

## **Conference on Hysteresis, Avalanches and Interfaces in Solid Phase Transformations** Lecture Room L3, Andrew Wiles Building, Oxford

### Monday 19 September

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#### Ultra-low fatigue of elastocaloric NiTiCu-based thin films

Caloric materials have the potential to serve as an environmentally friendly and more efficient alternative substitute in conventional vapor compression cooling. The principle of ferroic cooling is based on a solid state phase transformation initiated by an external field, in the case of elastocalorics by an external stress field. Combined with thin film processes this technology enables the development of small scale cooling devices required for mobile applications. Up to now, the major obstacles for the implementation of elastocaloric materials in cooling devices are the functional degradation and structural failure of the material. To investigate the underlying microstructural mechanisms TEM and synchrotron analyses of NiTiCu- based thin films are conducted in the pristine state and after superelastic cycling. A strong difference of superelastic degradation for Ti-rich compositions compared to near equiatomic compositions is found. While near equiatomic compositions already degrade severely during the first cycles, Ti-rich compositions are functionally stable for 10<sup>7</sup> full superelastic cycles (1). Using stress dependent in situ synchrotron investigations the change of lattice constants of B2 phase and stress induced B19 phase during the superelastic transformation can be quantified. This measurement enables the compatibility calculation of austenite and martensite phases which is known to have a strong influence on the superelastic hysteresis and the thermally induced transformation stability. The microstructural influences of grain size, precipitates and crystallographic compatibility on the functional degradation of NiTiCu-based thin films will be discussed.

(1) Chluba, C.; Ge, W.; Lima de Miranda, R.; Strobel, J.; Kienle, L.; Quandt, E.; Wuttig, M.: Ultralow-fatigue shape memory alloy films, Science, 348 (2015), 1004–1007.



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# Distribution of domain sizes in martensitic microstructures: a simple geometrical model with kinematic constraints

When cooling, many solid metals and alloys undergo martensitic transitions involving a change of symmetry of the unit cell. The low temperature martensitic phase might then nucleate and grow in the austenitic matrix in a number of directions related by the symmetry operations lost in the transition. The arrangement of these symmetry related variants forms complex microstructures that are important for the control of the physical properties of the materials.

Different factors influence this final arrangement: the main one is the elastic interactions between domains that favour the formation of twins. But also the presence of quenched disorder, the system boundaries, etc. In this work we show that the fact that the domains grow sequentially under cooling represents a kinematic constraint that has important consequences on the final microstructure. We present a very simple two-dimensional model that explains why domain sizes in the final microstructure are randomly distributed according to probability densities with fat tails, which in some cases become power-law tails. The model is solved first in the limit of martensitic domains being infinitely thin, and secondly assuming domains with a constant width on a finite lattice.

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#### Konstantinos Koumatos (Gran Sasso Science Institute)

#### On the morphology of lath martensite in steels via energy minimisation

The face-centred to body-centred cubic phase transition in low-carbon steels results in the formation of lath-shaped crystal grains in the martensite and the appearance of {5 5 7} habit planes between the laths. Widely accepted phenomenological theories in metallurgy that result in these habit planes are the so-called double-shear theories. However, they seem largely ad-hoc and require a significant number of postulated input parameters. In this work, we employ a standard energy minimisation framework and show that the {5 5 7} habit planes can result from second order lamination in the martensite, amounting to an



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instance of a double-shear theory. In addition, a selection mechanism is proposed which, not only explains, but predicts the {5 5 7} habit planes as those arising from a deformation with small atomic movement and maximal geometric compatibility. This is joint work with Anton Muehlemann.

#### Kirsten Martens (University Joseph Fourier Grenoble 1)

## Driving rate dependence of avalanche statistics and shapes in athermally driven yield stress materials

In the past decades, a widespread consensus has emerged about the heterogeneous response of yield stress material subjected to shear. However, the characterization of the transition towards the plastic flow regime remains an open issue. Especially the correct mean-field description of the transition shows to be controversial.

In sheared yield stress materials, the common picture is that local plastic rearrangements, the so-called shear transformations, lead to an elastic response of the surrounding medium. Due to the long range nature of the elastic kernel it is tempting to believe that mean-field considerations are meaningful to describe the resulting dynamics in the slow driving limit, close to the yielding transition. Nevertheless, the specific form of the elastic kernel prevents usual analytical assumptions to be applied, and the question about a mean-field or non mean-field criticality is still open.

The combined study of avalanche size and duration distributions together with the particular shape of avalanches has played an essential role in our understanding of the universal aspects of crackling noise and depinning dynamics. In this talk I will discuss numerical predictions for similar quantities in the case of the yielding transition, with a clear indication of a complex non mean field behavior [1]. Interestingly, mean field predictions are recovered only in the stronger driving limit, where the dynamics are effectively randomized [2].

[1] Driving Rate Dependence of Avalanche Statistics and Shapes at the Yielding Transition,
C. Liu, E. E. Ferrero, F. Puosi, J.-L. Barrat, and K. Martens, Phys. Rev. Lett. 116, 065501

(2016).

[2] Mechanical noise characteristics in driven disordered systems,

E. E. Ferrero, E. Agoritsas, C. Liu, J.-L. Barrat, E. Bertin, and K. Martens, to be published.

