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EFFECTS OF BISMUTH (BI) ADDITIONS ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF AZ91 ALLOY

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Abstract

In this study, the effects of bismuth additions of 0.2, 0.5 and 1 wt% on microstructure and mechanical properties of AZ91 alloy were examined. A permanent mold casting procedure was carried out to produce the alloy billets under a mixed gas atmosphere of SF_6 and CO_2. Microstructural investigations showed that Mg_3Bi_2 intermetallic phases were formed in all the samples and it coarsened with increasing amount of Bi in AZ91 alloy. Furthermore, a finer dispersion of $Mg_{17}Al_{12}$ intermetallic phases was observed in the structures as the amount of Bi in AZ91 increased. It was also showed that increasing Bi addition increased the hardness of AZ91 alloy. However, the highest hardness value was found for the alloy having 0.5wt% Bi addition that means high amount of Bi can decrease the hardness of AZ91 alloy. On the other, there were no considerable changes in the tensile strengths and yield strengths of the alloys as the amount of Bi increased although a slight increase in both strengths were observed with increasing amount of Bi. Percent elongation at break showed a decrease as Bi addition increased.

Keywords: Magnesium Alloys, AZ91, Bismuth, Microstructure, Mechanical properties

1. INTRODUCTION

As the conservation of energy resources and raw materials in the earth has been gaining more importance in recent years, the significance of the use of low weight and recyclable materials has also been increasing day to day [1]. Therefore, magnesium and its alloys, as the lightest metallic structural materials with superior specific strength, good stiffness, good castability, high damping capacity and excellent machinability, are raising their importance and they are increasingly used in numerous engineering areas including portable microelectronics, computers, telecommunication, aerospace and automobile industries [1-2]. In the last decade, AZ series of cast magnesium alloys, primarily AZ91 alloy (Mg-9Al-0.8Zn-0.2Mn), have been comprehensively studied and used as structural material in approximately 90% of all magnesium cast products [1-3].

Many research studies on the effects of minor additions of Ca, Bi, Sb, Pb, rare earth etc. in AZ91 alloy have been conducted so far in order to improve castability, microstructure stability, creep resistance or tensile strength [5-11]. It has been previously showed that addition of bismuth in AZ91 alloy can refine the β precipitates in the microstructure of as-cast alloy and create some rod-shaped, thermally stable Mg_3Bi_2 second phase particles that enhanced the creep resistance of AZ91 alloy [8]. Enhancement in the tensile properties of AZ series magnesium alloys, both at ambient and elevated temperatures, could be facilitated by using minor alloying elements that has a similar effect as Bi on AZ91 alloy such as Sb, also producing stable second phase particles in the as-cast structure of magnesium alloys. The effect of Bi additions (as minor alloying) to AZ alloy series of Mg, especially AZ91 alloy, in as-cast condition, is scarce. Therefore, the objective of the present study was to characterize effect of minor Bi additions on the microstructure and mechanical properties of as-cast AZ91 alloys.

2. EXPERIMENTAL PROCEDURE

Mg, Al, Zn, Bi ingots with a minimum purity of 99.9% were purchased from Sakarya Metal Co., Turkey. The alloys were prepared by melting pure Mg together with Al alloying additions in a graphite crucible under Argon gas atmosphere at 750 °C and then held for 20 min before pouring. Zn and Bi additions were carried out 5 min. before casting to avoid losses of Zn and Bi due to vaporization. The amounts of Bi in AZ91 alloy were selected as 0.2, 0.5 and 1.0 wt.%. The chemical compositions of the studied alloys are shown in Table 1.

