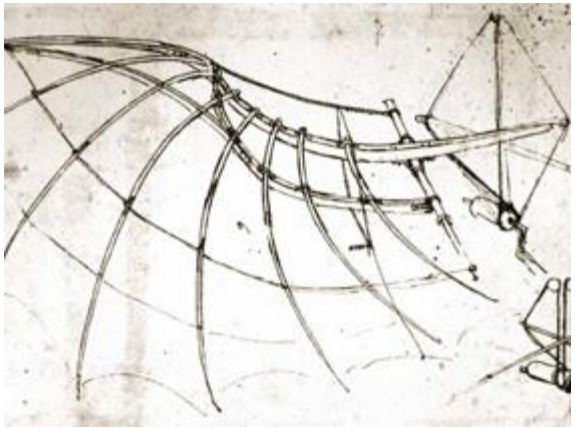
Materiali bioispirati e metamateriali elastici

Federico Bosia

Dipartimento di Fisica, Università di Torino

federico.bosia@unito.it

Bioinspiration & biomimicry

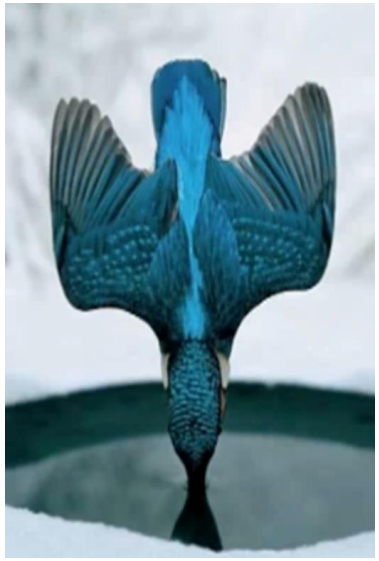


Wing design by Leonardo da Vinci

Arctium L. ***Velcro***

Bioinspiration & biomimicry

Transport



Kingfisher

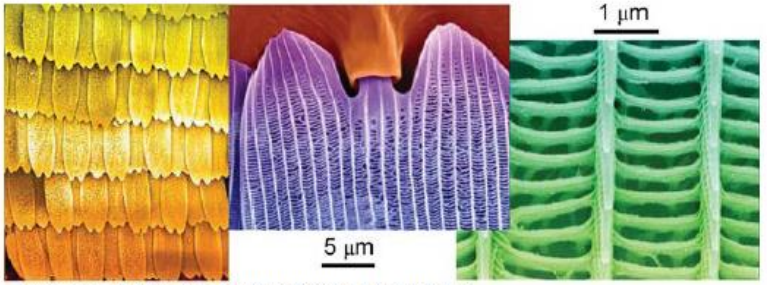
Shinkkansen bullet Train
(West Japan Railway Company)

Box fish

Mercedes Bionic car

Bioinspiration

✓ Complex constitutive behaviour emerges from simple components (e.g. Hierarchy)



J. Genzer, A.Marmur, MRS Bulletin 33 (2008) 742.

✓ Metamaterials

✓ Structure → Function

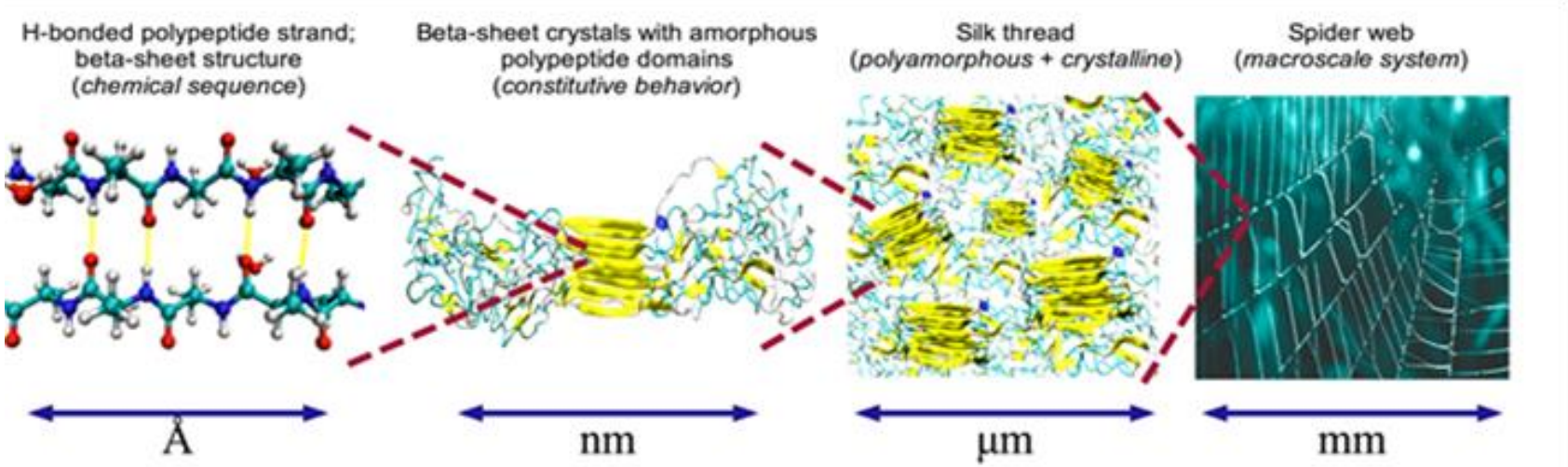
✓ Adhesion/friction

✓ Strength/low density

✓ Vibration Damping

Spider silk

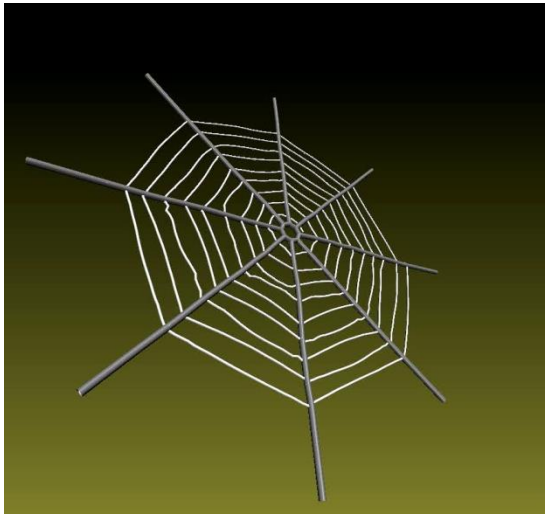
- **Hierarchical structure in spider silk** **STRENGTH ≈1 GPa, STRAIN >750%**

