6 Multiscale correlations in unstable plastic flow

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Investigations of crystal plasticity during last two decades proved that the ensemble of crystal defects represents a nonlinear dynamical system characterized by self-organization phenomena. Avalanche-like behaviour was first identified for various mechanisms of plasticity giving rise to macroscopic intermittency visible on stress-strain curves, in particular, under conditions of the Portevin-Le Chatelier effect (PLC) in dilute alloys, caused by interaction between dislocations and impurities. Due to the development of high-frequency measurement techniques, e.g., based on the acoustic emission (AE), these ideas were also confirmed in a more general case of macroscopically smooth plastic flow, albeit on finer scales. Indeed, power-law statistics of AE were found during smooth deformation of pure crystals, which led to a conclusion that plastic flow is an inherently intermittent scale-invariant process. These investigations, associated with different scales of deformation processes, were not for a long time related to each other. In particular, the macroscopic fluctuations of the deforming stress were often considered as a peculiar case. However, as they alternate with periods of smooth plastic flow, it was challenging to apprehend the relationships between the laws governing the dislocation dynamics in both cases, with an objective to understand the relationships between the short time scales related to self-organization of crystal defects and those relevant to the continuous approach of plasticity. The talk presents a multiscale study of self-organization of crystal defects, combining the analysis of deformation curves and the accompanying AE during deformation of AlMg and MgZr alloys. Both materials manifest macroscopic serrations on the strain-stress curves but the physical mechanisms of this unevenness are different : the PLC effect for AlMg and a combination of twinning and dislocation glide for the MgZr alloy. An essential feature of this research and a principal ground for getting insight into self-organization phenomena is the application of statistical methods (statistical, Fourier, correlation, multifractal) to treat experimental data.

Références