Table 1 Chemical composition of the alloys

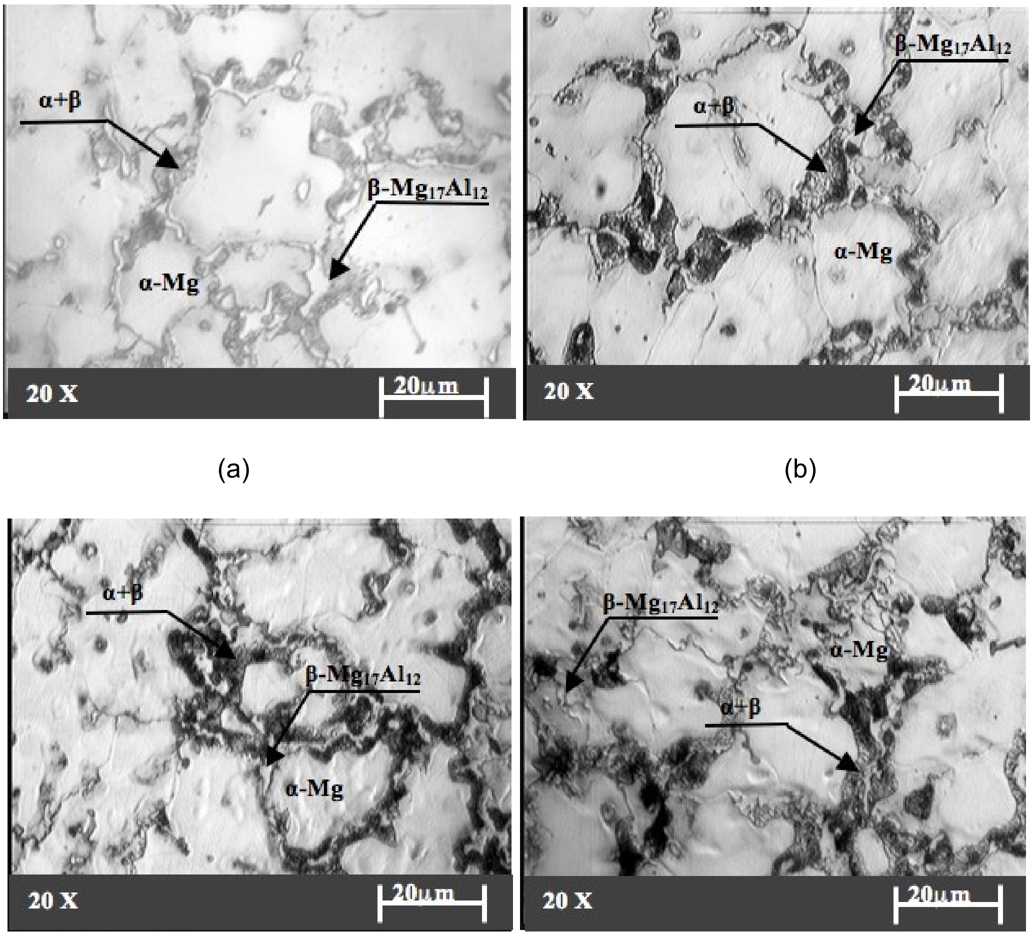
Alloys	Elements (wt%)					
	Al	Zn	Mn	Bi	Other	Mg
AZ91	9,11	0,76	0,16	-	0,021	Bal.
AZ91+%0,2 Bi	9,20	0,75	0,18	0,21	0,018	Bal.
AZ91+%0,5 Bi	9,25	0,77	0,19	0,53	0,018	Bal.
AZ91+%1 Bi	9,17	0,71	0,17	1,03	0,011	Bal.

The molten alloys were cast under protective SF_6 gas into a preheated (250 °C) cast iron mold. The alloy specimens were used as-cast condition for the experimental studies. The hardness values were determined by Vickers hardness testing with a load of 50 N. The tensile test samples having 40mm in length and 8mm in diameter were machined. The tensile tests were performed in accordance with ASTM E8M-99 standard with a crosshead speed of 0.5mm/min at room temperature. Samples having 10x10x10mm cube were cut from the center of each specimen, then one face of each cube was subsequently grinded with 220, 400 and 600 grit emery papers followed by polishing with 1µm diamond paste for microstructural investigations. Microstructure images were taken by optical light microscopy and Phillips XL30 ESEM scanning electron microscopy (SEM).

3. RESULTS AND DISCUSSION

3.1. Microstructure

Microstructures of as-cast AZ91+xBi(x=0, 0.2, 0.5, 1.0) alloys can be clearly seen in Figure 1. The microstructure image of as-cast AZ91 alloy in Figure 1(a) shows that as-cast AZ91 alloy consists of primary α-Mg matrix, dispersed eutectic β-$Mg_{17}Al_{12}$ phase and secondary precipitated β-$Mg_{17}Al_{12}$ phase. The eutectic phase precipitates in the form of network at grain boundaries. With the increase in Bi addition, α+β eutectic phase and β intermetallic phase are coarsened and the dispersions of these phases are enhanced.



