J. Int. Environmental Application & Science, Vol. 11(1): 36-41 (2016)

Study of Effects Distribution of Alloying Elements in Formation of Intermetallic Phases for Mg Alloys AZ91 and AM50

Mursel Rama, Ali Sadiku*, Bastri Zeka, Zarife Gashi

Department for Materials and Metallurgy; Faculty of Geosciences; University of Mitrovica "Isa Boletini"
Industrial Park Trepça, Mitrovica, KOSOVA

Received December 02, 2015; Accepted January 13, 2016

Abstract: Magnesium alloys have great use in automotive industry and as construction materials. These alloys are characterized by low density and good processing capabilities. The purpose of this paper was research of microstructure, constituent phases and distribution of elements and chemical composition of magnesium with aluminum alloys: AZ 91 and AM 50. These alloys are included in the group of alloys for casting; testing samples were taken in the longitudinal direction and transverse to the direction of hardening. Microstructure is investigation with light and electronic microscope (SEM and ESMA). Obtained results have proven that microstructure of alloys consisting of primary crystals rich with Mg-phase α, precipitations of inter metallic phase (β) - $Mg_{17}Al_{12}$ and another phase Mg_2Si. From the samples analysis we can concluded that the distribution of elements in testing samples was optimal, and this distribution makes these alloy very suitable for casting.

Keywords: *microstructure, alloys, phases, probe, SEM.*

Introduction

Use of magnesium alloys as constructional materials based on properties such are low specific weight and well processed. Magnesium alloys have large use in production of electronic equipment (computers, phones, cameras, etc.). These alloys improve the mechanical properties of electronic devices. Pure magnesium with density of 1.74 g / cm^3 is relatively soft metal, and for these reason Mg has not found use as a construction material, but alloying with Al, Mn, Zn, Cu, As, etc. and in this way, magnesium significantly improves mechanical properties.

Even the presence of foreign atoms changes plastic properties of base metal because it prevents the movement of dislocations. The strengthening mechanism depending from fully solubility of phases in alloys microstructure. The main mechanisms of strengthening the magnesium alloys are: formation of solid solutions, precipitation a discontinuous phase (Orawan mechanism), and precipitation of a continuous phase (aged), strengthening with dispersion, martensitic transformation, strengthening with distribution (ASM, Handbook 1999).

Through alloying of manganese, specific densities significantly reduced while simultaneously improving the properties of resistance to corrosion. Magnesium alloys classification in two major groups (tab. 1):

1. Cast magnesium alloys and
2. Wrought magnesium alloys

Table 1. Cast and wrought magnesium alloys (ASM, Handbook 1999).

Cast alloys		**Wrought alloys**	
Alloy	Constituent elements	Alloy	Constituent elements
AZ	MgAlZn	MgMn	M
AS	MgAlSi	MgAlZn	AZ
ZE	MgZnSEZr	MgThZrMn	HK
AM	MgAlMn	MgYSE	A
OE	MgAgSE	MgAl	WE
ZE	MgZnSEZr	MgZnZr	ZK
WE	MgYSE	MgLiAl	LA
AE	MgAlSE	MgZnSE	ZE

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*Corresponding: E-Mail: alisadiku@hotmail.com, Tel: +37744739439, Impact of some main alloying elements on properties and strengthening of magnesium alloys:

Aluminum (Al) - is the element classic and main alloying with magnesium. The aluminum content in magnesium alloy increases strength and hardness as a result of forming Mg17Al12 phase (Garbogini at al. 1994). Aluminum also improves the current properties of magnesium.

Silver (Ag) – In combination with rare metals lands it greatly increases the resistance to heat and corrosion.

Beryllium (Be) - distinctly decreases the ability of reduction of oxide of melting magnesium.

Calcium (Ca) - has an effect in creating of structure with micro grain and increases resistance to processes of creep.

Manganese (Mn) - increases resistance to corrosion, while with other elements as aluminum and iron builds phases that cause the effect of micro grain.

Silicon (Si) - exacerbates the flow of magnesium alloys with building stable silicates of types (Mg_2Si).

Zinc (Zn) - increases flow of magnesium alloys and has a positive impact on increases of the mechanical properties. Also, as well as aluminum, zinc impact in increases the micro porosity. But with increasing content of zinc above 2%, increases tendencies to create micro cracks and difficult welding process. During thermal treatment magnesium alloys with zinc would form intermetallic phases type: Mg_2Zn_3, MgZn (Mordike, B.L., Buch, F., 1997).

