ANOMALOUS TWINNING IN AZ 31 MAGNESIUM ALLOY DURING ELECTRICALLY ASSISTED FORMING

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The electro plastic effect (EPE) occurs in materials exposed to high electric currents, on the order of 10^2 to 10^4 A mm^{-2}, during elastic or plastic deformation. Current pulses with durations of about 10^{-3} s are usually used to limit resistive heating of the sample. As a result, a reduction the macroscopic of flow stress and enhanced ductility is observed, The EPE may therefore be exploited to support the deformation of inherently brittle materials. The underlying microscopic mechanisms enabling the flow stress reduction and increase in ductility are still unresolved. Besides the obvious contribution of Joule heating, various mechanisms of electron - dislocation interactions, resulting in increased dislocation mobility or changed dislocation density, have been proposed.

In the present study, the EPE was investigated using samples of extruded pure magnesium and AZ 31 Mg alloy, which were subjected to one or ten current pulses with a current density of 700 A mm^{-2} and 1 ms duration while subjected to constant compressive strain below the yield point. During the experiments the mechanical response of the sample to the current impulse, a drop of stress, the occurrence of residual plastic strain and hardening of the sample, was observed. The magnitude of the observed reduction in stress depends on the relative orientations of texture and current direction. In the case of multiple pulses, the first current pulse led to a significantly larger drop than the subsequent pulses. Reference experiments using hot air and inductive heating were conducted, in which samples were subjected to identical strains and similar temperature profiles. A similar softening could not be observed. The subsequent optical and EBSD microstructural observations, using appropriate metallographical preparation techniques, revealed unusual twinning in the samples subjected to current pulses.

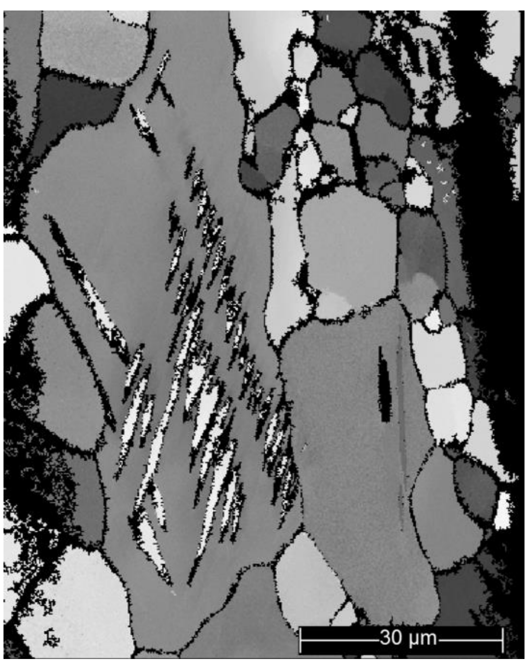

Figure 1- EBSD Map of AZ 31 subjected to one 700 A / mm² current impulse exhibiting columnar twin formation

Figure 1 shows twinning in samples subjected to one current pulse. The resulting twins are arranged in columns roughly in line with the direction of current flow. These twins exhibit wide, “sail-shaped” center sections and long, narrow “tails”. With subsequent pulses, these tails connect the individual columns until the grain is completely twinned. At that point further twinning as a result from the electrical pulse is no longer possible, resulting in a reduced macroscopic stress drop. Furthermore, twin formation is also observed along some grain boundaries. In contrast to the reference experiments, these twins do not propagate across grain boundaries.

This confirms that grain boundaries play an important role in explaining the EPE due to their different electrical properties compared to the bulk material. The formation of columns of twins in their shear plane in the interior of the sample indicate the capability of the current to activate twinning in more homogeneous regions of the sample. Twinning, along with enhanced dislocation mobility, has to be considered a micromechanism, of the electroplastic effect in magnesium. The interactions of increased dislocation mobility, possible generation of dislocations resulting from the current pulse and twinning have yet to be studied in further detail.