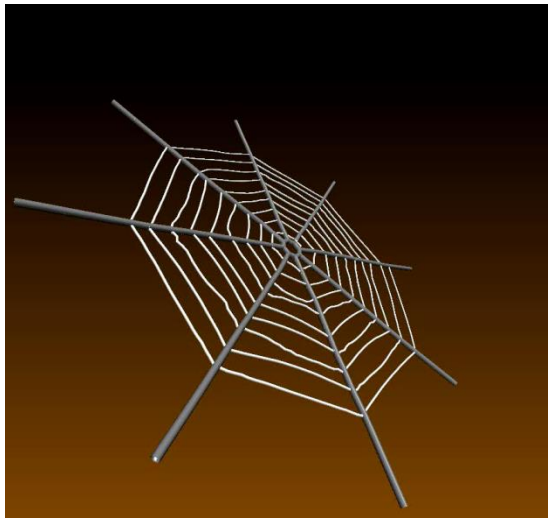


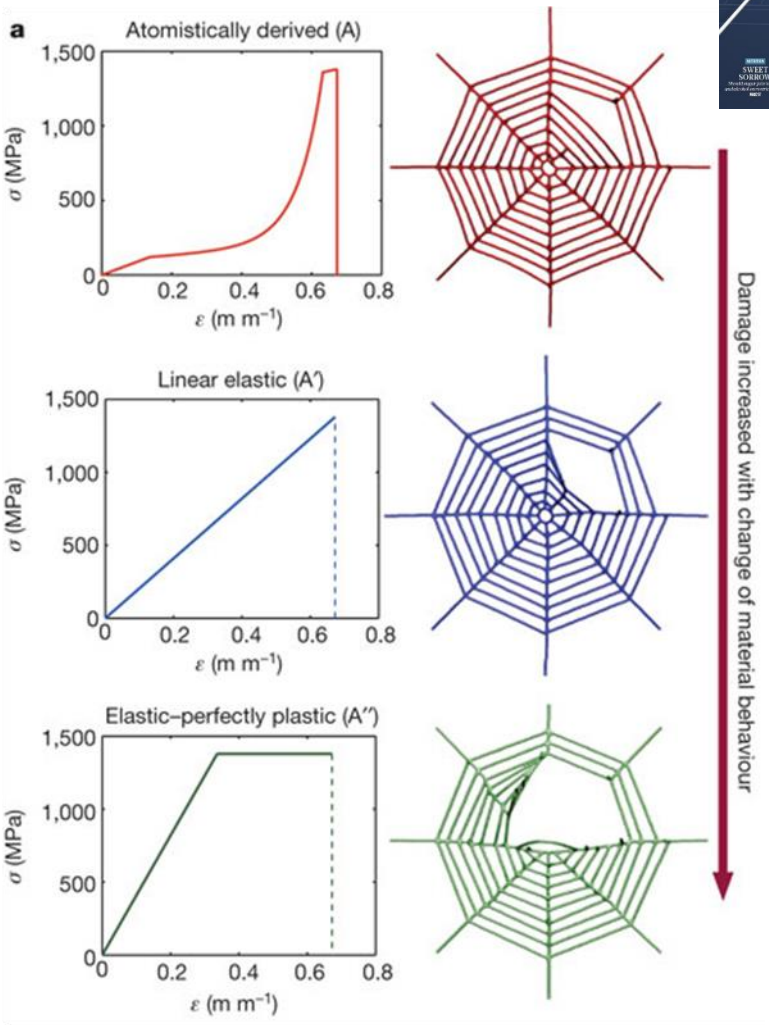
A.Nova, S.Keten, N.M.Pugno, A.Redaelli and M.J. Buehler, **Nanoletters** 10, 2626–2634 (2010)

Spider webs

LOCALIZED LOAD



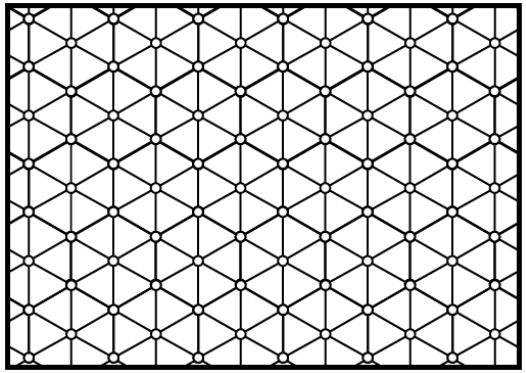


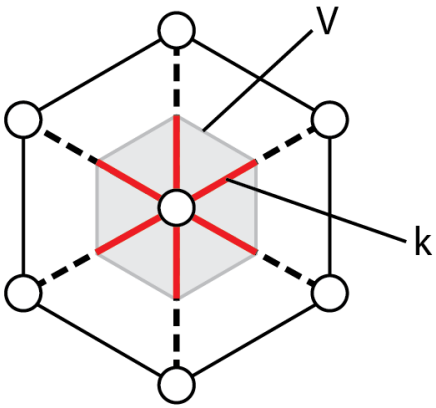


S.W.Cranford, A.Tarakanova, N.M.Pugno, and M.J. Buehler, **Nature** 482, 72–76 (2012)

Lattice Spring Model

- Numerical approach: Lattice Spring model (LSM)





$$U_\Omega = \frac{1}{2}\int_V \sigma\varepsilon \, dV$$

$$U_S = \frac{1}{2}k\Delta l^2$$

$$U_\Omega = \sum U_s$$

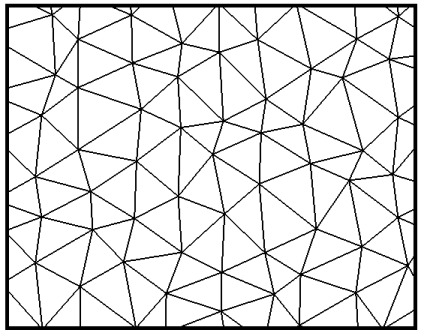
σ : stress tensor

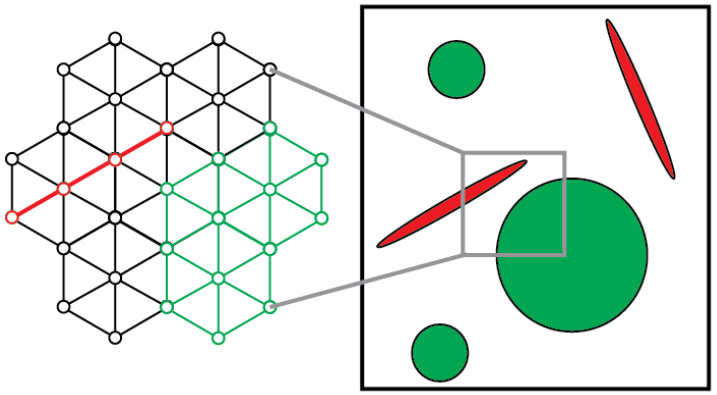
ε : strain tensor

k : bond stiffness

Δl : bond elongation

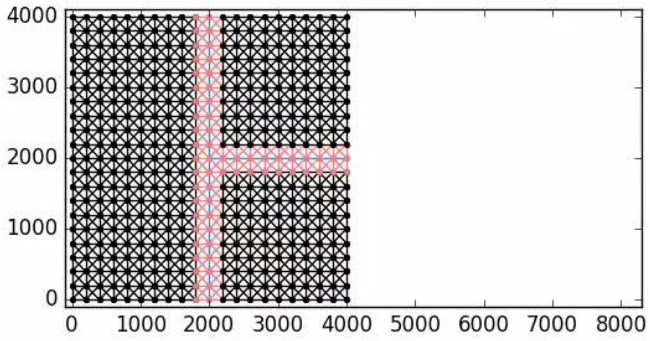
Disorder / Statistically assigned properties :

