THE DECOMPOSITION PROCESS IN RAPIDLY QUENCHED AlLiSc - ALLOYS

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ABSTRACT

The rapid quench from the melt improves the thermomechanical properties of AlLiX (X: Sc, Zr) alloys, produced by meltspinning. The important effect is the forming of primary metastable precipitations and the microstructure of the grains. The development of microhardness and electrical resistance by different treatments is investigated.

KEYWORDS:

Rapidly quenched alloys, AlLiSc–alloys, electrical resistivity, microhardness, kinetics value

1. The signification of AlLiSc alloys

Aluminium as a material of the lightweight design has a strong competition with other materials. For that reason experiments took and take place to produce Al materials aimed at reduction of costs and at increase of performance by economization of mass. Simultaneously thermomechanical properties shall be improved. A possible additional element is Li. AlLi alloys point at improved specific mechanical properties referred to the density. The problems turned out to be anisotropy, plane sliding, the precipitation free zones and the small thermal stability [1]. The thermal stability in casting alloys is determined by Oswald ripening of the spherical δ'–particles with $L1_2$–structure [2].

The growth kinetics can be influenced by both chemical composition and the lattice misfit between the decomposition and the matrix (caused by lattice distortions). Of some of the alloying elements (for instance Au, Ag, Sc) it is known that they decrease the growth rate of the coherent particles. The effect of scandium in aluminium alloys originate's from the formation of the stable Al_3Sc, leading to coherence tension due to high lattice misfit ($\delta = 1.3$ % in comparison $\delta = -0.3$% in Al_3Li) (coffee bean effect in TEM pictures [3]).

The coarsening of the coherent Al_3Sc–particles is caused by the lower diffusion. This was the start of reflections in order to get an improvement of the long time stability using Sc. Besides of that, Sc causes additional effects of grain refinement and acts as a crystallisation stop. According to previous knowledge there are no multi-stage decomposition processes in AlSc. Mainly the effect depends on the dispersion of the AlSc–particle in the as quenched state. There are no known ternary phases. The Al_3Sc–particles can be formed as primary decomposition as well as secondary decompositions. It will be defined that decomposition products formed directly after the quenching of the melt are named primary and decomposition products formed of the supersaturated solid solution after homogenisation and heat treatment are named secondary.

Different investigations of the authors on casting alloys of AlLiSc (ca) [4] will be compared with materials rapidly quenched from the melt to find out the influence of Sc (0 to 0.6 at%) on the decomposition process of AlLi (7 to 12 at%) alloys.

The structure is an important point of view for the evaluation and the influence on the material properties. Rapid quenched technique out of the melt influences the structure in such a way. The advantages are microstructural and chemical homogeneity. Some results of these investigations on AlLiSc–alloys after rapid quench will be reported in this paper.

2. Experiments

Tab. 1 shows the investigated alloys and the kind of quenching.

Tab. 1: Concentration and quenched–in states of the investigated alloys

Alloy concentration [wt%]	Alloy concentration [at%]	production type RQ (speed), SC or CA	thickness of bands d [μm]	hardness of quenched state HV(10p)	electr. resistance (quenched) ρ [μΩcm]
AlSc0.3	AlSc0.18	RQ (44 m/s)	37.4	41	4.67
		RQ (25 m/s)	62/162	42/55	4.44
		SC		40	4.9
AlSc0.6	AlSc0.36	RQ (44 m/s)	37.3/51.3	58/71	5.5
		RQ (25 m/s)	94.6	78	4.6
		SC		48	6.69
AlSc1.0	AlSc0.6	RQ (44 m/s)	34.6	67	5.5
		SC		46	9.1
AlLi3	AlLi10.73	RQ (44 m/s)	43.3	33	4.8
		SC		39	4.3
		CA		24	7,2
AlLi2Sc.03	AlLi7.36Sc0.17	RQ (44 m/s)	37.1	43	15.009
		SC		38	7,9
		CA		29	
AlLi3Sc0.3	AlLi10.74Sc0.17	RQ (44 m/s)	43.2	50	19.605
		SC		35	9.8
AlLi3Sc0.7	AlLi10.76Sc0.39	RQ (44 m/s)	34.2	70	25.25
		SC		53	12,7

The casting alloys (CA) were produced from materials 5N Al and 4N Sc and the additional elements. The RQ– and SC–samples were produced from these casting alloys on a melt spinning plant with a copper disk (RQ) and a splat cooling plant (SC).

The structures were investigated by TESLA TEM and OLYMPUS LM. The change of the structure during the ageing will be investigated mainly by hardness and electrical resistance development.

