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Electrical Resistivity and Thermal Conductivity of Pure Aluminum and Aluminum Alloys up to and above the Melting Temperature[1]

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Experimental improvements of a four-probe technique to measure the electrical resistivity of molten metals led to an improvement of the measurement uncertainty to less than 6%. Measurements of pure Al and AlSi-, AlSiMg-, and AlSiCu-alloys with a systematic variation of individual components are described. The problem of the calculation of the thermal conductivity has been investigated, and the resulting values of the binary system have been discussed in terms of behavior during melting and solidification. There is a remarkable difference of the thermal conductivity before melting and after resolidification.

KEY WORDS: aluminum alloys; electrical resistivity; four-probe technique; molten metals; pure aluminum; thermal conductivity.

1. INTRODUCTION

Thermophysical properties of metals in the melting range are crucial to optimize processes, e.g., powder production by atomization or to numerically simulate solidification in casting processes. Existing calculation programs model both the bulk heat transfer and the fluid dynamic process during solidification attempting to predict, e.g., time-dependent temperature profiles in the various states of the material: liquid, mushy region, solid, solidification rates, etc. These numerical models are important tools

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for a better understanding of the physics of solidification and to improve quality of products. However, they are extremely sensitive to thermophysical properties. The demand and availability of these properties is summarized by Ludwig et al. [1]. In addition of the viscosity and surface tension, a knowledge of the thermal conductivity is of particular importance, whereby the thermal conductivity during resolidification is especially critical because the microstructure of the solid material and therewith its thermal conductivity depends sensitively on the cooling rate. Therefore, the measurement technique should enable measurements of the thermal conductivity in the solid state, in the mushy region, in the liquid state, and also during resolidification.

Only very limited thermal conductivity results of aluminum alloys have been published until now. Taylor et al. [2] reported measurements of the thermal diffusivity and electrical resistivity of commercial-grade aluminum alloys 1100-F (0.95 mass% Si + Fe), 2004-T4 (3.8–4.9 mass% Cu, 1.2–1.8 mass% Mg + others), 6061-T6, and 7075-T6 (1.2–2 mass% Cu, 2.1–2.9 mass% Mg, 5.1–6.1 mass% Zn + others). Blumm et al. [3] measured the thermal diffusivity of LM25 (7.15 mass% Si + others), Szelagowski and Taylor [4] measured the thermal diffusivity of three commercial Al casting alloys (LM25, LM4, Al3004), and Overfelt et al. [5] measured the thermal diffusivity and electrical resistivity of three commercial casting alloys (A319, A356, A210). Investigations of the thermal conductivity of aluminum alloys with a systematic variation of individual components are not available.

Unfortunately, direct measurement of the thermal conductivity in the liquid state is extremely difficult because of long measuring times to reach thermal equilibrium and therefore possible chemical reactions between the crucible and specimen. Also the contact resistance between the crucible and sample and convection in the molten state may cause measurement errors. Indirect determination is possible by measurement of the thermal diffusivity and calculation of the thermal conductivity if the specific heat capacity and density of the material are known. When measuring the thermal diffusivity, problems also arise with the crucible from additional heat flow through the crucible and possible convection and crucible/melt interactions. Such measurement uncertainties are negligible if the electrical resistivity is measured. For calculation of the thermal conductivity using the Wiedemann–Franz law, the value of the Lorentz number is needed. Recent experimental investigations of Overfelt et al. [5] on aluminum alloys have shown that the Lorentz number near the melting temperature and in the liquid zone can be assumed to be close to the theoretical value of Sommerfeld. Powell [6] demonstrated the validity of this assumption, especially in the liquid state of metals where the heat transport is dominated by free electrons.

