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MECHANICS OF EXTREME MATERIALS

Editorial

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This Special Issue discusses some recent advances in the field of "extreme" materials, where with this term we wish to refer to the unprecedented physical, mechanical, thermal, optical and electrical characteristics achieved in many fields of materials science exploiting novel fabrication techniques, material systems (including nanomaterials), nano- or-micro-structuring, or bioinspired processes such as self-healing. Materials that exhibit complex microstructures or hierarchically organized architectures at different scales have recently attracted wide interest in the scientific community as well as in industry because their macroscopic mechanical and, more in general, physical performance, can be drastically and sometimes unexpectedly enhanced.

At nanoscale, Graphene has emerged in the past years as the most promising extreme material due to its exceptional strength. Lee et al. [1] discuss the

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conditions for stable crack growth in Graphene using atomistic simulations, highlighting the dependence on crack tip sharpness. Also at nanoscale, the functionality of proteins in biology is linked to their vibration modes. Scaramozzino et al. [2] present a new method to predict low frequency vibrations using coarse-grained finite element space truss model, validating their model with experimental data and other widely used methods such as the anisotropic network model. Another important topic in biomechanics is the modelling of tumor growth: in [3], the authors discuss the effect of high mechanical stresses on a tumor mass, modelled as a hyperelastic sphere undergoing finite heterogeneous growth, showing how this can lead to remodeling, growth-induced stiffening and development of heterogeneity, with local auxetic material properties, all of which can explain the experimentally observed phenomenology.

An intriguing bioinspired characteristic which is being investigated in the quest for extreme materials is the ability of self-healing. Perepelkin et al. [4] discuss how this can be achieved in soft polymeric materials, demonstrating experimentally the viscoelastic and self-healing behavior of a recently synthesized polyurethane material. Future extreme materials will also be reliant on actuating elements: a mathematical formalism to describe the behavior of electrically-activated soft dielectric transducers is presented in [5].

In all bioinspired extreme materials, internal structure plays a decisive role. The paper by Rueger et al. [6] discusses the nonclassical elastic effects in torsion and bending emerging in materials exhibiting a lattice-type microstructure, and how they can be described through the theory of Cosserat elasticity. These effects are highlighted through experiments on 3-D printed samples, and the length dependence predicted by the theory is verified. In [7], the authors investigate another type of extreme effect deriving from microstructure, i.e. auxeticity combined with elastic wave band gap formation. The numerical optimization of these types of structures leads to chiral and anti-chiral layouts with negative Poisson's ratio and full band gaps, which could be exploited for tunable waveguides and phononic crystals.

Another type of extreme mechanical properties derives from the possibility of achieving tunability of material parameters. In [8], a periodic square tensegrity architecture is exploited to achieve an optimized design with minimal mass with small shear stiffness, opening the way for new materials with force-tunable shear modulus.

At various size scales, periodicity, heterogeneity and architecture contribute in determining extreme dynamic characteristics in elastic or acoustic metamaterials, with effects such as band gaps, negative refraction, focusing or cloaking. On this topic, Bacigalupo et al. [9] discuss the possibility of creating acoustic waveguide filters using an infinite stack of periodic massive blocks connected by elastic joints, determining stop bands in the ultra-low frequency range. Instead, in [10], the authors introduce the concept of inertial amplified resonators as building blocks for metasurfaces with tunable bandgap properties.

This special issue is a collection of key papers presented at the AIMETA 2017 conference in the minisymposium on Mechanics of Extreme Materials organized by the Guest Editors, and also includes—by invitation only—other related key contributions. It aims to provide further insight into the possibilities open to researchers to design and fabricate materials with novel mechanical properties, both in the static and dynamic range, bridging some of the gaps remaining in the fundamental understanding of the behavior of these extreme materials and providing indications on how to optimize their desirable characteristics.

References

1. Lee S, Pugno N, Ryu S (2019) Atomistic simulation study on the crack growth stabilityof graphene under uniaxial tension and indentation. Meccanica. https://doi.org/10.1007/s11012-019-01027-x
2. Scaramozzino D, Lacidogna G, Piana G et al (2019) A finite-element-based coarse-grained model for global protein vibration. Meccanica. https://doi.org/10.1007/s11012-019-01037-9
3. Carotenuto AR, Cutolo A, Palumbo S, Fraldi M (2019) Growth and remodeling in highly stressed solid tumors. Meccanica. https://doi.org/10.1007/s11012-019-01057-5
4. Perepelkin N, Martin-Martinez J, Kovalev A et al (2019) Experimental testing of self-healing ability of soft polymer materials. Meccanica. https://doi.org/10.1007/s11012-019-00965-w
5. Volpini V, Bardella L, Gei M (2019) A note on the solution of the electro-elastic boundary-value problem for rank-two laminates at finite strains. Meccanica. https://doi.org/10.1007/s11012-019-00974-9

6. Rueger Z, Ha C, Lakes R (2019) Cosserat elastic lattices. Meccanica. https://doi.org/10.1007/s11012-019-00968-7
7. Bruggi M, Corigliano A (2019) Optimal 2D auxetic microstructures with band gap. Meccanica. https://doi.org/10.1007/s11012-019-00981-w
8. De Tommasi D, Puglisi G, Trentadue F (2019) Tunable shear stiffness in a metamaterial sheet. Meccanica. https://doi.org/10.1007/s11012-019-00994-5
9. Bacigalupo A, Gambarotta L, Lepidi M et al (2019) Acoustic waveguide filters made up of rigid stacked materials with elastic joints. Meccanica. https://doi.org/10.1007/s11012-019-00959-8
10. Zeighami F, Palermo A, Marzani A (2019) Inertial amplified resonators for tunable metasurfaces. Meccanica. https://doi.org/10.1007/s11012-019-01020-4