Kumamoto University

Faculty of Advanced Science and Technology
Division of Materials Science and Chemistry

Reviewer's report on the doctoral thesis entitled "Study of advanced high strength magnesium alloys by *in situ* techniques" by Ms. Klaudia Fekete, née Horváth for the degree of Doctor of Philosophy at Department of Physics of Materials, Charles University.

Magnesium (Mg) alloys, light-weight structural materials, have received considerable attention from various industries because the weight saving of structural component by material replacement from conventional heavier materials to light-weight materials could be a reasonable strategy for tackling serious environmental issues globally. Among various alloys, Mg-Zn-Y alloys with a long period stacking ordered (LPSO) phase, originally developed by Prof. Kawamura in 2001, are promising candidates for next generation light-weight materials because they show superior mechanical properties compared with conventional Mg alloys.

Despite persistent efforts to elucidate deformation behavior of LPSO-type Mg alloys over the past 20 years, details of the deformation mechanisms in terms of crystal plasticity remain limited. One of the main reasons for this limited insight may be the complicated microstructure of LPSO-type Mg alloys especially after the metal forming processes, which are essential to gain mechanical strength of the LPSO-type Mg alloys. For instance, $Mg_{97}Zn_1Y_2$, which is a typical LPSO-type Mg alloy consisting of an α-Mg phase and a LPSO phase, shows multi-modal microstructure after thermomechanical processing. For alloys with complicated microstructures, quantitative evaluation of relationships between microstructure and macroscopic properties is difficult by conventional methods routinely used in materials science and mechanical engineering.

In this doctoral thesis, a comprehensive understanding of deformation mechanisms of LPSO-type Mg alloys was demonstrated by state-of-the-art *in-situ* techniques. A number of these will make significant contributions to other academic/technical fields, including structural design, material modelling, and the further development of new alloys.

The thesis consists of: "1. Theoretical background", "2. Aim of the thesis", "3. Experimental materials and methods" and "4. Results and discussion". In the theoretical background, fundamental knowledge required to understand the remainder of the thesis was explained in detail, which is useful for all potential readers. The objective of this study was stated, clearly and concisely in section (2). In section (3), experimental materials and methods, specific materials used in this study were described followed by detailed descriptions of the methods used for these materials. In section (4), results and discussion, the underlying deformation mechanism of LPSO-type Mg alloys of WZ42 and WZ104 were clarified based on solid evidences obtained by microscopic observation, *in-situ* synchrotron diffraction, and acoustic emission. Finally, three clear conclusions were summarized.

This reviewer totally agrees with the main results, discussion, and conclusions in this doctoral thesis. While this thesis is of satisfactory quality in its current version, the following questions may be still useful for discussion during public defense.

1. On page 67 and page 70, the words "higher Young's modulus of the LPSO phase" were used for explanations. To the best of this reviewer's knowledge, it may be better to replace this phrase with "higher CRSSs of the LPSO phase". While quite high values for Young's modulus for the LPSO phase have been reported in previous studies, recent comprehensive research by experimental measurement and first principle calculation (Tane et al., Acta Mater. 61 (2013) 6338) showed that polycrystalline Young's modulus of the LPSO phase is about 55 GPa, which is not significantly higher than that for α-Mg phase, which is about 45 GPa. These Young's modulus of each phase were comparable to the experimental results in tensile/compressive loading tests of α-Mg/LPSO single phase alloys undertaken by this reviewer. Effects of the insignificant elastic incompatibility on deformation behavior may be limited. On the other hand, the differences of CRSSs between α-Mg phase and the LPSO phase seems to be significant, especially for non-basal slip systems, although specific values of CRSSs for the LPSO phase have yet to be established.

2. On page 94, line 19, the author states that simultaneous activation of <c+a> slip and dynamic recrystallization was responsible for the local maximum around 40 degrees in the axial distribution of the (0002) peak. While possible influences of dynamic recrystallization on deformation were discussed prior to this explanation, <c+a> slip was not mentioned. Consequently, the explanation as presented appear to be not very logical. It would be helpful to explain experimental evidence and/or references for <c+a> slip at high temperature before the presenting the explanation about the local maximum around 40 degrees.

3. On page 95, the author stated that the decrease of lattice strain after yielding suggests dominance of the dynamic recrystallization process. While this reviewer agrees with that idea in the present case, a decreased lattice strain is not necessarily due to dynamic recrystallization. The decrease of lattice strain is phenomenologically caused by a decrease in macroscopic stress, regardless of physical reasons. Therefore, this reviewer suggests a phenomenological explanation, which is then followed by an explanation for possible physical reasons.

As mentioned above, this reviewer totally agrees with the main results, discussion, and conclusions in the doctoral thesis. Please note that the above questions are minor points which could be useful to improve the overall clarity of the doctoral thesis.

In summary, the doctoral thesis by Ms. Klaudia Fekete, née Horváth provided a number of novel insights for challenging and important topics both in science and engineering. These insights were based on high quality experimental results and careful interpretations. As such, this thesis demonstrates the author’s extensive knowledge and remarkable creativity, as I can confirm. Consequently, this reviewer enthusiastically recommends the thesis be accepted.

Sincerely,

Tsuyoshi Mayama

Associate professor
Kumamoto University
2-39-1, Kurokami, Chuo-ku, Kumamoto, 860-8555, JAPAN
E-mail: mayama@kumamoto-u.ac.jp
Tel.: +81-96-342-3946

Additional minor comments:

On the schematic illustration of tensile twinning in Fig.4.23, the labels “tw” (twin) and “m” (Matrix) seems to be reversed. Please check.

On p.5, line 6, “strain of 0.2%” may be better stated as “plastic strain of 0.2%”

On p.16, line 21, “Hess-Barnett” is actually “Hess-Barrett”.