3. Results

3.1. The as - quenched state of the investigated alloys

The higher as–quenched hardness of the rapid quenched materials in comparison with the casting alloys and the as–quenched values of the electrical resistance (Tab. 1) are signs for in quenched coherent complexes (primary precipitation). These complexes have got such critical values of sizes that the as–quenched materials have sufficient strength.

The structure of the as–quenched state (results of LIMI– [light] and TEM–[transmissionelectron microscopy] images). The as–quenched state shows for all three alloys small grains and fine disperse precipitations at the grain corners.

The increase of the grains will be stopped by pinning effects because the precipitations are placed on the grain corners.

3.2. Isothermal ageing

The hardness developmenmt of the rq–AlScLi alloys is a typical example for a two step process. The decomposition at low temperatures $\vartheta \leq 200°C$ shows a first and second incubation time (Fig. 1). For the higher temperatures only the second incubation can be seen. The first process begins with the ageing from the beginning. Fig. 2 shows the diagram of ln τ as a function of (1/ T) of t_{inc2} as we know from the JMAK–modelling [5-9] for the determination of the activation energy. Up to $\vartheta = 200°C$ the results are on a good line fit. The two step nature at ca AlLiSc alloys is not as clear as the comparison between AlLiSc–rq–and ca–alloys shows Fig. 3.

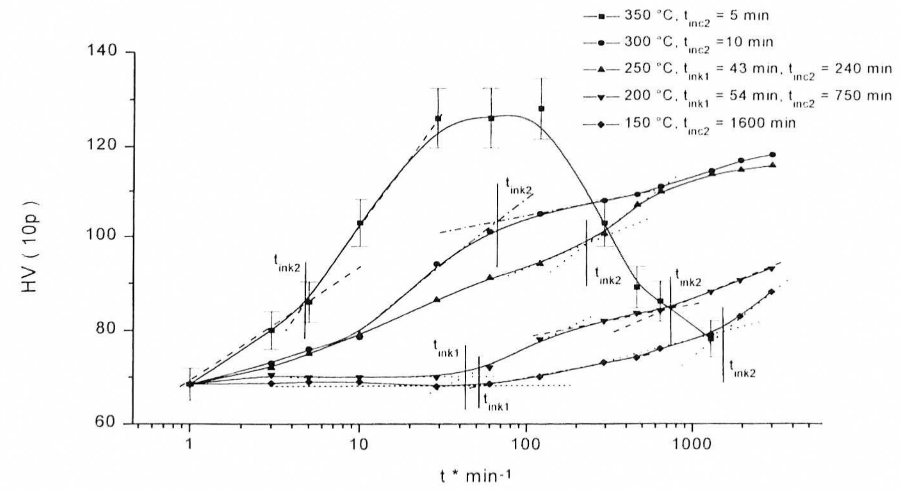

Fig. 1 : Hardness development of the rq - AlLi3Sc0.7wt% alloy during isothermal ageing