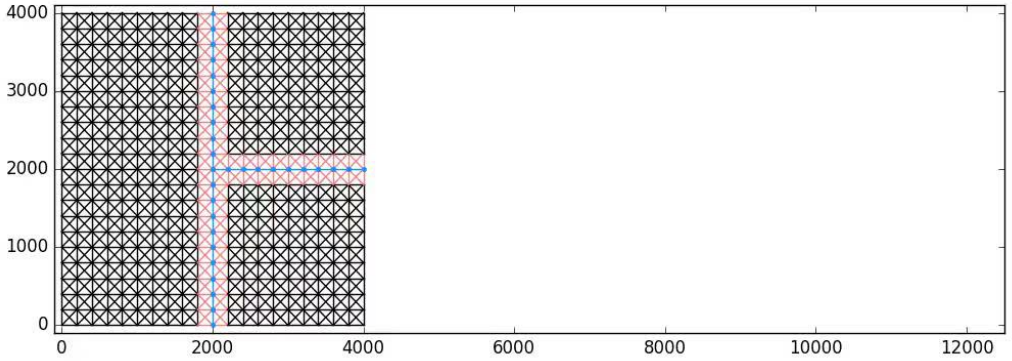




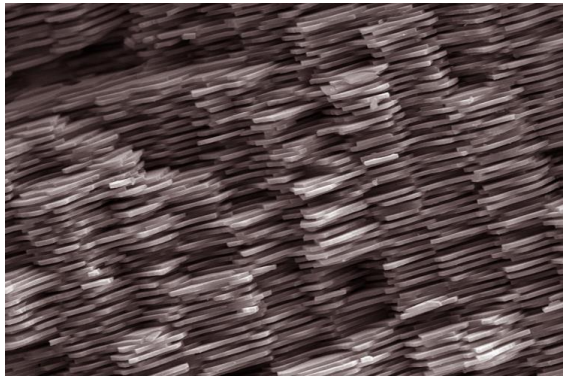
- *L. Brely et al., Front. Mater. (2015)*

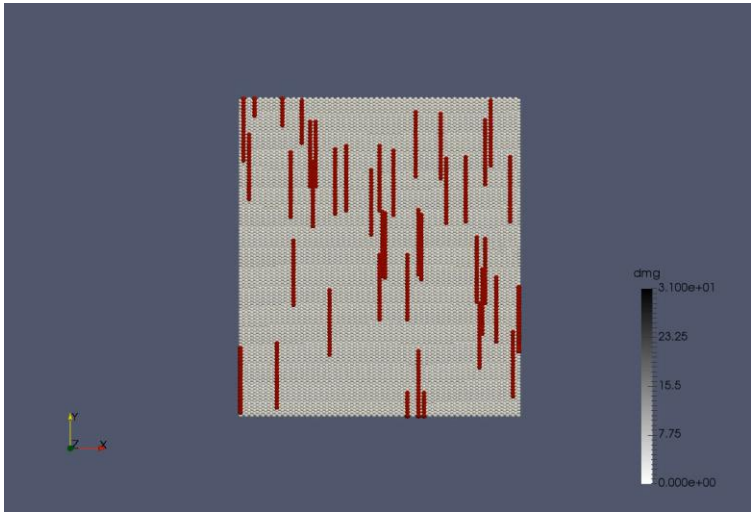
Simulations



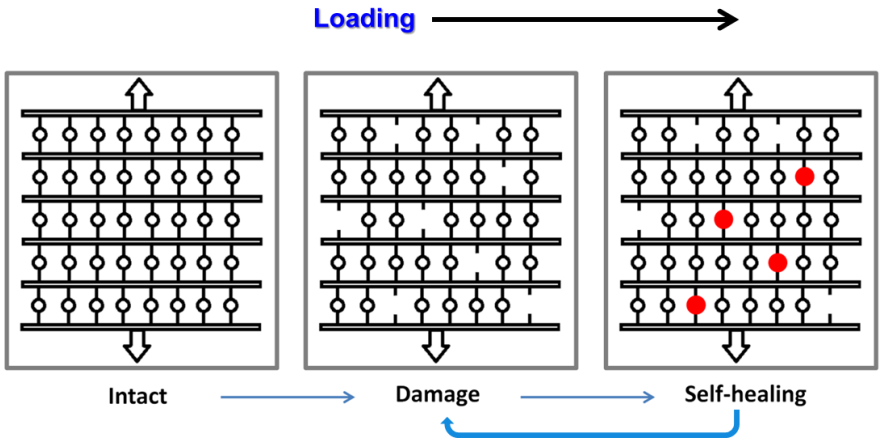


Nacre





Self-healing in artificial materials

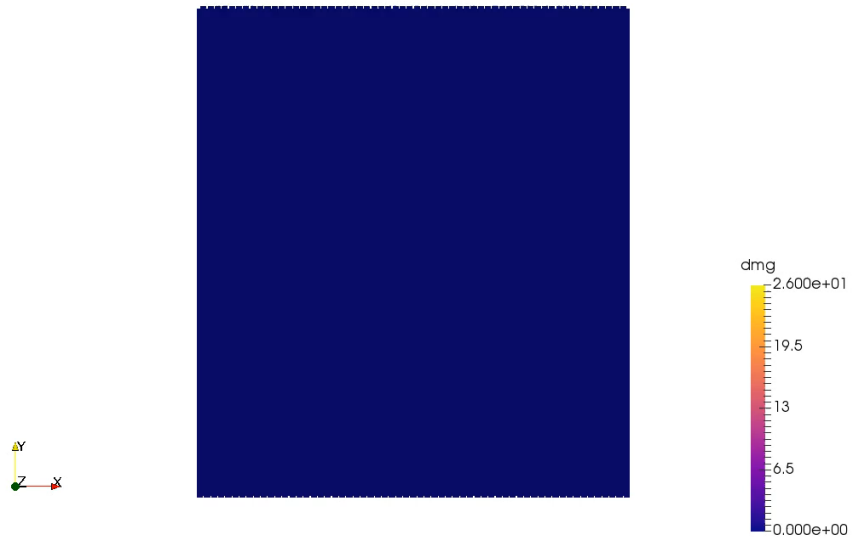


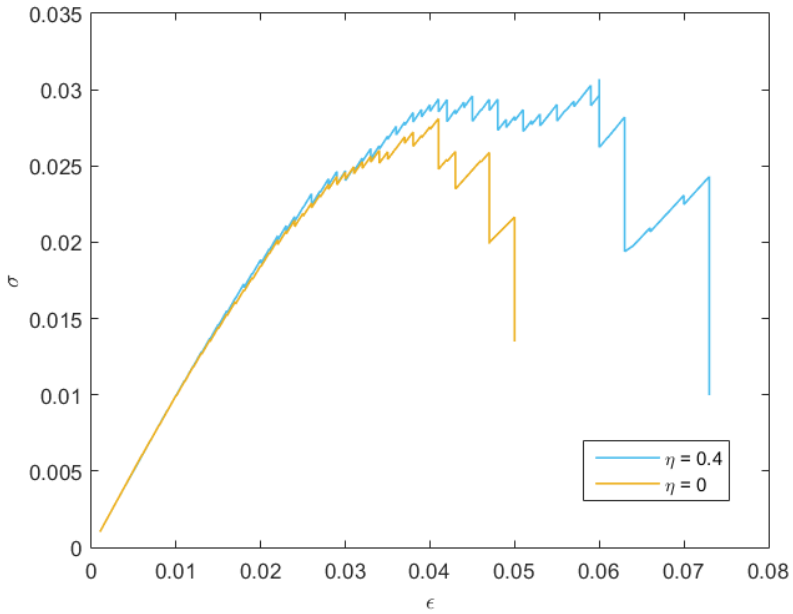
$\eta = \eta(t)$: ***ratio between fractured and healed fibres per unit time***

[Bosia et al., **Langmuir** 30, 1123-1133 (2014)]

Self-healing simulations

η: SH paramete $\eta = \frac{N_{heal}}{(N_{broken})_{n-p}}$





[Bosia et al., **Langmuir** 30, 1123-1133 (2014)]

Adhesion

➢**Tokay Gecko**

Adhesion due to van der Waals and capillary forces;

