Self-organization and Criticality in Martensite

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Pierluigi Cesana obtained his PhD in Applied Mathematics at the International School for Advanced Studies in Trieste, Italy (2009). Subsequently, he held postdoc positions at Caltech (Division of Mechanical Engineering) and at the Math Institute at Oxford (OxPDE group). He moved to La Trobe University as a Senior Research Fellow and since 2017 he is an Associate Professor at the Institute of Mathematics for Industry of Kyushu University. In his research, he combines methods from vectorial calculus of variations and probability theory to study smart materials and functional molecules, in particular, liquid crystals, martensite, microplasticity.

Abstract

The austenite-to-martensite phase-transformation is a first-order diffusionless transition occurring in elastic crystals and characterized by an abrupt change of shape of the underlying crystal lattice. In a temperature-induced transformation, austenite evolves into martensite through a series of energy releases and structural changes. This process leads to the formation of a highly inhomogeneous microstructure characterized by sharp angles and interfaces separating different variants of martensite. Statistical analysis of acoustic activity during the transformation suggests a power law behavior with characteristic exponents, indicating universality classes based on symmetry reduction in the transformation, regardless of chemical composition. Inspired by Bak's cellular automaton model for sand piles, we introduce a conceptual model for a martensitic phase transition and analyze the properties of the patterns obtained. Nucleation and evolution of martensitic variants is modeled as a fragmentation process in which the microstructure evolves via formation of thin plates of martensite embedded in a medium representing the austenite. We investigate distribution of the lengths of the interfaces in the pattern and establish limit theorems for some of the asymptotics of the interface profile. This is a collaboration with J.M. Ball and B. Hambly (Oxford).

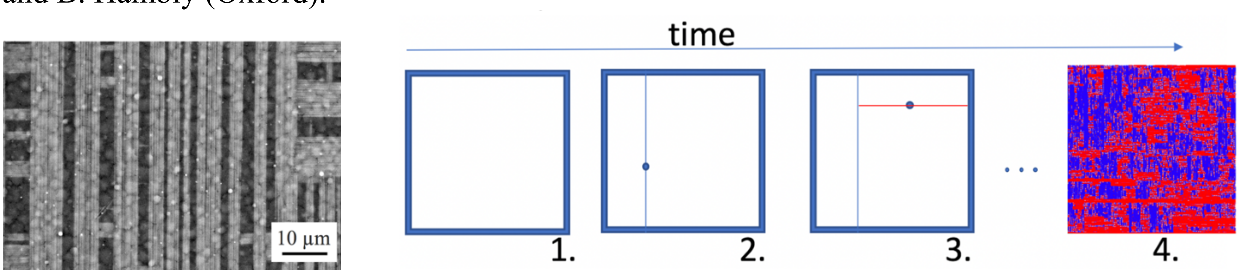

Figure 1. Left: Snapshot from a temperature series of scanning electron micrographs of the alloy NiMnGa. Here the dark grey area corresponds to untransformed material (austenite) and the light grey 'needles' evolving in vertical or horizontal direction correspond to the domain already transformed into a martensitic phase. Courtesy of Robert Niemann, reproduced with the

permission of the author [2]. Center/Right. Implementation of an à-la-Bak conceptual fragmentation model for martensitic avalanches on a unit square, [1], [2].

References:

[1] J.M.Ball, P.C., B.Hambly, Proc. ESOMAT, p 2008.1-6, 2015.

[2] P.C., B. Hambly, J. of App. Prob., 59(4), 2022.