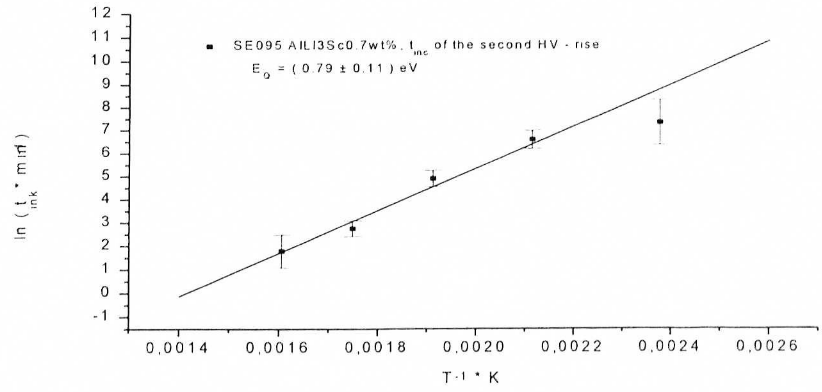

Fig. 2: JMAK–fit of the second hardness process

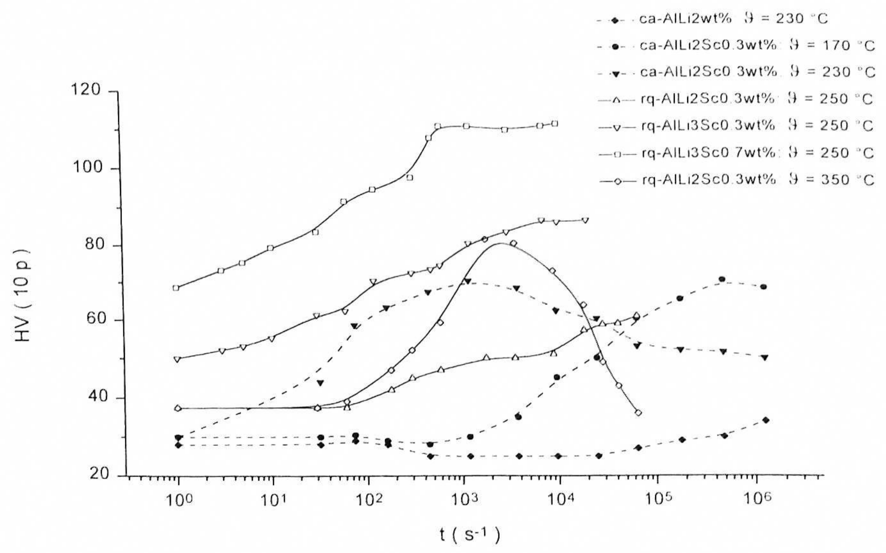

Fig. 3: HV development of rq-- and ca– AlLiSc–alloys

3.3. The development of the electrical resistance

The change of the electrical resistance of the investigated alloys was measured by isothermal ageing in temperature region 130°C up to 300°C and different heating rates, 1–36 K/min.

3.3.1. Isothermal ageing

The measurements will be called into the determination of the kinetic value. The used method is the fitting of JMAK–equation [5-7]. The fit parameters are the resistance values $\rho 0$ (R0) (resistance at the beginning of the measurement), ρE (RE) (the resistance at the end of the transition process), the kinetic exponent n, the time τ (63.2% of the transition): A proportion of the different transition we can find from the value $\Delta\rho / \rho 0$ ($\Delta\rho = \rho_0 - \rho_E$). The best fitting results n (kinetic exponent) and $(\rho 0 - \rho E) / \rho 0$ for the rq–AlLiSc alloys by isothermal ageing between $\vartheta = 130$°C and 300 °C are shown in Tab. 2. From this result we can see, there are two different processes in the decomposition. At small temperatures up to 190°C for the AlLi10.76Sc0.39at% - alloy the values of the kinetic exponents are in the order of $n \approx 0.5$. This can be interpreted as heterogeneous growth of the precipitations in presence of nucleus in the as quenched state. For the AlLi10.74Sc0.17at% and AlLi7.36Sc0.17at%–alloy the kinetic exponent for the first decomposition process is greater then 1.15. This is a hint to homogenous nucleation and growth of the precipitations. At temperatures $\vartheta \geq$ 190°C a change of the decomposition process appears. The kinetic exponent decreases to ≈ 0.5. The results of the characteric time τ are shown in an the Avrami–plot in Fig. 4.. Two different processes can be analysed too with different values of the activation energy.

In ca–AlLiSc alloys the forming of precipitation is remarkable (growing of the value for the $(\rho_0 - \rho_E)/\rho_0$–resistance) at temperatures higher than 200 °C. In the rq–alloys the resistance decreases from the beginning of the isothermal ageing. From the knowledge of the development of the resistance no new particles will be formed in the beginning of the decomposition

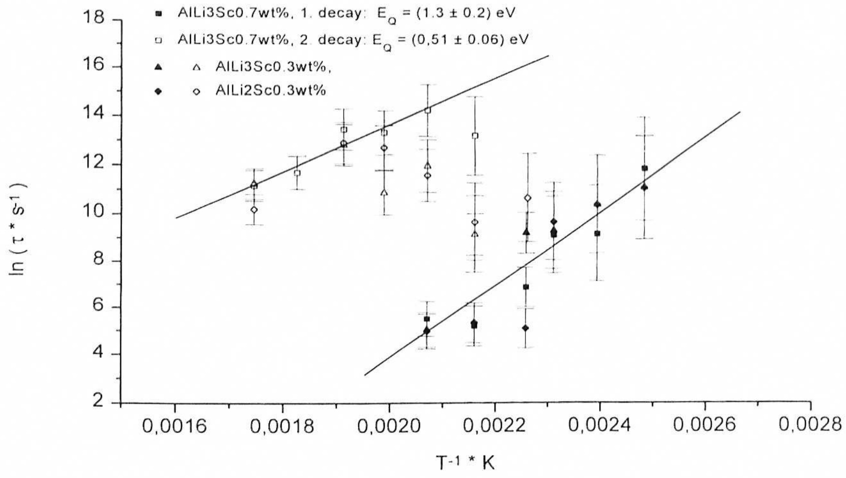

Fig. 4 JMAK–fit of the isothermal ageing of the electrical resistance development