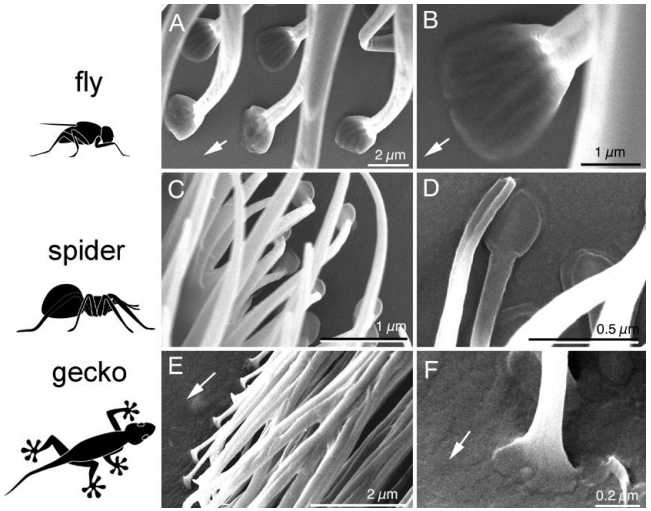
Adhesion strength of about 1 MPa, i.e. 10 times its body weight

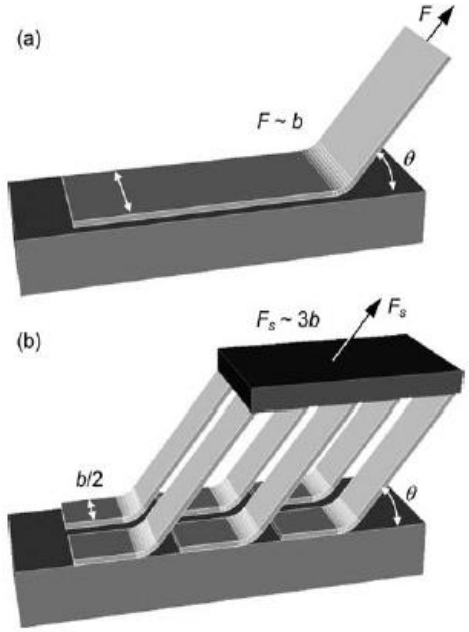
3 requirements:

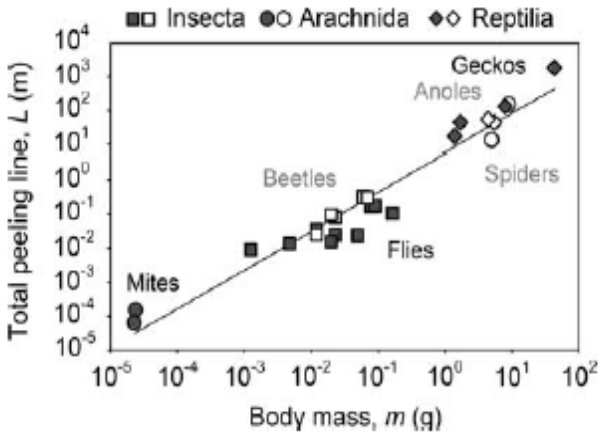
- Strong adhesion
- Easy detachment
- Self-cleaning mechanisms

Optimization of Adhesion

Contact splitting







1) Super-adhesion by nanocontacts: $F \propto b$ **(*b* total peeling line)**

2) Easy detachment by controlling the peeling angle: $F \propto 1/(1-\cos\theta)$

3) Self-cleaning → "Lotus effect" (Hierarchical architectures)

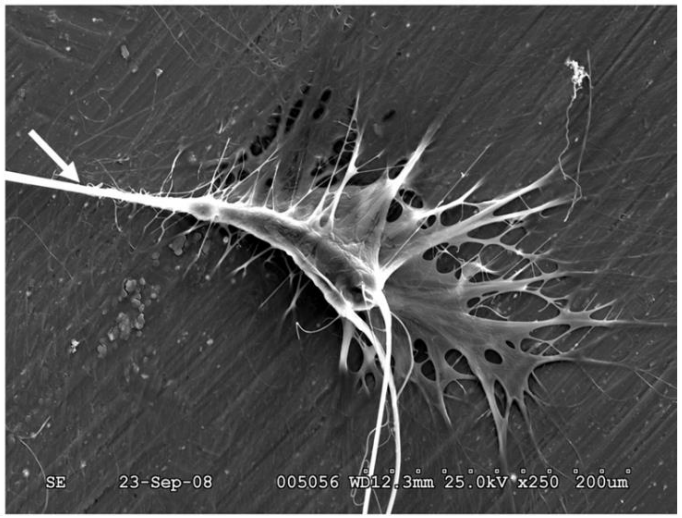
Bioinspired adhesion

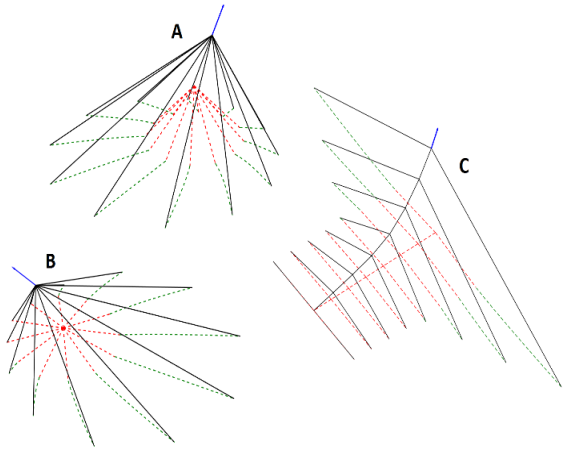
Design of “Spiderman suit”:

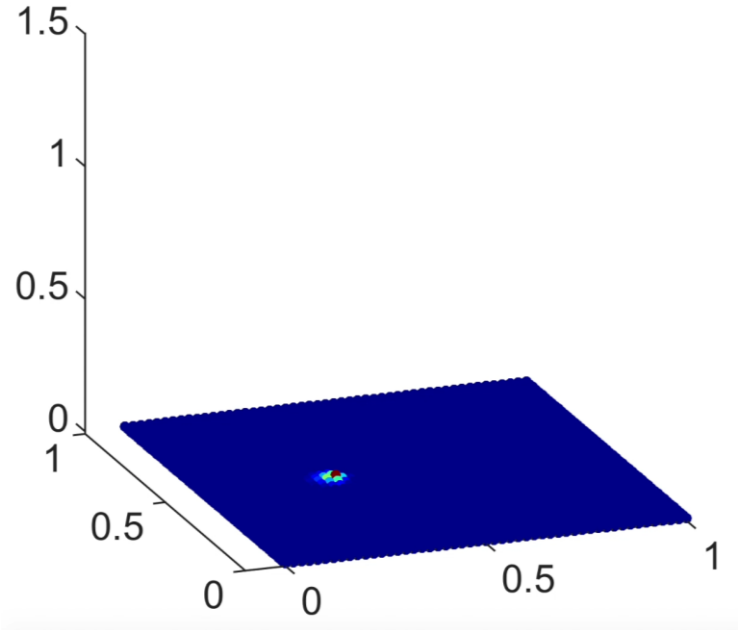
- **Nano-fibres**
- **Hierarchical design**
- **“Tapered” spatula**

