

## DUCTILE-BRITTLE-TRANSITION OF FLASH ANNEALED FE-BASED METALLIC GLASS RIBBONS

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Fe-based metallic glasses show a ductile-brittle-transition (DBT) after annealing above a critical temperature, which makes the further processing of annealed ribbons complicated. However, the annealing step is necessary to improve the soft magnetic properties of these materials for industrial applications. For the future development of ductile (partial-) nanocrystalline Fe-based ribbons with excellent soft magnetic properties, it is important to understand the mechanisms behind the DBT.

Therefore, tensile and bending tests were performed to determine the DBT of 15-20  $\mu\text{m}$  thin, flash annealed Fe<sub>85.2</sub>B<sub>9.5</sub>P<sub>4</sub>Cu<sub>0.8</sub>Si<sub>0.5</sub> ribbons in terms of critical stress intensity factor and bending ductility. Microstructure analysis has been done via X-ray diffraction (XRD), differential scanning calorimetry (DSC) and atom probe tomography (ATP).

The investigated material shows a sharp DBT at annealing temperatures between 330°C and 350°C in bending tests. The critical stress intensity factor drops between 350°C and 360°C. Whereas the fracture morphology is changing from a typical vein-like (ductile) fracture pattern (see figure 1a) to a periodic striped pattern (Wallnerlines, brittle fracture) (see figure 1b) and finally to an "intercrystalline" fracture behavior (see figure 1c) with increasing annealing temperature. Furthermore, Cu-clustering was investigated by ATP before the onset of primary crystallization, the precipitation of  $\alpha$ -Fe, which occurs at 370°C.

Thus, the DBT already takes place in the X-ray amorphous condition, but the mechanisms behind the DBT are still not fully understood. Relaxation processes lead to a decrease in free volume and in consequence to smaller shear transformation zones (STZs), the carrier of plastic deformation in amorphous metals. Cu- and Fe-clustering during the heat treatment, as well as precipitations, lead to local stress concentrations and subsequently to local fracture events, promoted by a decrease in STZ volume. The result is a global embrittlement/failure of the annealed Fe<sub>85.2</sub>B<sub>9.5</sub>P<sub>4</sub>Cu<sub>0.8</sub>Si<sub>0.5</sub> alloy.

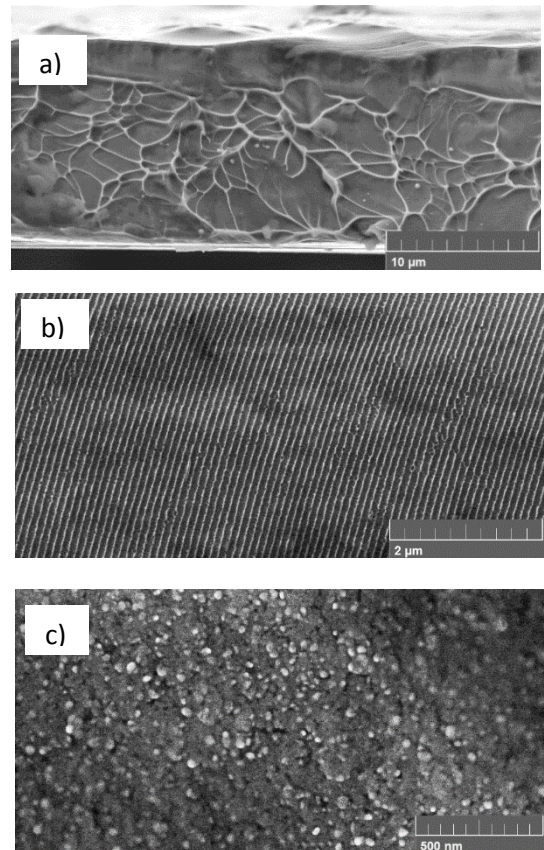


Figure 1: Fracture surfaces in the as-cast condition (a), relaxed condition (b) and partially crystalline condition (c).