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# Twinning, grain orientation and texture variation of AZ31 Mg alloy during compression by EBSD tracing

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## ABSTRACT

In order to investigate the micro-mechanism of warm forming of Mg alloys, three specimens cut from a rolled AZ31 sheet were chosen to be compressed along the Rolling Direction (RD) at 100 °C, 170 °C and 230 °C, separately. During compression, an in situ measurement of grain orientation in the plane of RD × TD (Transverse Direction) was carried out with EBSD method. Experimental and analytical results show that temperature has remarkable impact on activation of twinning and variation of texture. As the temperature was raised from 100 °C to 230 °C, the number of grains with twins activated decreased substantially during deformation, and rolling texture varied from quick vanishing at 100 °C to always existing at 230 °C. Tracing for orientation of individual grains during deformation shows that there are obvious different orientation changes between grains with twins activated and those without twins activated. Twinning plays a significant effect on texture variation during compression. The extension twin variant really activated during deformation is the one with maximal Schmid factor.

## 1. Introduction

Mg alloys are promising metallic materials for structural applications due to their low density and high specific strength, while research activities regarding plastic forming technique of Mg alloys have been surging in recent years. However, die casting is still the main technique for producing Mg alloys parts up to now, in which process defects are hard to be avoided, such as shrinkage porosity, shrinkage void and relatively low strength. Plastic forming technology is an alternative for Mg alloy casting to avoid above defects. While as a hexagonal close-packed (hcp) metal, Mg alloys have poor formability at room temperature due to insufficient number of independent slipping systems.

Since the formability of Mg alloys is poor at room temperature, raising deformation temperature may be the easiest way to improve their formability. The melting temperature of magnesium is about 650 °C, thus the deformation temperature of magnesium alloys will be remarkably lower than this value, and deformation at temperature over 350 °C should usually be classified as high temperature deformation for Mg alloys. Taking into account the poor oxidation resistance of Mg alloys and the high costs for production, high temperature was not suitable for sheet metal processes, other than for hot rolling and hot extrusion when high temperature is a necessity. Warm forming of Mg alloys is attracting more and more attentions from researchers [1–4] as a newly developed plastic forming technology in recent years, due to its advantages of avoiding poor formability at room temperature and over-oxidization at high temperature simultaneously. Specifically, warm forming of Mg alloys usually means that the deformation temperature is below 250 °C [5,6].

As a newly developed technology of texture measurement in recent twenty years, the Electron Backscatter Diffraction (EBSD) technique could measure metal texture on the individual grain scale, and possesses higher precision than XRD for texture measurement on the micro-scale, the EBSD method has thus been used for studying the deformation technique of the Mg alloys by many researchers in recent years [7–28]. Up to now, research activities on the formability of Mg alloys are mainly focused on the processes of the Equal-Channel Angular Pressing (ECAP)[14,20,29], uniaxial tension [9,12,13,22] or compression [12,15,16,22,30], rolling [10,11,19,23,25,26], special extrusion [17,28,31], twin roll casting (TRC) [32,33], etc., and related deformation mechanisms studied in their work are mainly about Dynamic Recrystallization (DRX) [10,20,24,27–32], superplasticity [14,27,33] and activations of slip system and twinning [16–18,25]. Among the numerous papers cited above, though some researches are related to investigations on the micro-mechanism of warm forming of magnesium alloys, there are no reports on tracing variations of texture on individual grains scale, this is maybe because deformation temperature is higher than the temperature of recrystallization in many

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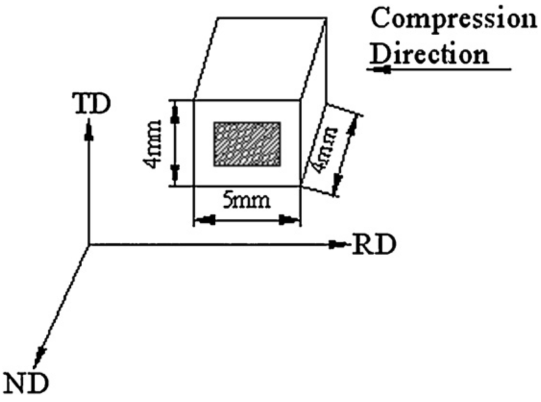

**Fig. 1.** Schematic illustration of the specimen for compression and EBSD.

experiments and this makes it hard to trace individual grains, or there are many inconveniences for realizing this process in the experiments.

In the experiments and research reported in the present article, an in situ measurement of grain orientation of AZ31 magnesium alloy in the plane of RD × TD during deformation was carried out by using the EBSD method under conditions of compression at 100 °C, 170 °C and 230 °C, separately. The aim is to reveal the micro-mechanism of warm deformation on individual grain scale.