Optimization of Adhesion

MULTIPLE PEELING AND MEMBRANE ADHESION

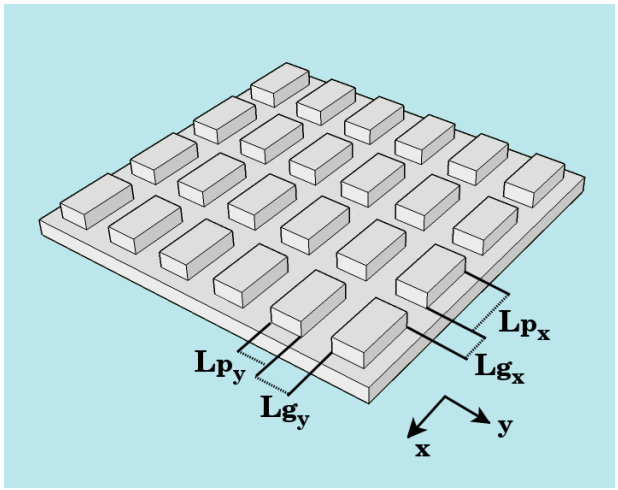




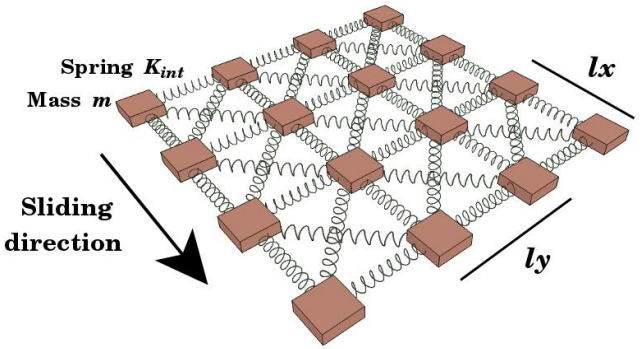


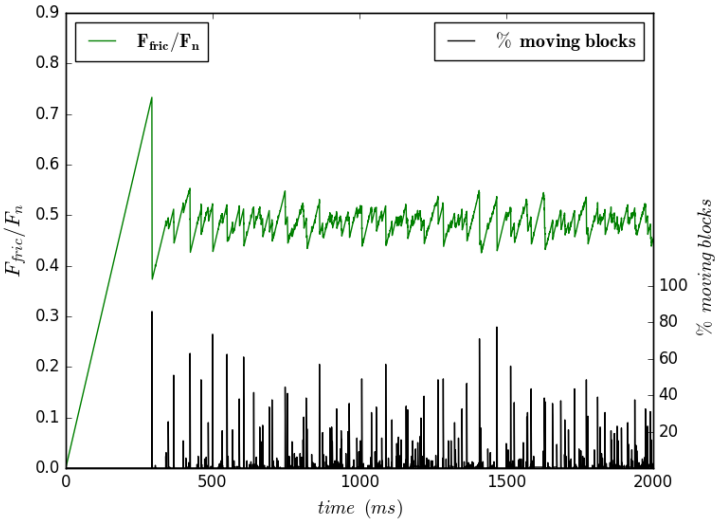
[Wolff et al., submitted to **PNAS** (2018)]