Zirconium (Zr) - is the most influential in the formation of fine grained structure. Grained structure impact the change-enhancing mechanical properties of alloys specifically to maximize increases of strength while impact negatively in the ability of deformation magnesium alloys. But the impact of zirconium in creating grained structure distinctly reduced if magnesium alloys containing aluminum and silicon.

Materials and methods

Samples are taken in form longitudinal and transverse to the direction of casting in the mold (fig. 1) specifically samples for alloy AZ 91 are taken in direction with direction of the spill while alloy samples AM 50 indirectly. Preparations of the samples were conducted in automatic equipment for grinding and polishing (Rama, M. 2009). Parameters and conditions of grinding, polishing and etching of metallographic samples are given below (Table 2).

Table 2. Parameters of grinding, polishing and etching of metallographic samples

GRINDING				POLISHING				ETCHING			
Number of Paper abrasive	Force/N/	Time /s/	addition	Polishing cloths	size of grains /µm/	Force /N/	Time /s/	Etchants	Quantity /ml/	Time /s/ AZ/91	Time /s/ AM/50
800	500	30	Water	DUR	6	80	180	Pikrin acid	4,2	3-4	8–10
1000	500	40	Water	MOL	3	80	180	Water	10	3-4	8–10
1200	500	40	Water	NAP	1	80	30	Vinegar	10	3-4	8–10
2400	500	50	Water	NAP	1	80	20	Ethanol	70	3-4	8–10
4000	500	500	Water	CHEM	0,5	-	-	-	-	-	-

Experimental results -wdx analysis

Phase characterization is done using optic microscope LEICA DMRX in bright and dark field, as well electron microscope (Figure 2) (Duly, D at al.1995). After preparation of metallographic samples were determined the chemical composition of alloy AZ 91 (Table 3) using ESMA.

Measurements are conducted with three types of tensions acceleration (10 keV, 15 keV, 20 keV) (Mordike, B.L., at al. 1997). Linear and surface analysis were conducted in ESMA during a segment with a length of 0.2 mm (fig. 3) and an area of 100 μm^2 (Figure 4).

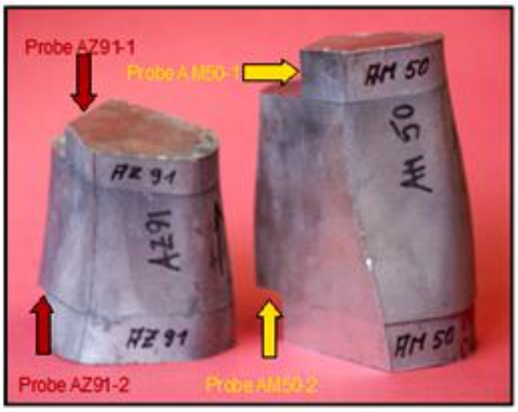
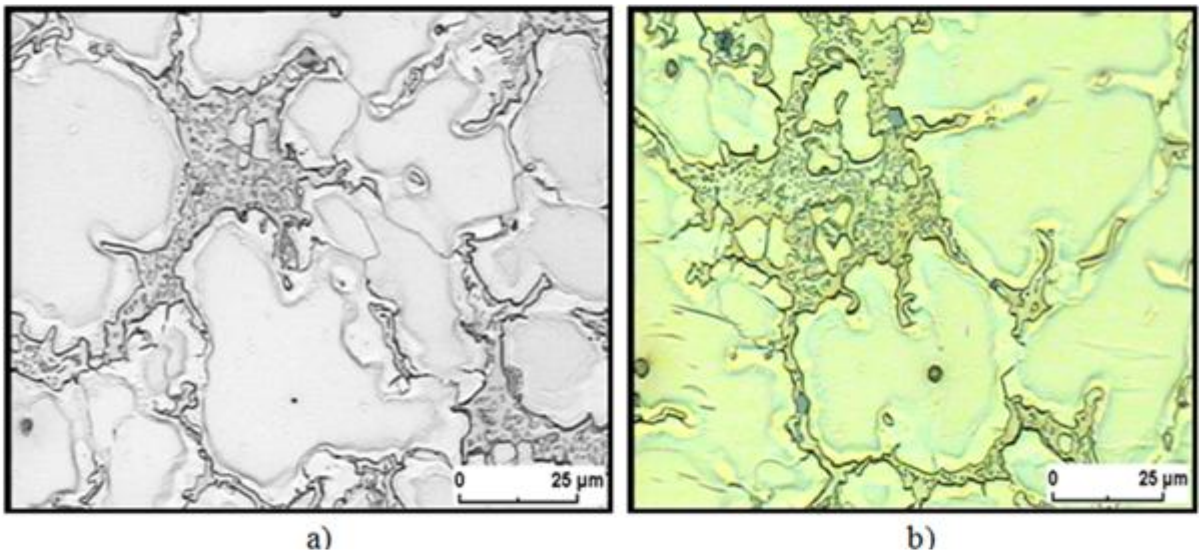


