The applicability of fracture-mechanics considerations to the fatigue- and fracture behaviour of thin metallic foils

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Thin foils as essential parts of micro-electro-mechanical devices (MEMs) are dynamically loaded in a wide spectrum of frequencies ranging from much less than 1 Hz (i.e. almost monotonically strained by thermal fluctuations) up to the order of MHz (due to their use in very fast switches). For the design of MEMs in order to assure safe operation it is of increasing demand to rely upon accurate fatigue data.

In the present investigation the fatigue and fracture behaviour of free standing foils in the thickness range of 20 µm to 250 µm has been determined.

Fatigue life data appeared to be influenced by a variety of different extrinsic and intrinsic parameters such as loading mode, grain-size, -shape and –distribution in respect to the geometrical dimension. This makes it difficult to compare the behaviour of foils of nominally identical thickness if one or more of these influencing parameters are not specified.

The fatigue crack growth- and threshold-behaviour is rarely given in literature In the present study in a first attempt this behaviour has been described by use of fracture mechanics (FM)-considerations. A comparison to fatigue data of bulk material (thickness 1 mm and more) yielded a noticeable geometrical size-effect mainly characterised by the transition of a state of plane strain to plane stress with decreasing thickness. This could be proved by both a direct observation of the plastic zone size by means of a electron-channelling-contrast imaging technique in a scanning electron microscope revealing the global dislocation structure and a determination of the dimensional constraint.

Although both arrangement and movement of the dislocations as well as the mechanisms of crack growth are similar to those in bulk materials, a geometrical size-effect (similar to that mentioned before) was detected. These findings could be transmitted to the interpretation of the fracture-strain, plastic strain range, creep strain and fracture topography depending on foil-thickness. A reduced number of gliding systems with decreasing thickness is obvious.

A further comparison to data of thin films (thickness < 1µm) given in literature [1] clearly indicates the limitation of the applicability of conventional linear elastic- and elastic-plastic fracture mechanics. This is mainly characterised by a different dislocation motion resulting in a break-down of classical relationships such as those of the Hall-Petch type.

1. Arzt, E. (1998) *Acta Mater.* 46, 16, pp. 5611-5626