANS

COMPUTATIONAL METHODS:

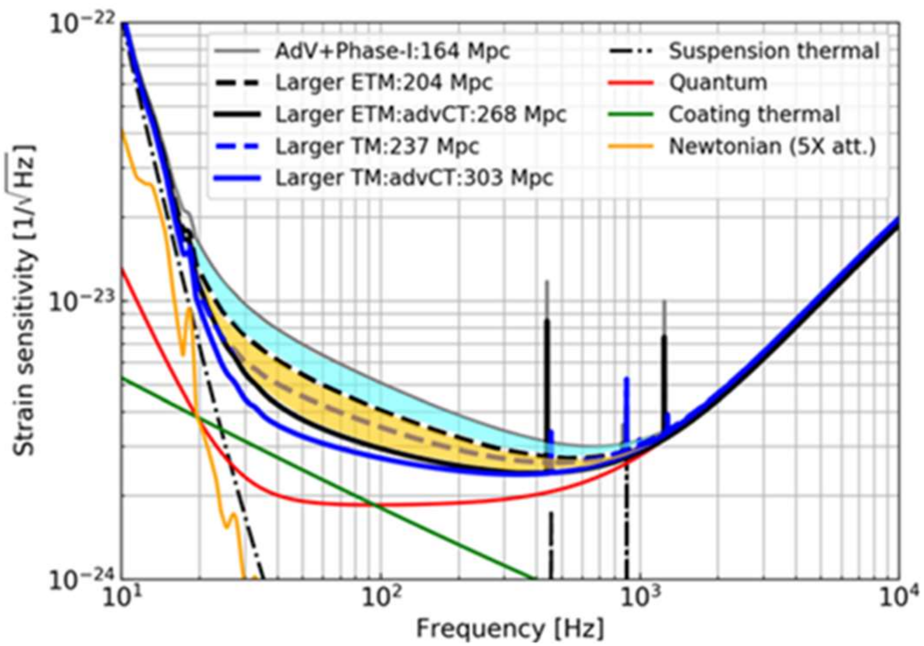
- Molecular dynamics
- Molecular docking

CRD-Coating Research and Development

- A major limiting factor to the sensitivity of gravitational waves detectors at their most sensitive frequencies is the noise rising from thermal fluctuations within the films used as optical coatings in the interferometer mirrors, noise related to the internal friction of coating material.

- Developing new coating materials with a 3-fold reduction of the mechanical losses

The impact on the sensitivity curve is shown in yellow:



Proposta VETRO

2. Caratterizzazione elastica mediante spettroscopia Brillouin di nuovi materiali di rivestimento degli specchi nei rivelatori di onde gravitazionali

The origin of noise in coatings (TLS)

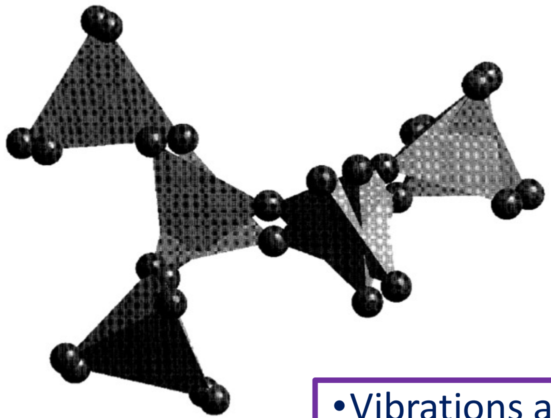


FIG. 5. Superposition of the orientations of a small group of tetrahedra within a larger configuration of silica glass before and after a sudden jump in the orientations of the group of tetrahedra.