Figure 1. Direction of metallographic sampling



a) b)

Figure 2. Microstructure of AZ 91 alloy in: a) dark field; b) bright field

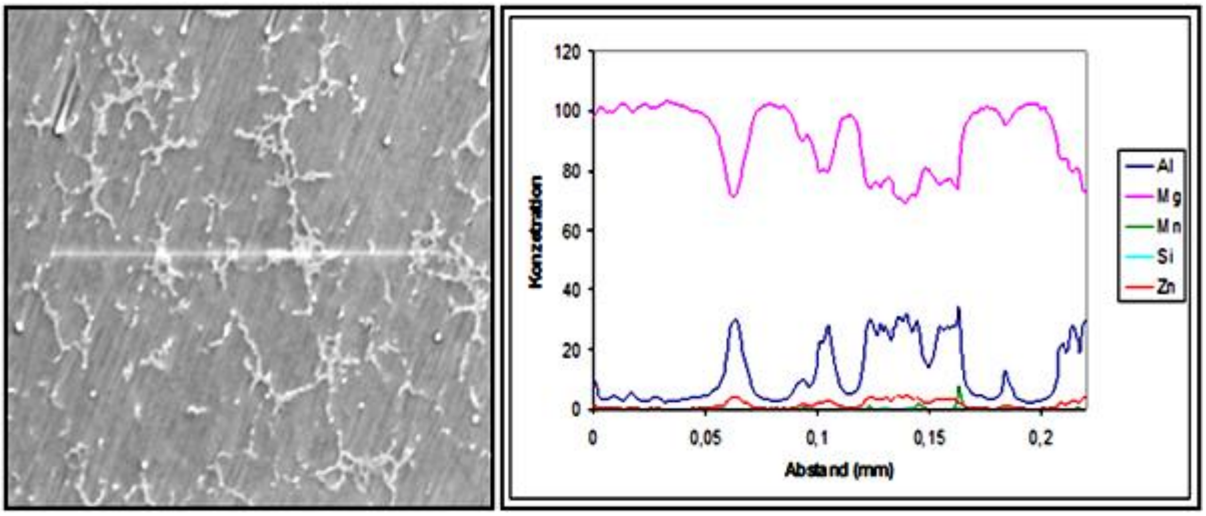


Figure 3. Linear analysis for alloy AZ 91 and results with ESMA

Table 3. Chemical composition of samples of AZ 90 alloy

Tension	Measure	Elements %											
		O	**Mg**	**Al**	**Si**	**Mn**	**Zn**	**Fe**	**Cu**	**Cr**	**Ni**	**La**	**Ca**
10 keV	1	4,38	92,61	3,01	-	-	-	-	-	-	-	-	-
	2	5,26	89,25	5,49	-	-	-	-	-	-	-	-	-
	3	5,13	85,49	9,38	-	-	-	-	-	-	-	-	-
	4	5,76	63,14	31,11	-	-	-	-	-	-	-	-	-
	5	8,77	48,69	34,08	-	3,17	-	-	1,58	1,66	0,83	1,21	-
	6	35,95	38,56	7,73	12,19	4,90	-	0,30	-	-	-	-	0,37
	7	6,10	64,49	29,41	-	-	-	-	-	-	-	-	-
	8	12.95	11,76	30,77	1.98	41,52	-	0.87	-	-	-	-	0.15
15 keV	1	3,76	92,21	4,02	-	-	-	-	-	-	-	-	-
	2	3,63	89,31	6,73	-	0,34	-	-	-	-	-	-	-
	3	3,99	78,84	17,17	-	-	-	-	-	-	-	-	-
	4	3,64	65,50	30,07	-	-	0,79	-	-	-	-	-	-
	5		52,27	33,93	-	6,70	-	-	1,42	3	1,09	1,59	-
	6	10,67	10,98	23,19	6,71	46,27	-	1,63	-	0,56	-	-	-
	7	3.59	74.73	20.99	0.69	-	-	-	-	-	-	-	-
	8	17.66	35.36	21.09	1.33	-	-	0.53	-	0.17	-	-	-
20 keV	1	5,36	88	6,63	-	-	-	-	-	-	-	-	-
	2	5,97	85,26	8,77	-	-	-	-	-	-	-	-	-
	3	4,94	85,05	10	-	-	-	-	-	-	-	-	-
	4	5,58	65,28	28,84	-	-	0,30	-	-	-	-	-	-
	5	5,88	65,24	25,08		1,42	0,26	-	0,26		1,86	-	-
	6	25,83	33,82	14,16	7,87	16,91	-	1,20	-	0,20	-	-	-
	7	7,47	74,72	15,56	2,25	-	-	-	-	-	-	-	-
	8	21,32	35,64	21,49	1,74	18,96	-	0,85	-	-	-	-	-