The reasons explained above led to the development of a new measurement apparatus to study the electrical resistivity in the solid, liquid, and mushy regions with the possibility for measurements in the solid during both heating and cooling. Within the framework of the European Network Programme "Microstructural Engineering by Solidification Processing" (MEBSP), a number of aluminum-based alloys have been produced by Hydro Aluminium Deutschland GmbH. Specimens of the Al–Si binary system, of the Al–Si–Mg ternary system, and of the commercial Al–Si–Cu multicomponent system have been distributed to various laboratories in order to measure the density, thermal expansion, surface tension, viscosity, thermal conductivity, and electrical resistivity as functions of temperature and chemical composition. The complete list of all 21 different materials has been presented by Brandt and Neuer [7] together with the geometrical densities determined at room temperature and the electrical resistivities measured at 25, 50, and 75°C. However, the geometrical density determined on the same specimen rods as used for measuring the electrical resistivity are not as accurate as desired. Therefore, the density measurements have been repeated in this paper, now by using the immersion technique, which is more precise.

2. MEASUREMENT TECHNIQUE

The electrical resistivity was measured by using the four-probe technique, whereby a cylindrical sample of diameter $D = 5\,\text{mm}$ is loaded by a direct current I. The electrical resistivity ρ is determined by measuring the voltage drop ΔU between two probes positioned at a distance of $S =$ 50–80 mm using the following equation:

$$\rho = \frac{\Delta U}{I} \frac{\pi}{4} \frac{D^2}{S} \tag{1}$$

All these parameters can be measured with relatively high accuracy. Systematic errors in the determination of the voltage drop ΔU because of the thermoelectric voltage between the sample and the electrodes can be eliminated by providing a commutator at the power supply in order to change the direction of the electric current and using the mean of the two values in both directions. Measurements in the molten state of a metal are much more difficult than measurements on only solids because the sample must be kept inside a ceramic tube. This means that geometric data and the sample temperature are more difficult to be determined and the complicated mechanics of the electrodes may lead to increased measurement errors. Therefore, two apparatus have been developed: one for measurements on solids only at moderate temperatures where ideal conditions can be realized for precise measurements and the second for measurements in the solid and molten states. By comparing the results in the overlapping temperature range, the values of the measurements in the ceramic tube can be controlled and, if necessary, corrected.

2.1. Measurements in an Oil Bath

For high accuracy measurements the specimen is mounted on a vernier calliper (VC) with electrically insulated razor blades on the flanks, as shown in Fig. 1. Measurements can be performed on specimens of 3–10 mm in diameter and 100–200 mm in length. The razor blades are used to measure the voltage drop ΔU at different positions along the length L. This allows measurements of the electrical resistivity at different positions along the axis of the sample rod. The input of the current is only at the top and bottom faces of the rod via two copper felts in order to ensure homogeneous current density distribution. The whole arrangement is dipped in an oil bath with continuous circulation to get a well defined and homogeneous temperature distribution. The maximum temperature depends on the type of oil.

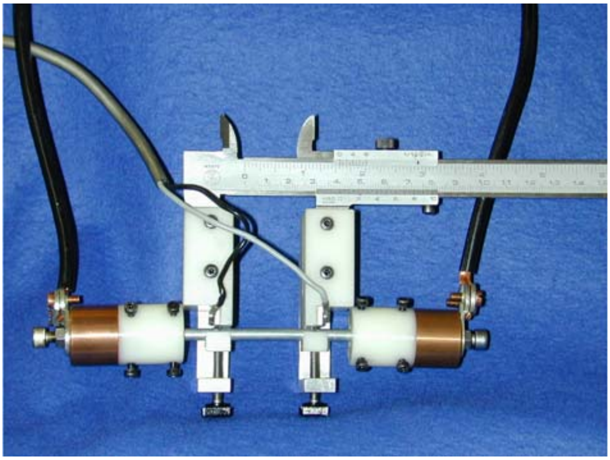

Fig. 1. Arrangement with vernier calliper to measure the electrical resistivity at temperatures between 25 and 100°C in an oil bath.

