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LETTER

Superplasticity evaluation in an extruded Mg–8.5Li alloy

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With the remarkable feature of a combination of ultra lightness and improved formability at room temperature, magnesium–lithium (Mg–Li) base alloys are deserving increased attention among the high-performance Mg alloys for either academic or technical interest [1, 2]. It has been reported that Mg–Li base alloys in the eutectic composition range, with their microstructure consisting of two phases of hexagonal α (Mg-rich phase) and centered cubic β (Li-rich phase), can produce superplasticity under appropriate thermo-mechanical processing and testing conditions [3–7]. But to date, only few of them were found to show large elongation at high strain rates more than 10^{-2} s $^{-1}$ [8]. Similar to aluminum alloys and other metal-based materials, developing high strain rate superplasticity in magnesium alloys would be of benefit for their commercial forming applications [9]. An attempt to obtain superplasticity in a Mg–8.5Li alloy prepared by stir casting and high ratio extrusion has been made in this work and the results will be introduced herewith.

The composition of the studied binary Mg–Li alloy was selected as Mg–8.5Li (wt. %) which is within the typical eutectic range and has been proved to make a (α + β) two-phase mixture microstructure [10, 11]. The alloy was cast by a stirring route followed by high ratio (100:1) extrusion at 623 K. Round tension specimens with a 2.5 mm diameter and a 15 mm gage length were directly made from the extruded rods of 4 mm in diameter. Tension test specimens were deformed at initial strain rates ranging from 9×10^{-4} to 9×10^{-1} s^{-1}and at 573 K, 623 K and 673 K, respectively. Microstructure of the specimens before and after deformation was examined by optical microscopy.

Superplastic characteristics of the Mg–8.5Li alloy at the examined temperatures are shown in Fig. 1. As seen from Fig. 1 (a), the flow stress of the Mg–8.5Li alloy increases as the strain rate increases or as the testing temperature decreases. The strain rate sensitivity exponent, m value, is about 0.40 at 623 ~ 673 K at strain rates ranging from 10^{-3} to 10^{-1} s^{-1}, and decreases to 0.20 at the strain rate higher than 10^{-1} s^{-1} .The variation of total elongation in the Mg–8.5Li alloy with strain rate is illustrated at Fig. 1 (b). At the same strain rate, the Mg–8.5Li alloy exhibits higher an elongation value at 623 K that at 573 K and 673 K. A maximum elongation of more than 500% is obtained at the strain rate of 1×10^{-2} s^{-1} at 623 K, indicating that the studied Mg–8.5Li alloy has the potential to produce superplasticity at higher strain rate. Typical deformed specimens along with the tension specimen before test are shown in Fig. 2.

The superplastic behaviors reported to date in the Mg–Li based alloys depend much on the fabrication and processing history and the resulting microstructure of the alloys, and almost all involve a rolling process [3–6]. The Mg-8.5–9%Li laminates prepared by a foil metallurgy route exhibited a larger elongation of 450% ~ 460% at initial

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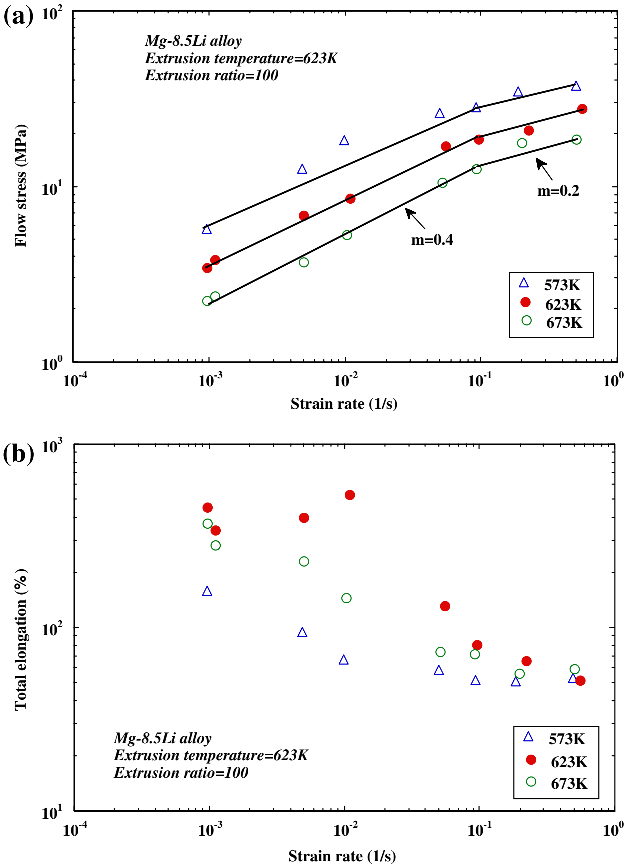

Fig. 1 Flow stress (**a**) and total elongation (**b**) vs. the initial strain rate of the as-extruded Mg–8.5Li alloy tension tested at various temperatures

