# Metamaterials designed to display material instabilities

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Homogenization of periodic elastic grids subject to axial prestress is introduced to obtain equivalent elastic materials exhibiting material instabilities, driven by the microstructure of the grid and its level of prestress. Instabilities include shear band fromation and Hopf bifurcation, thus leading to odd elasticity.

A design strategy is introduced for metamaterials displaying tailored instabilities. When the latter occur at the microscale, they are analyzed with a Floquet-Bloch wave technique, while analysis of macroinstabilities leads to the definition of an equivalent elastic material. This material can be obtained via homogenization theory for periodic elastic structures, subject to a state of axial prestress and incremental deformation involving axial and shear forces and bending moment [1]. Macroinstabilities in the form of shear bands usually occur only for compressive prestress, so that the stability domain for the equivalent material results unbounded in tension. We show that it is possible to design a material for which the stability domain is bounded, in other words, for which shear bands may form under tensile loads. The architecture of this structure leads to multiple band gaps, flat bands, and Dirac cones [2]. The possibility of a Hopf bifurcation is introduced, as related to the presence of follower loads [3], or nonholonomic constraints [4], or discontinuity in the constraint curvature [5]. When this instability is implemented in a material [6], apparently work is produced in a closed strain cycle, so that conservation of energy is apparently violated. As mentioned, this violation is only apparent, as the material is able to “suck and release” energy from the environment. When a material is subject to a Hopf bifurcation, mechanical waves propagate through it without decaying, rather with amplification, because energy is extracted from the surroundings.

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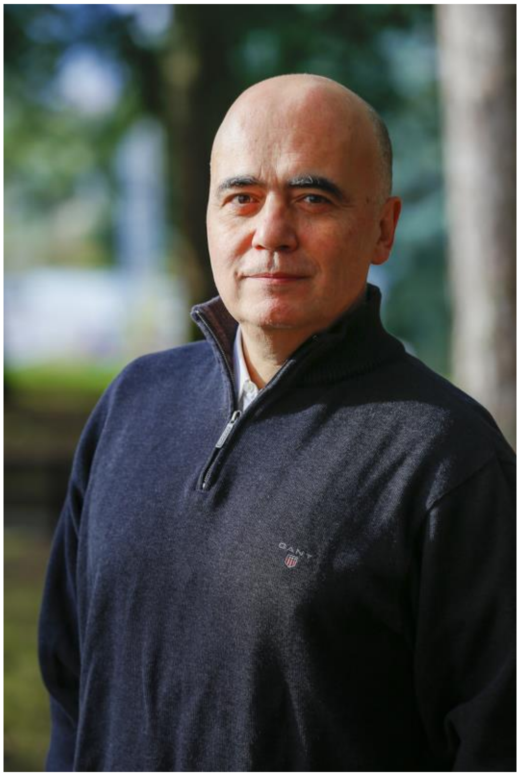

**Bio**

From 2001 Davide Bigoni holds a full professor position at the University of Trento (Italy), where he is leading a very active group in the field of Solid ad Structural Mechanics. He was elected in 2009 Euromech Fellow (of the European Mechanics Society), received in 2012 the Ceramic Technology Transfer Day Award (of the ACIMAC and ISTEC-CNR), and in 2014 he was awarded the Doctor Honoris Causa degree at the Ovidius University of Constanta. He has received the Panetti and Ferrari Award for Applied Mechanics (from the Accademia delle Scienze di Torino), in 2018 he was Guest Lecturer for the Midwest Mechanics Seminars, in 2019 he was nominated Fellow of the Istituto Lombardo, Accademia di Scienze e Lettere, he was awarded a 60th Anniversary Issue of the Journal of the Mechanics and Physics of Solids. His research has been featured on 9 covers of International Journals. He has coordinated and has been involved in 3 European grants between academia and industry. He has been awarded 2 ERC advanced grants from the European Research Council, the first in 2013 and the second in 2021. He is co-editor of the Journal of Mechanics of Materials and Structures, is associate Editor of Mechanics Research Communications and member of the editorial boards of: Archives of Mechanics, International Journal of Solids and Structures, Journal of Elasticity, Journal of the Mechanical Behavior of Materials, Acta Mechanica Sinica, and International Journal of Applied Mechanics. He is reviewer for more than 150 international journals. He was vice chair of the panel PE8 for the European Research Council Starting Grants.