- Vibrations around equilibrium positions
- Relaxing time τ

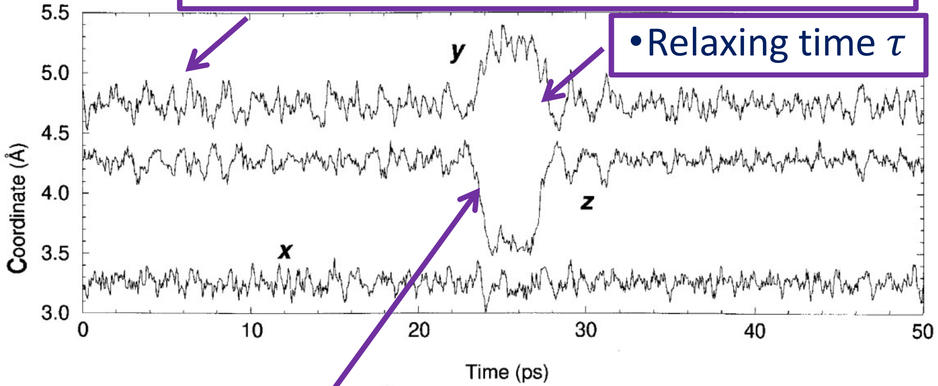
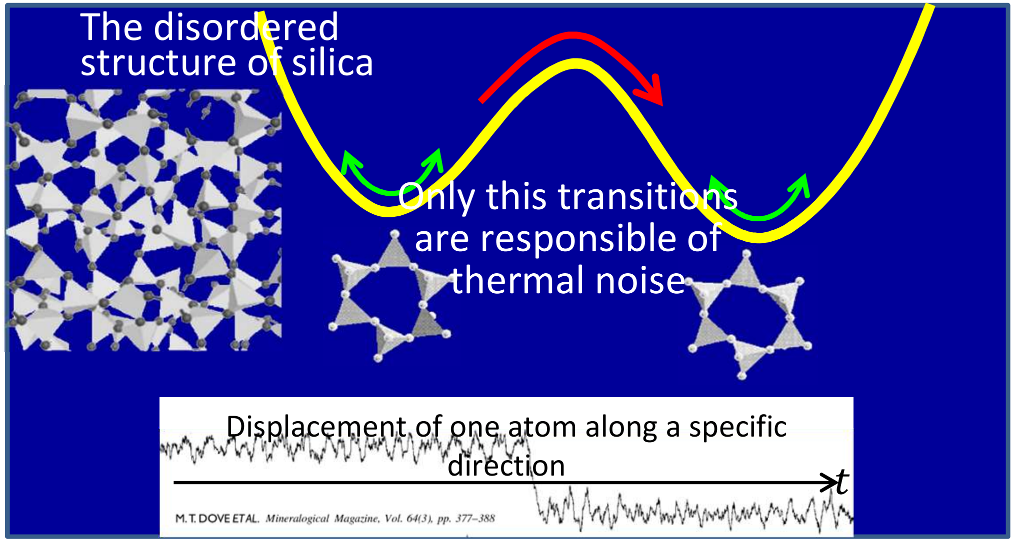


FIG. 6. The atomic coordinates x,y,z (in Å) of individual oxygen atoms within the part of the silica glass configuration that undergoes sudden tetrahedra reorientational jump events. The upper plot shows the behaviour of one of the oxygen atoms in the group shown in Fig. 5.

- Transitions responsible of thermal noise

The Asymmetric Double Well Potential

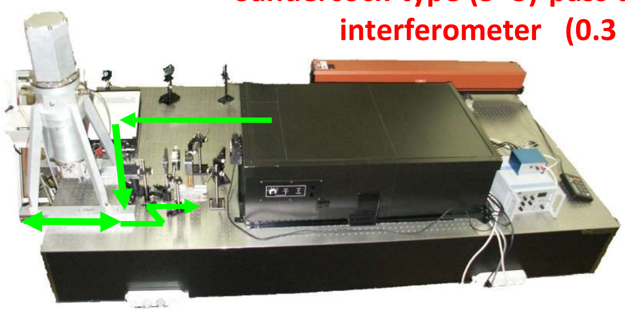


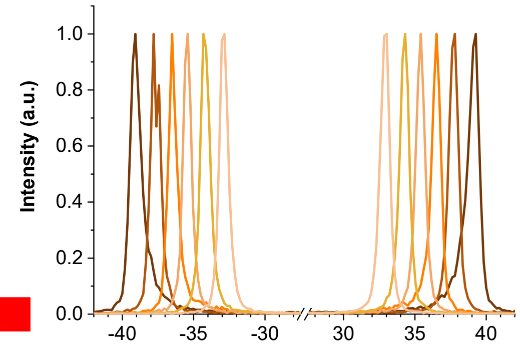
New coatings from an integrated strategy