Friction



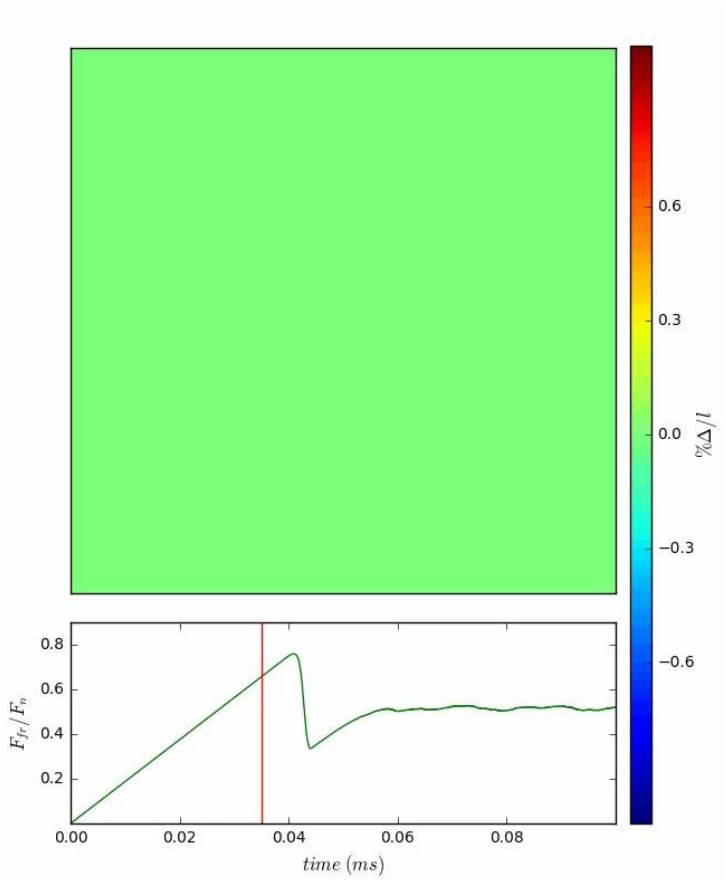
Spring-block model

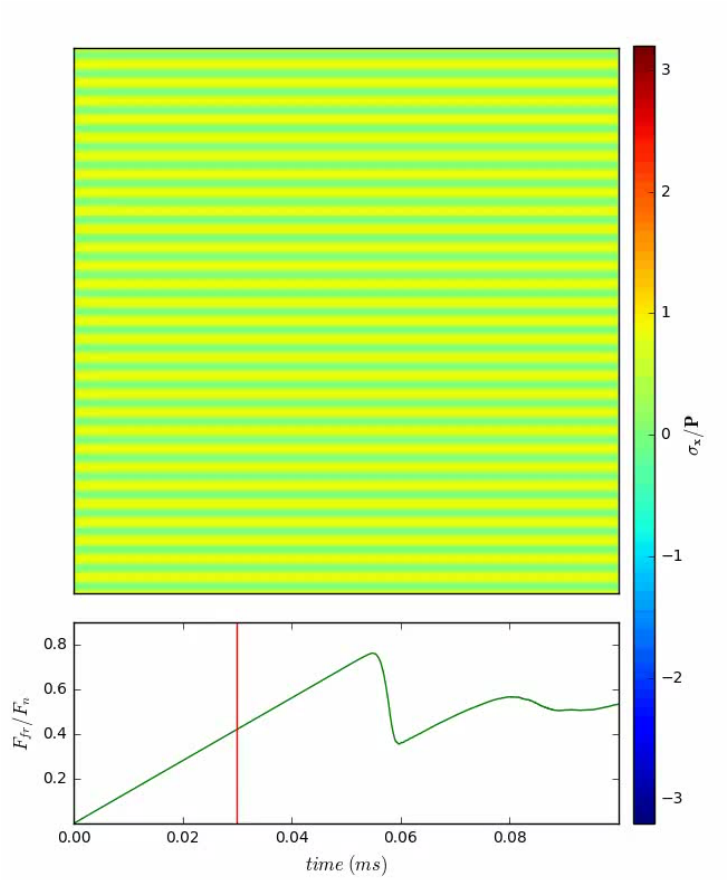




Friction

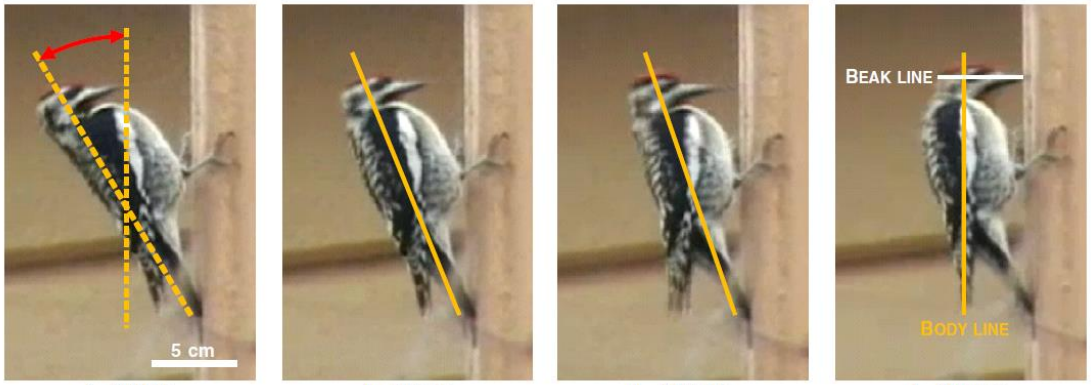
Friction reduction through patterning



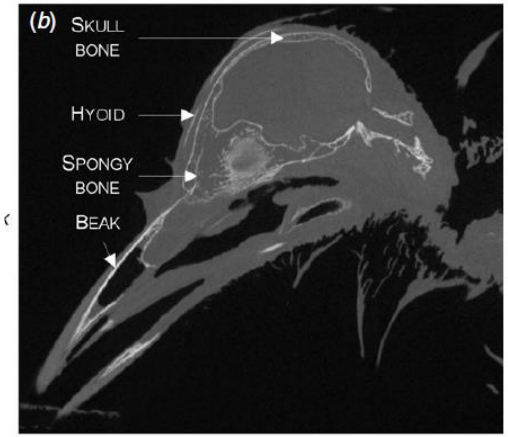


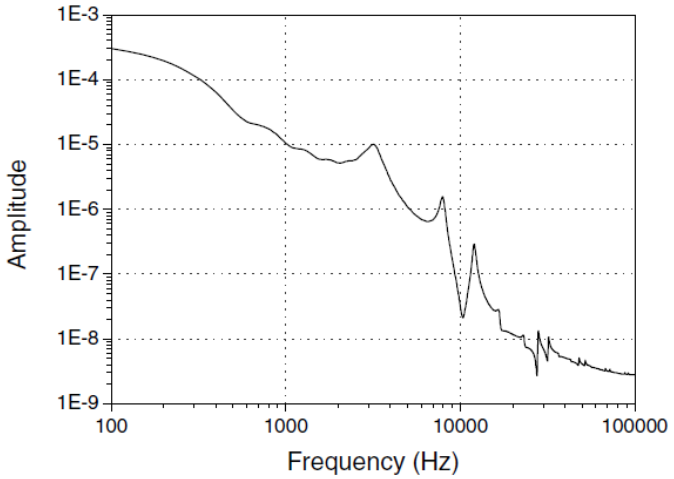
G. Costagliola, F. Bosia, N. M. Pugno, **JMPS** (2016)

Vibration damping

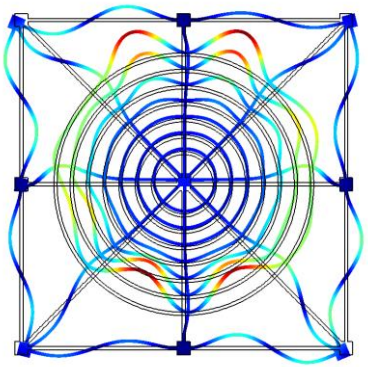


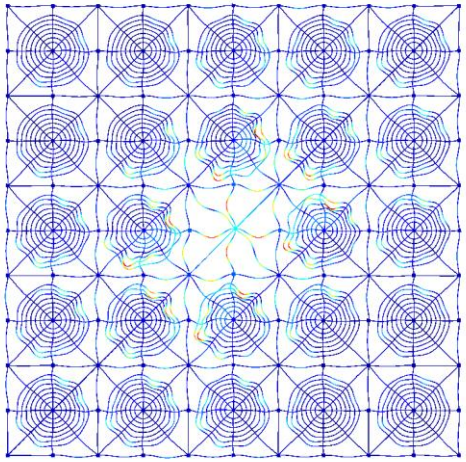
t = 0 msec t = 7 msec t = 13 msec t = 20 msec

