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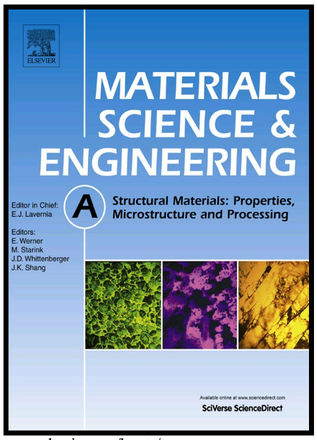

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PII: S0921-5093(17)30726-8
DOI: http://dx.doi.org/10.1016/j.msea.2017.05.098
Reference: MSA35114

To appear in: *Materials Science & Engineering A*

Received date: 2 March 2017
Revised date: 24 May 2017
Accepted date: 25 May 2017

Cite this article as: F. Toth, C. Kirchlechner, F.D. Fischer, G. Dehm and F.G. Rammerstorfer, Compressed Bi-crystal Micropillars Showing a Sigmoida Deformation State – a Computational Study, *Materials Science & Engineerin A,* http://dx.doi.org/10.1016/j.msea.2017.05.098

Compressed Bi-crystal Micropillars Showing a Sigmoidal Deformation State – a Computational Study

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Abstract
It is the aim of this paper to show the mechanisms behind the experimental observations of rather smooth sigmoidal deformations in bi-crystal micropillar tests (in contrast to single crystal micro-compression tests) and to point out that the appearance of such deformation modes are a further reason for being careful when interpreting the force-axial displacement behavior in terms of stress-strain curves.
Instabilities, i.e., buckling and subsequent post-buckling deformations, inhomogeneous strain fields and substantial deformations of the base as well as pronounced free surface effects are considered. The influences of imperfections and of friction as well as a possible clearance in the guidance of the loading device are taken into account, too. From these studies, the experimenter may get information how and with which limitations material parameters can be obtained from such compression tests in combination with simulations.

Keywords pillar compression • buckling • finite element method • hardening • micromechanics

Introduction:
The evaluation of material properties by extraction from deformation tests performed on micro- or nano-specimens is one of the important goals in materials science in the last two decades. One of most established test-configurations is a micropillar setting. We consider it, therefore, as motivation to explore the coupling between the pure material behaviour with the mostly rather large deformation process, i.e. the geometrically nonlinear behaviour, and concentrate on micropillar compression tests.
Occasionally, in micropillar compression tests substantial deviations of the deformation states from such ones under pure axial compression can be observed. In many cases this is the consequence of activation of single slip systems (see Fig 1b, pillars (1), (2), and (4), (5), representing micropillars of a single crystal); see e.g. [1] as well as the recent paper [2]. However, sometimes a smooth transversal deviation, associated with bending deformations, appears, particularly if the deformation is not induced by just a few slip systems, as is the case with the bi-crystal micropillar shown in Fig. 1a and pillar (3) in Fig. 1b. The appearance of such transversal deformations has been reported frequently, see, e.g., [3 - 11]. The authors of [3] offered an interpretation of the transversal deformations as a consequence of bifurcation from the trivial, i.e., purely axial compression state. This explanation is based on the treatment of the micropillar as "structure" and not only as a single piece of "material". Therefore, some terms from structural stability shall shortly be recalled. If we consider a perfect, fully symmetric pillar under a perfectly axial compression, acting along the pillar axis, we can observe a deviation from the purely axial deformation by a transversal displacement, e.g. measured at the top of the pillar, occurring for a distinct load, i.e. the buckling load. (For a slender, linear elastic beam, this load is called Euler buckling load. In the considered situation of the compression test, the beam representing the pillar is neither slender nor buckles it in the elastic range. It has started yielding long before buckling