2.2. Measurements in a Furnace

For measurements at higher temperatures the specimen is vertically positioned in a vacuum chamber surrounded by a tube furnace as shown in Fig. 2. This allows measurements in vacuum or in each available gas atmosphere at temperatures between 30 and 1600°C. If the resistivity will only be measured in the solid state, sample rods with variable diameters and a length up to 120 mm can be measured, their faces being directly connected with the current electrodes. For measurements in the molten state the specimen must be kept within a ceramic tubular crucible with two movable current electrodes (graphite) in order to allow for the different thermal expansions between the sample and crucible and the volume change at melting and at solidification. For the same reason the voltage taps to measure the voltage drop ΔU must be movable. Their tips consist of simple leads of 0.9 mm diameter, which easily can be replaced after each melting run. They are fed through holes in the crucible and should be moved back from the sample during solidification in order to not obstruct contraction during cooling. Graphite as an electrode material was used to prevent wetting and chemical reaction with the melt. Three thermocouples (TC) are installed in the crucible to measure the mean temperature and the temperature distribution along the sample. For calculation of the electrical resistance the specimen diameter D must be corrected by the thermal expansion of the specimen material and the distance L between the voltage taps by the thermal expansion of the crucible.

3. TEST MEASUREMENTS

Test measurements were carried out in the solid state on a steel sample up to 800°C and in both solid and liquid states on tin, zinc, and aluminum, whose electrical resistivity at the melting point is well known from the literature. These measurements have been previously described in more detail [7]. They show very good agreement with literature data with deviations less than 0.5% for measurements with the vernier calliper and less than 3% for measurements in the furnace in solid and liquid states.

The test measurements also indicated a slight temperature difference between melting and solidification temperatures during dynamic heating and cooling, depending on the rate of heating and cooling. This seems to be caused by the fact that the temperature is not measured directly in the specimen but in the wall of the crucible and, as the specimen is heated mainly by radiation from the surrounding ceramic tube via the crucible, the temperature slope of the specimen lags behind the measured

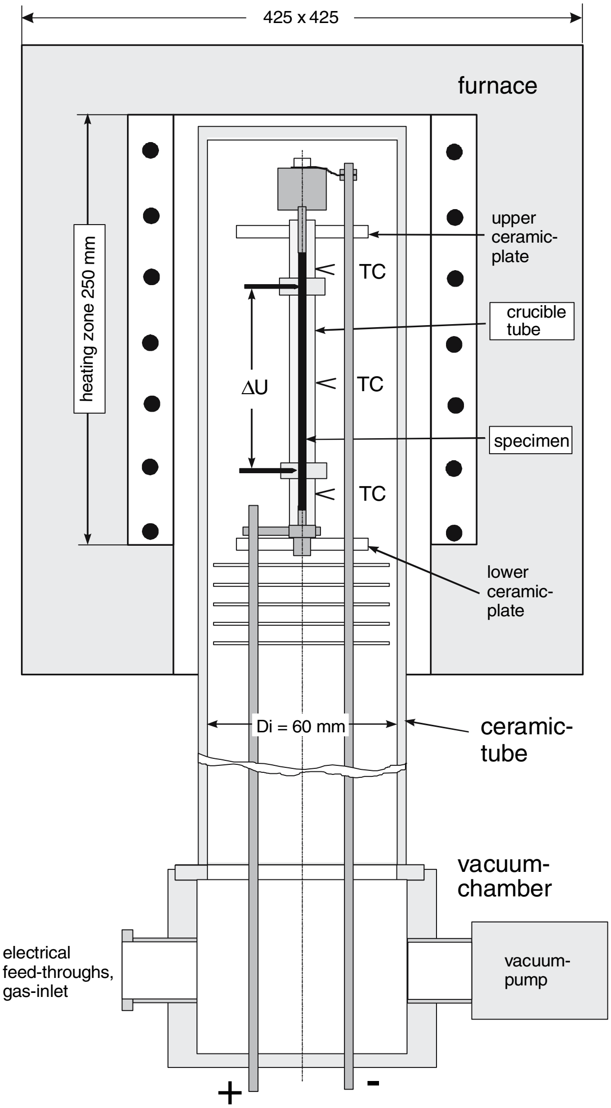

Fig. 2. Arrangement to measure the electrical resistivity of metals up to and above the melting point.

temperature slope of the crucible. As a consequence, the heating/cooling rate should be kept very low around the melting/solidification temperature to obtain reliable results.