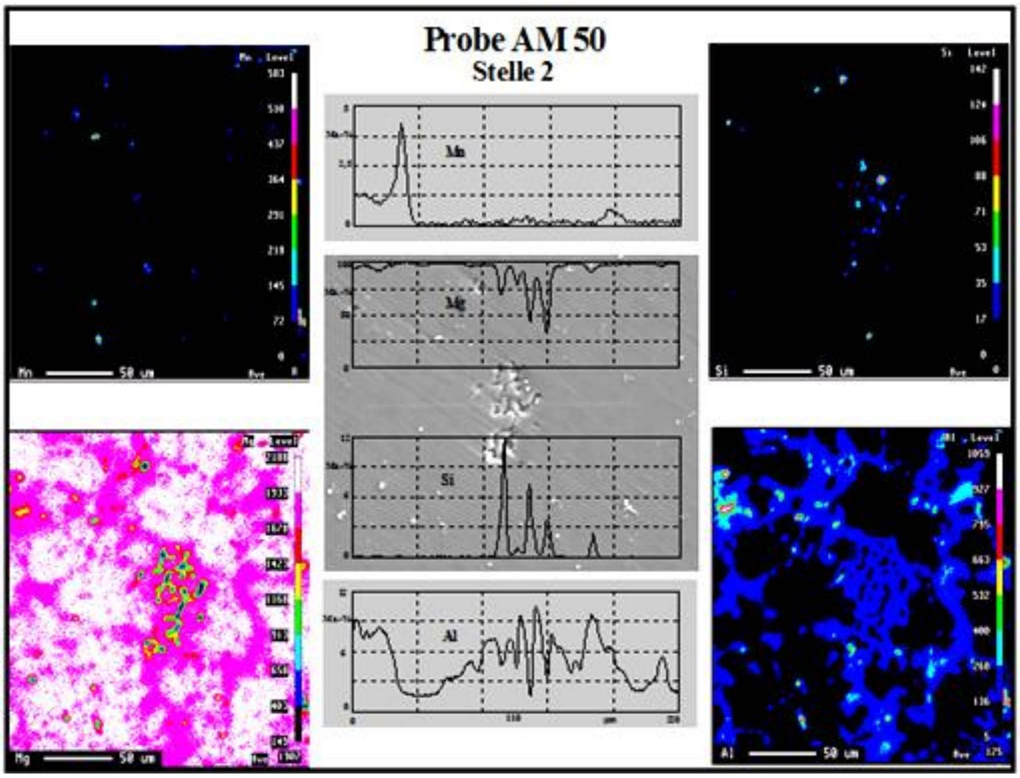
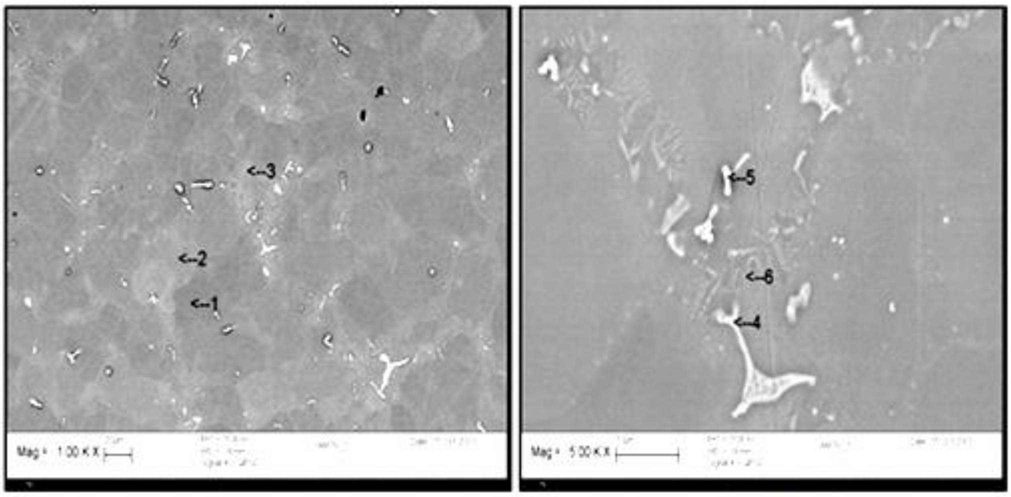