(a) (b)

(c) (d)

Fig. 1 Microstructure images of as-cast structures a) AZ91, b) AZ91+0.2%Bi, c) AZ91+0.5%Bi, and d) AZ91+1%Bi

Figure 2 (a-d) shows higher magnifications of SEM micrographs of AZ91 alloys with and without Bi addition. Evidently, low amount of Bi addition to AZ91 alloy (0.2 wt%) gives rise to the formation of Mg_3Bi_2 phase and this phases were coarsened with increasing amount of Bi in AZ91 alloy. In Figure 2(d), higher magnification of AZ91 alloy containing 1wt%Bi is revealed with EDS results giving the chemical composition of second phase particles. As it can be seen from the EDS result table on Figure 2(d), a similar amount of Al as Bi can be seen on the point where the compositions were taken near α-matrix. That is to say that some β-$Mg_{17}Al_{12}$ phases are also present at this point.

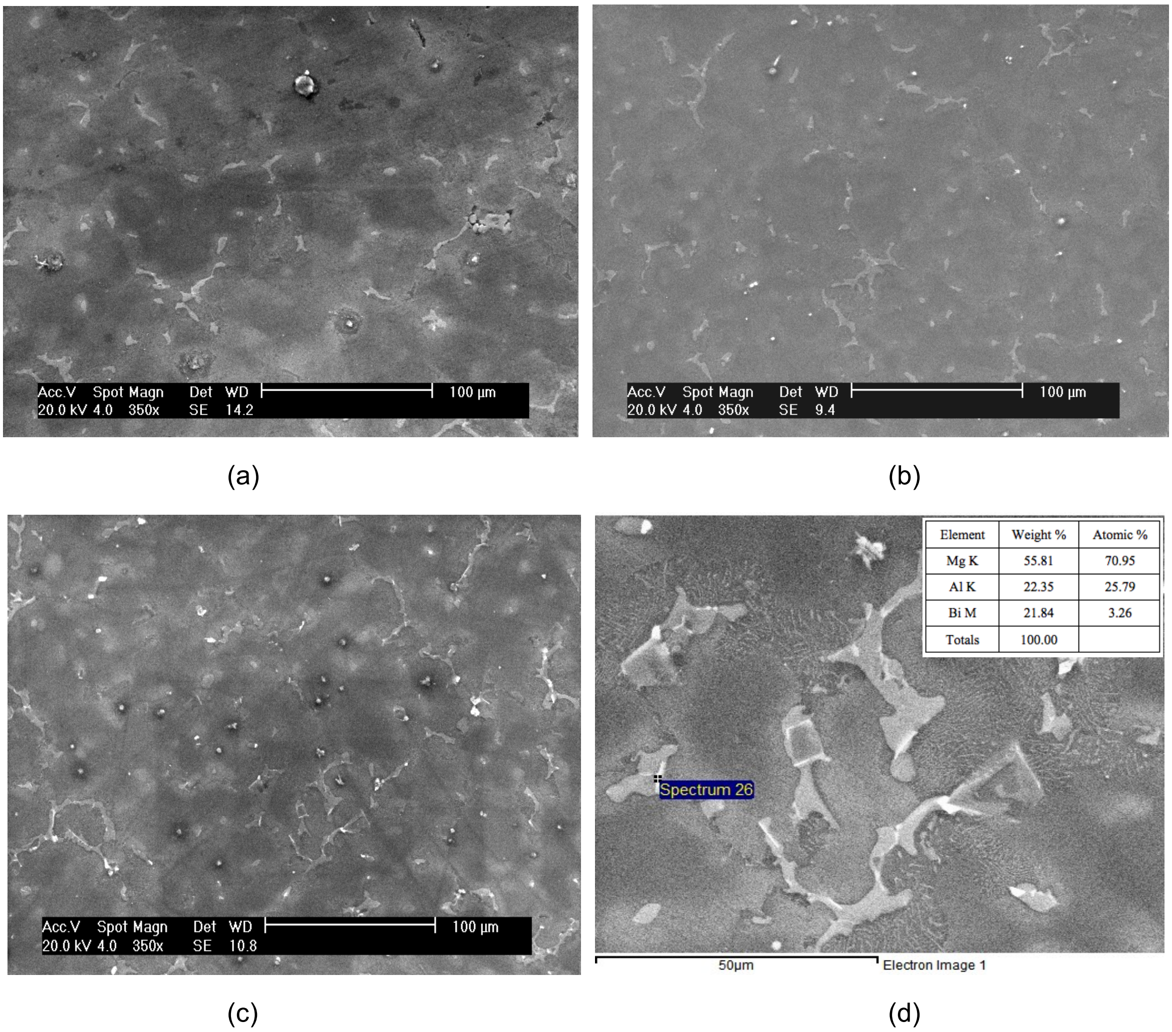


Fig. 2 SEM micrographs of as-cast structures a) AZ91, b) AZ91+0.2%Bi, c) AZ91+1%Bi, and d) Higher magnification for AZ91+1%Bi with EDS results

3.2. Mechanical Properties

Mechanical properties of AZ91 alloy containing different Bi content are shown in Figure 3. It can be seen from Figure 3 that increasing amount of Bi in AZ91 alloy does not efficiently change the mechanical properties since there is slight fluctuations in ultimate tensile strengths of AZ91 alloy containing varying amount of Bi. However, it can be said that yield strength and hardness has a tendency to increase as the amount of Bi increases even though the highest