In-situ texture measurements during uni-axial loading of extruded magnesium alloys

S. Yi1, J. Bohlen1, J. Victoria-Hernandez1, N. Schell2, B. Schwebke3, H.-G. Brokmeier2,3, K.U. Kainer1, A. Schreyer3 and D. Letzig1

1Magnesium Innovation Centre, Helmholtz-Zentrum Geesthacht, Max-Planck-Str. 1, 21502, Geesthacht, Germany
2Institute of Mater. Sci. Eng., TU-Clausthal, Agricola Str. 6, 38678, Clausthal-Zellerfeld, Germany
3Structural Research on New Mater., Helmholtz-Zentrum Geesthacht, Outer Station at DESY, Notkestr. 85, 22607, Hamburg, Germany

A high directional anisotropy and poor cold formability of magnesium alloys, resulting from its hexagonal crystal structure and the lack in independent deformation systems, hinder their wide applications. The activities of potential deformation modes are highly dependent on the crystallographic texture and the loading (straining) direction. Recent studies have shown that the addition of rare-earth elements into magnesium leads to an increase in the activities of non-basal type deformation modes and, further, alteration of a strong basal-type texture to a weak one with widely distributed basal poles. Therefore, magnesium alloys containing rare earth elements show a significantly reduced mechanical anisotropy. The mechanism of such a texture transition led by alloying variation is, however, still unclear. The present study has been carried out to contribute to a basic understanding of the relationship between alloying compositions, texture evolution, activation of various deformation systems and mechanical properties. Based on the experimental results, important implications for the texture transition mechanisms and the active deformation modes in rare earth containing magnesium alloys can be analysed.

Tensile and compression samples taken from extruded round bars of AZ80 (8Al-1Zn-0.4Mn-Mg) and experimental alloy MN11 (1Mn-1Nd-Mg in wt.%) containing rare earth element Neodymium, were tested using a loading device mounted on a rotation ($\omega$) and translation (x, y) stage at the HEMS-P07B beamline, PETRA III, at the initial strain rate of $10^{-3}$/s. The texture evolution during the loading was measured in-situ at characteristic deformation stages, e.g. at the beginning plastic deformation ($\epsilon=2$-5%), during strain hardening, at quasi steady state plastic deformation and after fracture. At each measuring point loading was stopped (but not released) during the irradiation of the sample. The sample was rotated together with the loading device through 96° in 3° steps; at each position Debye-Scherrer patterns were collected for revealing the {10.0}, (00.2), {10.1}, {10.2}, {11.0} and {10.3} reflections from the area detector images after background correction.

Figure 1 presents the stress-strain curves and texture development during tensile and compressive loading of the alloys. The texture is best described by using inverse pole figures, due to the rotational symmetry of the initial material and the uni-axial loading. Furthermore, the texture simulation based on a visco-plastic self-consistent scheme was carried out to investigate the activities of different deformation mechanisms. The simulation is conducted in combination with the experimental results from the in-situ texture measurements, such that a higher reliability in the simulation result, e.g. activities of the deformation modes, is obtained.

A high yield asymmetry in the AZ80 alloy can be understood as the result of difficulties of basal $<$a$>$ slip, while extension twinning is highly promoted during compression, consequently leading to lower yield stress in compression rather than in tension. An $<$00.1$>$ fibre-type texture parallel to the loading direction is developed with $I_{max} = 6$ m.r.d. in the fractured samples. It should be mentioned that the mechanical twinning and rigid body rotation are hindered by higher amount of Mg$_{17}$Al$_{12}$ precipitates in the AZ80 alloy, in comparison to that in the Mg alloys with a lower Al content like AZ31. Consequently, the texture intensities in the fractured AZ80 samples are relatively lower than those of AZ31 [1]. The texture development in the MN11 alloy is distinct from the AZ80 alloy. The MN11 alloy shows the formation of non-basal texture components, i.e. tilted basal poles from the main deformation axis, after tensile and compressive fracture, even after fracture at $\epsilon = 46\%$ (tension) and 31% (compression). An important result of the VPSC texture simulation is the relative activities of various deformation modes including twinning activities, Fig. 2. The tensile loading of the AZ80 leads a high basal $<$a$>-$slip activity, whereas a high activation of the tensile
twinning is observed in the initial plastic deformation under compression. However, the MN11 alloy, different to the AZ80, shows a moderate activity of the tensile twinning under tensile loading as well as compression. Moreover, a higher activity of the \(<c+a>\) slip is observed. The development of texture having tilted basal pole in the MN11 alloy can be attributed to the high activity of the non-basal deformation mechanism.

![Fig. 1 Mechanical response and texture evolution during the tensile (black) and compressive (red) loading of the examined alloys.](image1)

![Fig. 2 Relative activities of different deformation modes during the tensile and compressive loading of the AZ80 and MN11 alloys. Calculated results from the VPSC texture simulation using the following deformation modes; basal \(<a>\) slip, prismatic \(<a>\) slip, pyramidal \(<c+a>\) slip, tensile twinning and compression twinning.](image2)