Tab. 2: JMAK–model calculation results from the JMAK–fitting (n: the kinetic exponent, and $(\rho_0-\rho_E)/\rho_0$: the change of the resistance)

	SE 095 AlLi10.7Sc0.39		SE 096 AlLi10.74Sc0.17		SE097 AlLi7.36Sc0.17	
ϑ [°C]	$(\rho_0-\rho_E)/\rho_0$	n	$(\rho_0-\rho_E)/\rho_0$	n	$(\rho_0-\rho_E)/\rho_0$	n
130	0.047	0.66±0.01	0.056	1.21±0.01	0.056	1,32±0.01
160	0.0332	0.62±0.01	0.064	1,15±0.01	0.058	1,31±0.01
170 1. decay 2. decay	0.026	0.82±0.02	0.063	1.03±0.01	0.008 0.083	2,2±0.1 0.64±0.02
190 1. decay 2. decay	0.014 0.14	1.75±0.76 0.50±0.01	0.073	0.825±0.001	0.008 0.057	2.25±0.03 1.46±0.01
210 1. decay 2. decay	0.0047 0.202	2.38±0.01 0.40±0.01	0.015 0.23	2.11±0.05 0.548±0.01	0.007 0.194	1.63±0.02 0.44±0.01
230	0.174	0.416±0.004	0.16	0.41±.0.0	0.48	0.50±0.01
250	0.264	0.4300.004	0.583	0.54±0.01	0.49	0.515±0.003
300	0.429	0.478±0.004	0.39	0.767±0.003	0.29	0.586±0.002

3.3.2. Resistance measurement at constant heating rate

The following method was applied. The samples were heated at constant heating rates $\dot{T}$ from room temperature up to 500°C or 600 °C and under identical conditions the measurements were repeated. The advantage of this method is that the unknown temperature effect can be eliminated, assumed that the stable final state was reached after the first heating. In the following the difference curves (first - second measurement) are derived once and were normed to the start value (resistance coefficient) (Fig. 5).

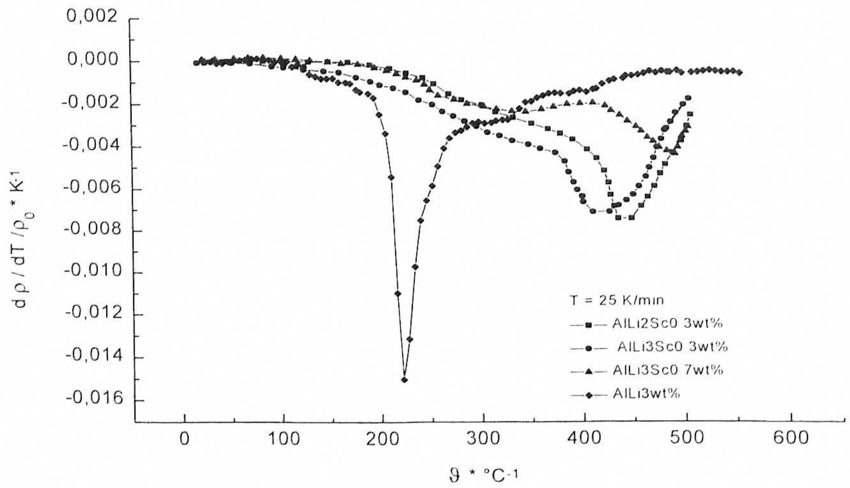

Fig. 5: Development of the resistance coefficient of rq–AlLiSc - alloys

The activation energy can be determined by these measurements with a Kissinger plot [8]. The difficulties of the determination of the activation energy with this method will be discussed in an other paper.

4. Conclusions

In comparison to the ca–alloys the thermal and mechanical properties of the investigated rq–AlScLi–alloysare different during the fine disperse primary precipitation. In the rq–AlScLi–alloys where Sc is contributed in order to retard the breaking of the coherence of the AlLi–particles we find a two step process in the hardening and the electrical resistance measurements.

This result could be in coincidence with the knowledge of the investigation of the ca–AlLiSc. Beside the δ'–particles in the AlLiSc alloys of Al_3Li (small particles) large particles of duplet structure were found [3, 4]. From X–ray analysis Sc in the centre enclosed with Al_3Li–precipitations.

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