hardness was found for the alloy having 0.5wt% Bi addition that means high amount of Bi (1wt%Bi) can slightly decrease the hardness of AZ91 alloy. This decrease can be attributed to the coarsening of Mg_3Bi_2 phase with increasing amount of Bi concentration. Percent elongations at break are also shown in Figure 3. As the concentration of Bi increases in AZ91 alloy, percent elongations tended to decrease and this is also attributed to particle coarsening of Mg_3Bi_2 in accordance with previous studies [6-7].

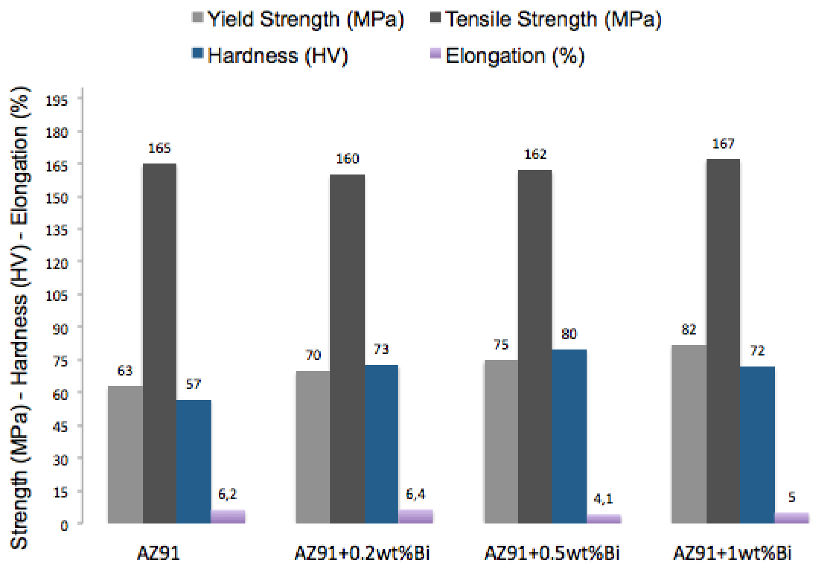


Fig. 3 Ultimate tensile strength, Yield Strength, Hardness and % Elongation (EL) of AZ91 alloy as a function of Bi content

4. CONCLUSION

The following conclusions can be drawn from the present study:

- Mg_3Bi_2 intermetallic phases were formed in all the samples and it coarsened with increasing amount of Bi in AZ91 alloy.

- A finer dispersion of $Mg_{17}Al_{12}$ intermetallic phases was observed in the structures as the amount of Bi in AZ91 increased.

- Highest hardness value was found for the alloy having 0.5wt% Bi addition that means high amount of Bi can decrease the hardness of AZ91 alloy.

- There were no considerable changes in the tensile strengths and yield strengths of the alloys as the amount of Bi increased although a slight increase in both strengths were observed with increasing amount of Bi.

- Percent elongation at break showed a decrease as Bi addition increased.

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