## 2. Experimental details

Fig. 1 shows the AZ31 magnesium alloy specimen cut from a rolled AZ31 sheet (the rolling process: a 6 mm thick extruded blank was rolled into a 4 mm thick sheet with 0.6 mm pass reduction at 400 °C), the dashed region in the plane of RD × TD is the region where the texture is measured with EBSD method. Specimens prepared for EBSD measurement were ground by carbide silicon sand paper and mechanically polished by velour, and then electro-polished in a solution of 10% perchloric acid and ethanol solution, chilled to −30 °C, using a 15 V potential. The texture measurements were carried out by using a JECOL6500F field emission SEM equipped with a HKL Channel 5.0 software, the scanning step size is 1.5 μm and the magnification is 300.

Under the conditions of $1.0 \times 10^{-3}$ Pa vacuum and 0.1 mm/min compression velocity, three specimens were compressed uniaxially on a Gleeble1500 thermal simulator at temperatures of 100 °C, 170 °C and 230 °C, separately. For every specimen, the texture in the selected region was measured with EBSD method before compression, then the specimen was compressed to a strain along the direction as shown in Fig. 1. After this deformation, the specimen was unloaded from the Gleeble1500 and the texture in the same region was measured with EBSD method again. In this way, this specimen was subsequently compressed and measured for other two times in the following steps, i.e. every specimen was compressed to three different strains, four EBSD measurements were carried out correspondingly (including measurement before compression). In the experiments, three Vickers hardness marks were separately made on the three corners of the rectangular scanning region in the plane of RD × TD for every specimen, which aims to keep every EBSD measurement to be carried out in the same region, as shown in Fig. 1.

## 3. Results and discussion

### 3.1. Deformation textures

For the specimen compressed at 100 °C, the grain orientations in the same measured region at different strains are shown in Fig. 2, 20 complete grains numbered from 1 to 20 could be traced in the measured region throughout the deformation process. Colors representing grain orientations in Fig. 2 are obviously different between the orientation without height reduction and that with height reduction of 7.5%. On the contrary, there are almost no differences for colors in orientation maps related to height reductions of 7.5%, 11% and 13.6%, which means that there are many changes of grains orientation for compression from 0% to 7.5% but less from 7.5% to 13.6%.

Changes of texture during deformation could be illustrated explicitly by pole figures in Fig. 3, where typical basal texture exists

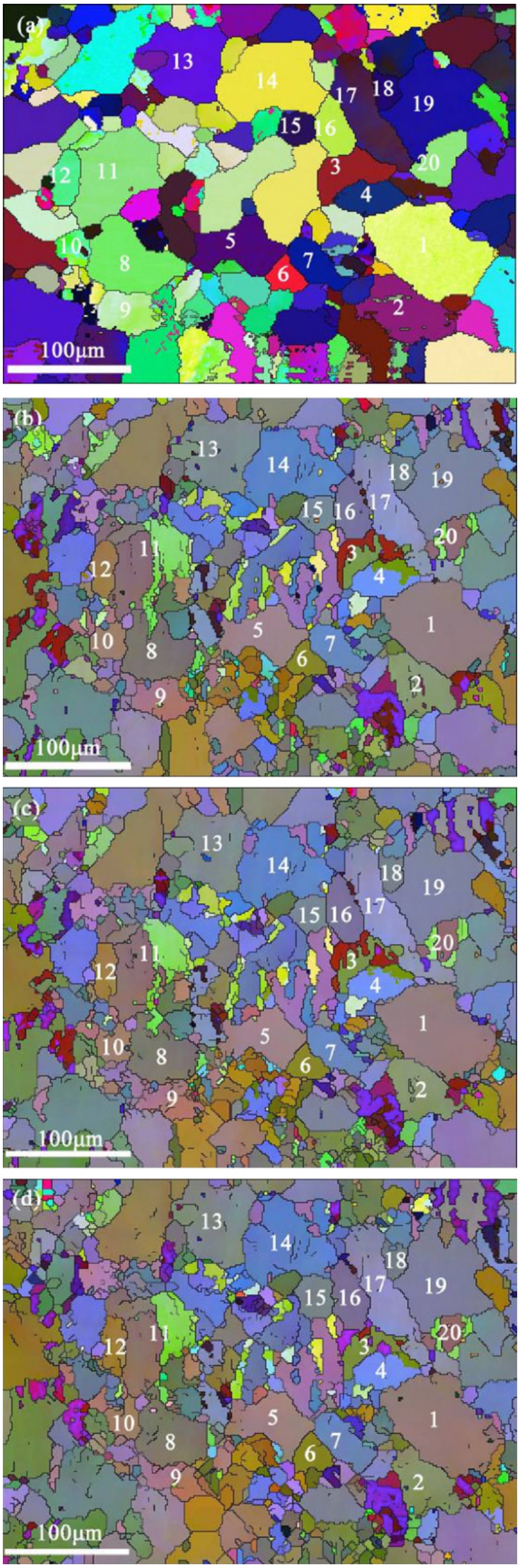

**Fig. 2.** Orientation micrograph of grains at different strains during compression at 100 °C, (a) 0%, (b) 7.5%, (c) 11% and (d) 13.6%.