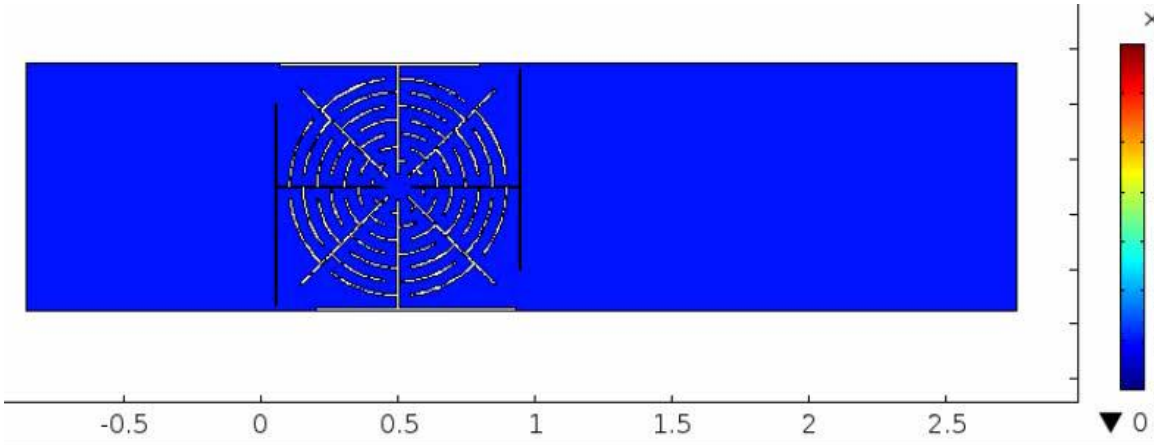




Elastic Metamaterials



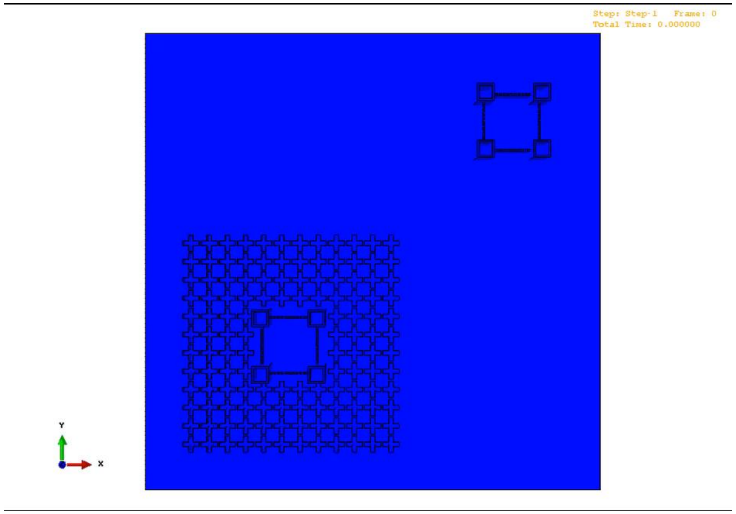


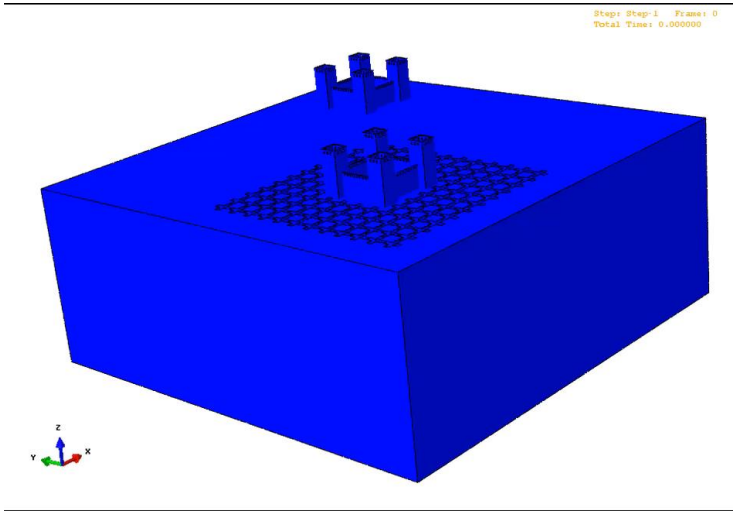


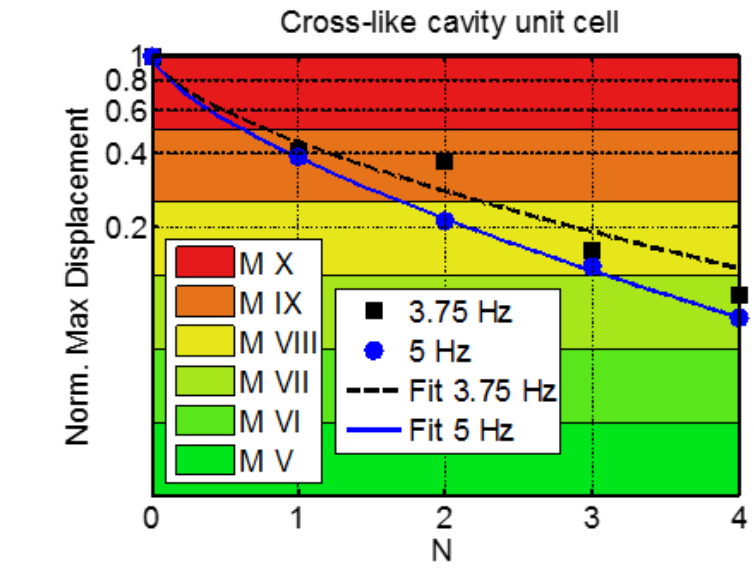
Miniaci et al., **Appl. Phys. Lett.** (2016)
Krushynska et al. **New J. Phys**. 19 (2017)

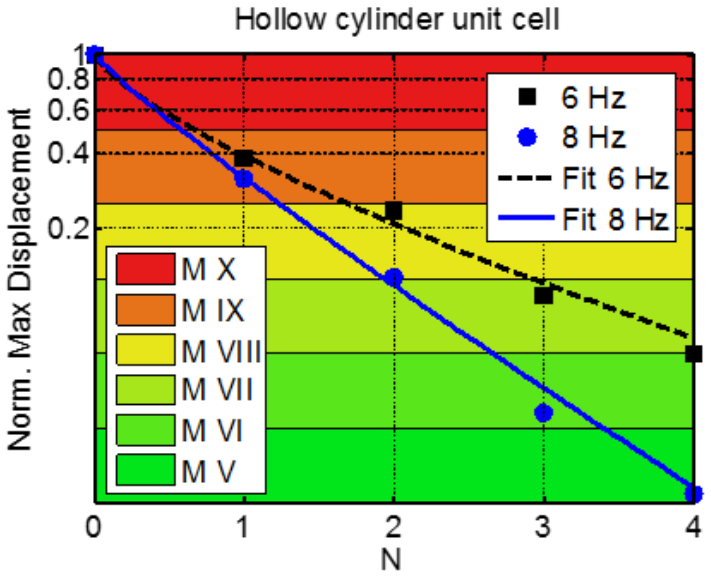
Elastic Metamaterials

- Seismic shielding





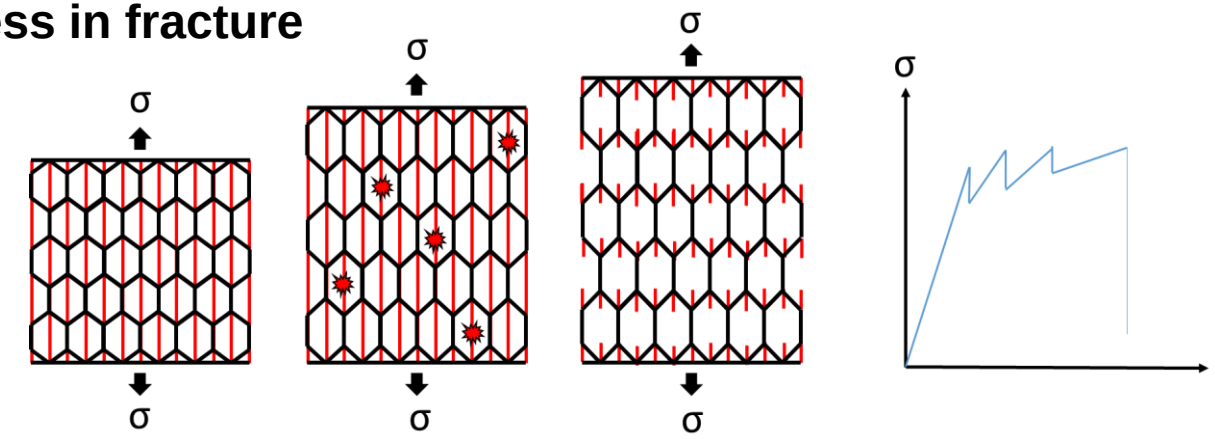




Miniaci et al., New J. Phys. 18 (2016) 083041

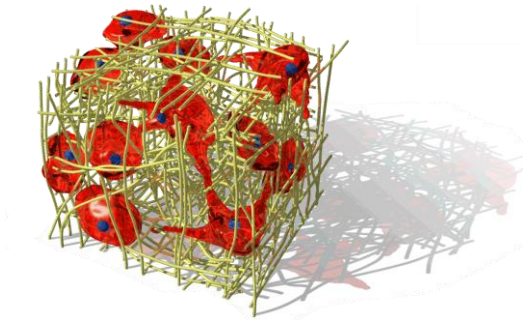
Tesi: 1) fenomeni di frattura

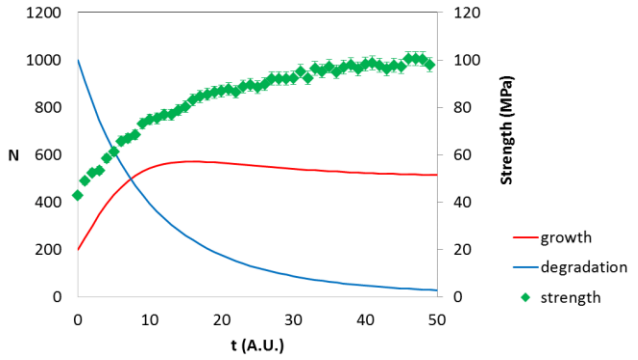
➢ **Simulation, 3D printing and mechanical characterization of reticular structures with “sacrificial bonds” to maximize energy dissipation and toughness in fracture**



➢ **Modelization of the mechanical behavior of materials with growth / self-healing constitutive laws (e.g. biological tissue, “self-healing” artificial materials)**