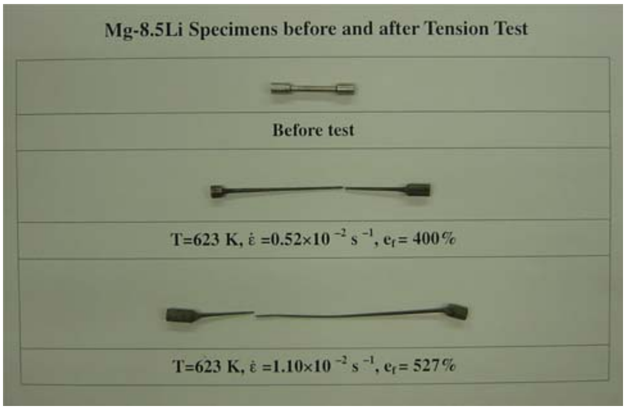

Fig. 2 Mg–8.5Li alloy tension specimens show larger elongation tested at 623 K

strain rates of 3 ~ 5.6 × 10^{-4} s^{-1} at 373 K ~ 523 K [4, 6]. A warm rolled Mg-8Li-1Zn alloy was observed to display a maximum elongation of 840% at an initial strain rate of 4.2 × 10^{-4} s^{-1} at 573 K [3]. Another work reported that a warm rolled Mg–8.5Li sheet showed a higher elongation to failure of about 610% at 4 × 10^{-4} s^{-1} at 623 K [5], while the rolled Mg–8.5Li–1Y alloy exhibited a larger elongation of 400% at a higher strain rate of 4 × 10^{-3} s^{-1} at 623 K [8]. As can be seen, all the Mg–Li based alloys mentioned above exhibit superplasticity at conventional strain rates.

The Mg–8.5Li alloy investigated in this study was prepared by stir casting and high ratio extrusion. The optical microstructure of the as-extruded sample displays a banded ($\alpha + \beta$) morphology along the extrusion direction (Fig. 3 (a)), and α phase (whitish phase) distributes uniformly within the β matrix (Fig.3 (b)). Optical examination of the deformed specimens demonstrated that both α phase and β phase tended to change their morphology from lamellae to equiaxial grains after deformation, indicating that dynamic recrystallization occurred during superplastic deformation. A representative microstructure of the deformed specimen is shown in Fig. 4. The apparent activation energy for superplastic deformation in the current Mg–8.5Li alloy at 573 ~ 673 K within m = 0.4 range is calculated to be about 80 kJ/mol, revealing that the dominant deformation

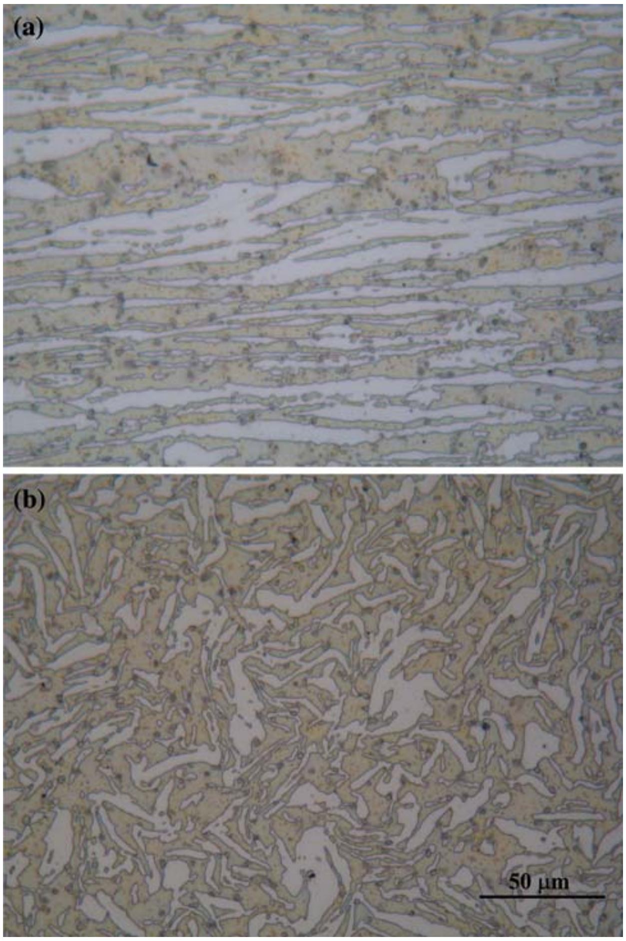

Fig. 3 Representative longitudinal section view (**a**) and transversal section view (**b**) microstructure in the as- extruded Mg–8.5Li sample

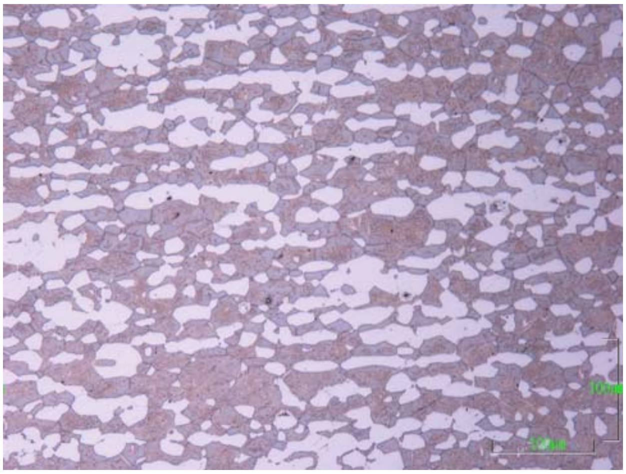

Fig. 4 Optical microstructure in the Mg–8.5Li alloy specimen deformed at 623K at an initial strain rate of 1.1×10^{-2} S^{-1}. ($\varepsilon = 1.28$). The tension direction is horizontal

mechanism in this alloy is still grain boundary sliding. Therefore, grain boundary sliding and dynamic recrystallization during superplastic flow should be responsible for the superplastic characteristics observed in present work.

Clearly, it is necessary to reduce the optimum superplastic temperature suggested by this work which seems to be high for practical application of Mg–8.5Li alloy, and it is also essential to modify the composition of the binary Mg-Li alloy by alloying elements addition for mechanical properties improvement. These works are in progress. It is interesting to notice the implication from current investigation that high ratio extrusion has the potential to induce dynamic recrystallization during extrusion or superplastic deformation in Mg–Li based alloys. As a consequence, the Mg–Li base alloy bulk materials produced by high ratio extrusion would be more deformable in the subsequent hot work process, benefiting from the increase in forming speed.

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