Figure 4. Analysis surface of sample alloy AM 50.

Formation intermetallic phases of type $Mg_{12}Al_{17}$ and phase Mg_2Si precipitated in cast alloys (fig. 5) are documented during the investigation with an electron microscope beam of electrons moved.



a) b)

Figure 5. Intermetallic phase $Mg_{12}Al_{17}$ precipitated in alloy AZ 91 (a) and AN 50 (b).

Discussion of Results

Investigation of alloy microstructure AM 50 has proven that, matrix composed of: Mg-rich with α-crystals, eutectic degrading shape (α-β) and intermetallic phases of type $Mg_{12}Al_{17}$ distributed across grain boundaries and are shaped dendritic. Also, during the investigation of samples alloy AM 50, is proven that manganese were not found in shape precipitate primary but as intermetallic phase of type Al_8Mn_5. While microstructure of alloy AZ 91 characterizes: the matrix of magnesium phase intermetallic $Mg_{12}Al_{17}$ and phase Mg_2Si with low precipitation, that structure dendritic as an important parameter of microstructure that characterizes alloys for casting, while, crystals in grain borders differ because they have white color. Phases in AM 50 and AZ 91 alloys were identifying after etching (Table 1). Obtained results from conducted research shows that distribution of elements in investigated samples was optimal, and this distribution makes these alloys are easily for processing with casting.

Conclusion

Magnesium alloys are suitable materials for different electronic equipment and constructions. The primary aim of this paper was investigation effects distribution of alloying elements in formation of intermetallic phases for magnesium alloys AZ 91 and AM 50. Researching methods give good opportunities for characterization of the microstructure, intermetallic phases, distribution of elements and their chemical composition. With these equipment is proven that microstructure of alloys is composed of primary crystals rich with magnesium-α, from precipitated intermetallic phases $Mg_{17}Al_{12}$ (β) and phases of Mg_2Si. Solidation and hardness increase as a result of creation of crystals with low content of aluminum and phase with high aluminum content ($Mg_{17}Al_{12}$). The difference between alloys investigated is that in AM 50, manganese is not separated with primary precipitate but like intermetallic phase of type Al_8Mn_5.

References

ASM Specialty Handbook, (1999) *Magnesium and Magnesium Alloys*, Edited by Michael M. Avedesian and Hugh Baker,

Callister WD, 2003 *Material Science and Engineering an Introduction*, Sixth ed., Wiley Internationals Edition, Utah.

Duly D, Zhang W, Audier M, (1995) High-resolution electron microscopy observations of the interface structure of continuous precipitates in a Mg-Al alloy and interpretation with the 0-lattice theory, *Philosophical magazine* A, **71**, 187-204.

Garbogini A, McShane HB, (1994) Effect of zinc and silicon additions on structure and properties of rapidly solidified Mg-Al alloys, *Materials Sci. & Tech.*, **10**, 763-769.

Hunger H-J, (1995) Werkstoffanalytische Verfahren. Eine Auswahl, Deutscher Verlag fur Grundstoffindustrie, Leipzig-Stuttgard.

Mordike BL, Buch F, (1997) *Stand der Technik und Entwicklungspotentialevon Magnesium und seinen Legirungen*, DGN-Seminar Magnesium.

Rama M, (2009) Metodat hulumtuese në Laboratorin Qendror të Universitetit të Prishtinës”-“Untersuchungsmethoden in CLU–UP, Weiterbildungs-seminar, Prishtinë.