- Biodegradable scaffold + regeneration through cell growth

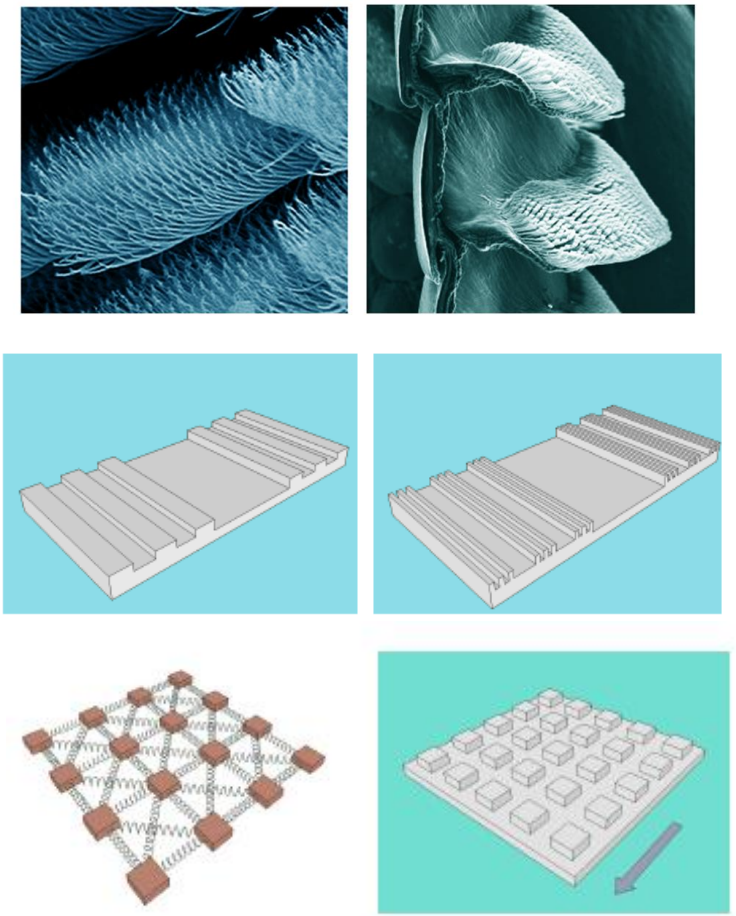


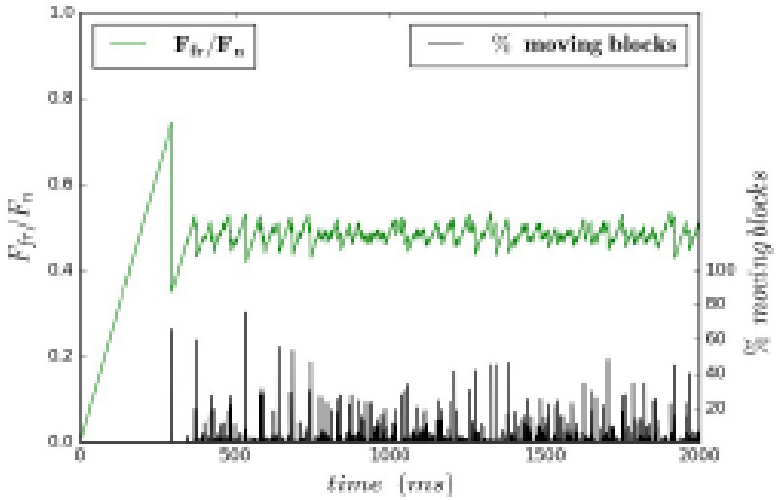


Contati: federico.bosia@unito.it

Tesi: 2) attrito

- **Modellizzazione e misure di attrito di superfici patternate 1D e 2D**

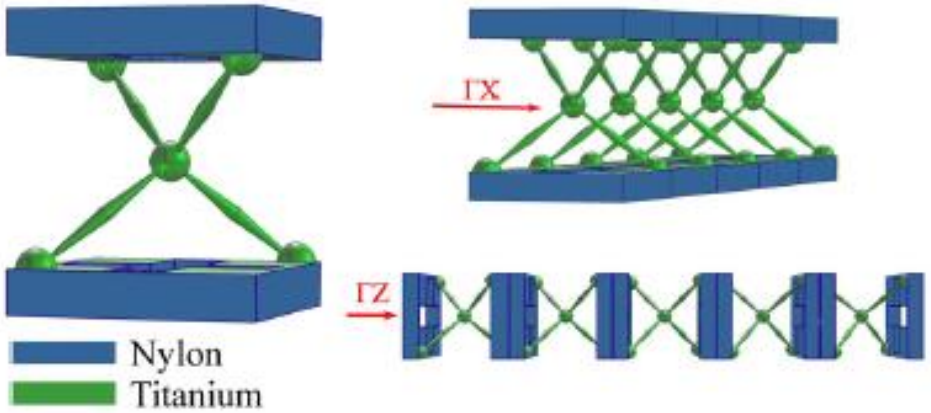


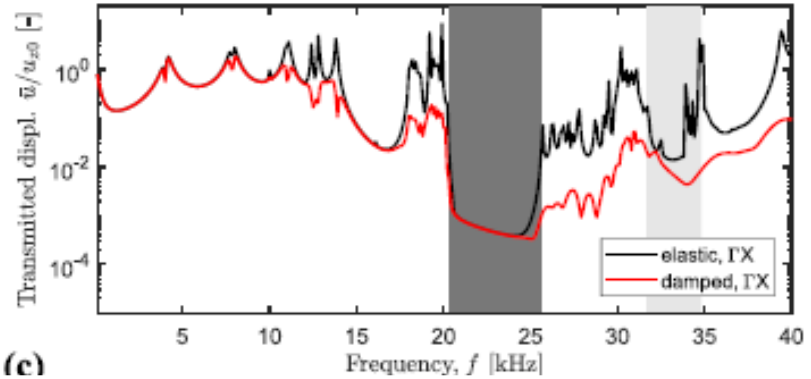


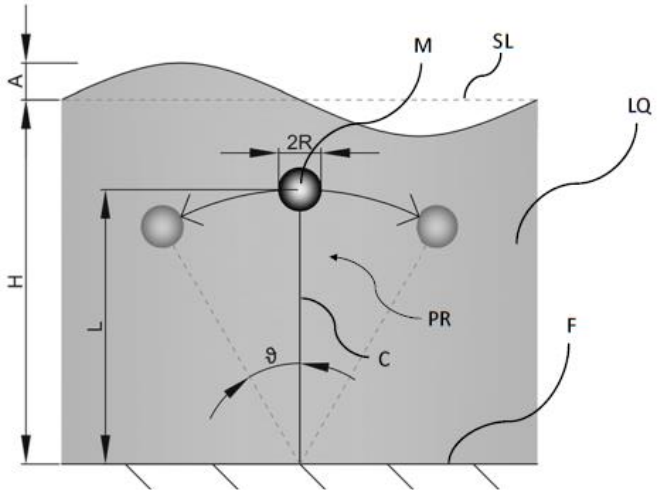
Time evolution of the total friction force

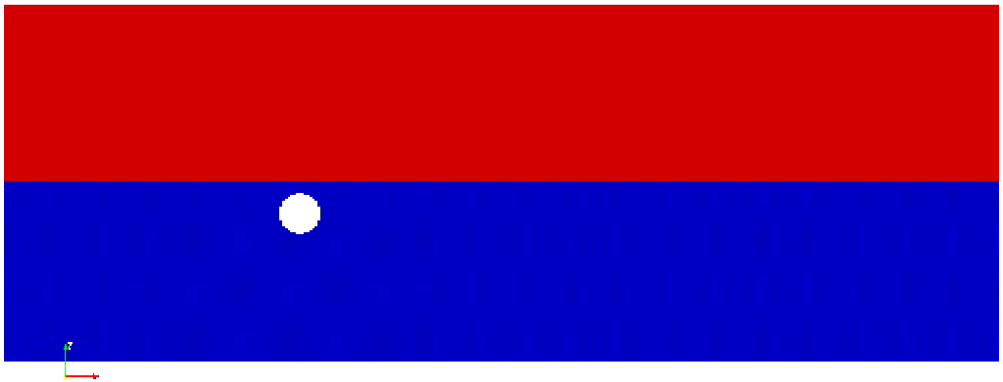
Tesi: 3) Metamateriali in elastici e nei fluidi

- **Modellizzazione ed esperimenti**









Contatti

Federico Bosia
Dipartimento di Fisica
federico.bosia@unito.it
tel.: 011 670 7889
ufficio: T34 (piano terra istituto vecchio)

http://www.dfs.unito.it/solid/index.html