- Synthesis
  - ♦ New materials
  - ♦ New coating deposition
  - ♦ New post-deposition treatments
- Modeling
  - ♦ Structure
  - ♦ Dynamics
- Microscopic and macroscopic characterization
  - ♦ TEM, SEM, AFM
  - ♦ XRD, XPS, XAS
  - ♦ GeNS
  - ♦ **Brillouin**
  - ♦ Raman
  - ♦ Dielectric
  - ♦ Density

Brillouin Light Scattering setup@PG

Sandercock-type (3+3)-pass tandem Fabry–Perot interferometer (0.3 GHz-40 THz)



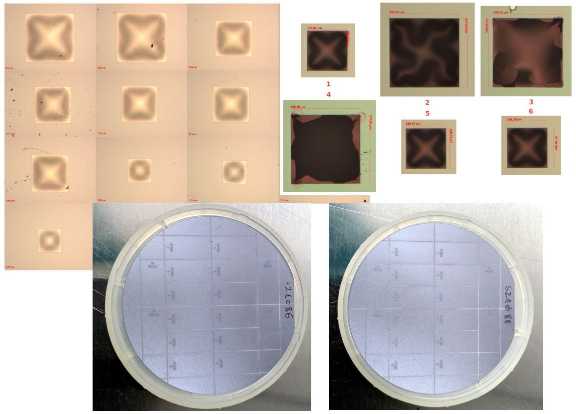


Elastic moduli

GROUPS: g-MAG, LMA, Firenze-Urbino, Perugia, Roma1, Sannio-Salerno,

RL7 - Annealing: Evolution of TLS distribution

Ta_2O_5 membranes SiO_2 membranes



Ta_2O_5 coating SiO_2 coating

GOAL: highlight the evolution of the barrier-height TLS distribution and the kinetics of relaxation after thermal treatments (annealing)

SAMPLES: and SiO_2 and Ta_2O_5 coatings (IBS)

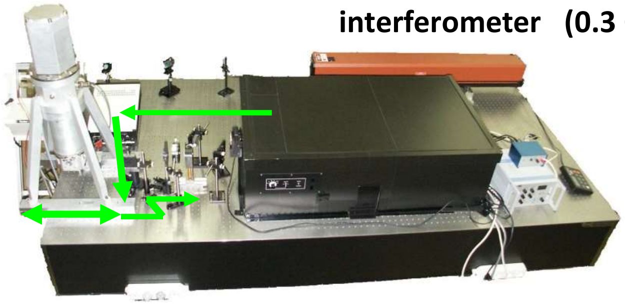
ATMOSPHERE: N_2 atmosphere / water vapour saturated atmosphere

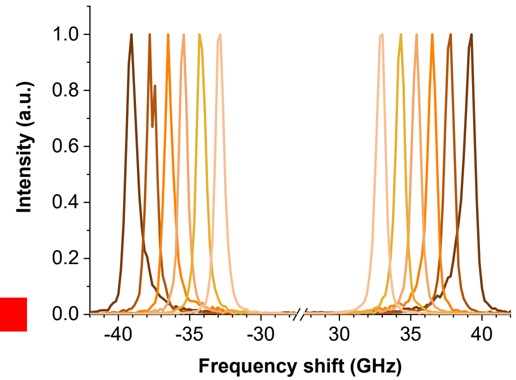
ANNEALING at 500 °C: incremental times 0.5h, +0.5h, +1h, +2h, +4h and +8h

ANALYSIS: Brillouin, Raman, IR

Brillouin light scattering @PG

Sandercock-type (3+3)-pass tandem Fabry–Perot interferometer (0.3 GHz-40 THz)





Elastic moduli