Another problem occurred during the melting experiments on aluminum and aluminum alloys. It could not be avoided that when the specimen is in the liquid state small amounts of metal vapor deposit on the surfaces of the ceramic parts (crucible, ceramic support plates, electrical insulations) and result in a reduction of their electrical insulation properties. This can cause considerable errors in the resistivity measurements; due to the contact resistance between the front faces of the specimen and the current electrodes, a voltage of about 1–4 V was necessary to produce a current of 2 A through the specimen. Because of the low electrical resistivity of aluminum, this causes a measured voltage drop signal of less than 1 mV. If there is not excellent electrical insulation between the current loop and the voltage taps, the measured signal becomes inaccurate because of leakage currents. Also, the measuring wires of the voltage taps are insulated in the "hot zone" by ceramic capillary tubes; contamination by metal vapor can produce creepage at their ends, which also causes measurement errors. Therefore, the electrical resistance of these ceramic parts must be checked after each run and the ceramic parts cleaned if necessary. Annealing in air at about 700°C gave good results.

4. MEASUREMENTS AND RESULTS

The geometry of the tubular crucibles with fixtures for the voltage taps is complex, and therefore the manufacturing of the crucibles is expensive. For this reason the crucibles should be usable for several measurements, i.e., it should be possible to press out the specimens after the measurements. This requires a flat surface of the hole with a very uniform diameter. Therefore, the crucibles were honed. This constant diameter of the hole is also necessary for precise measurements in the liquid state, because after melting this becomes the effective diameter of the specimen in calculating the electrical resistivity.

Furthermore, no wetting of the crucible, of the current electrodes, and of the voltage taps by the liquid sample material should occur. For measurements of aluminum and aluminum alloys, crucibles of aluminum nitride have been chosen; the electrodes were made of graphite. In 12 of the 17 melting experiments, the specimen could be pressed out after melting and solidification.

The measurements were carried out between room temperature and about 800°C using a constant electrical current of 2 A. Higher currents give better voltage drop signals but the high contact resistance between current electrodes and the specimen causes rapid heating of the sample edges. All measurements were performed under high vacuum conditions. A heating rate of $360\,\mathrm{K \cdot h^{-1}}$ was applied in the solid and liquid states with interrupts before each measuring point; during melting and solidification the heating/cooling rate was reduced to about $100\,\mathrm{K}\cdot\mathrm{h}^{-1}$ in order to get better resolution for the melting/solidification temperatures.

Measurements were first carried out on pure aluminum, followed by four binary AlSi-alloys, five ternary AlSiMg-alloys, and seven ternary AlSiCu-alloys. The electrical resistivity results of the heating (melting) curves are shown in Figs. 3–6 for all measured specimens. For comparison of the individual results, interpolated resistivity values at distinct temperatures are given in Tables I–III for heating as well as for cooling cycles. At the top of the tables the chemical composition and the density at room temperature, measured by the immersion technique, are presented. The specimen designation is the same as given in the earlier paper [7]. Also, the resistivity data for 25 and 75°C, measured with a vernier calliper, are taken from this paper. As can be expected, for all three alloy groups, the density decreases with increasing Si-content. From Table I it can be seen that the electrical resistivity of pure aluminum changes during melting by a factor ρ_L/ρ_S of 2.21, which is in good agreement with literature data [8]. Also, for the measured alloys, this factor was between 2.1 and 2.4 (see Tables I–III).

For the binary AlSi alloys, the solidus temperature was measured to be nearly constant (577–580°C), whereas the liquidus temperature decreased from 642°C (5 mass% Si) with increasing Si-content to 596°C (12 mass% Si, eutectic). This agrees very well with the phase diagram of AlSi known from the literature; e.g., see Ref. 9. The same qualitative behavior can be observed for AlSiMg and AlSiCu alloys.

In the liquid state the electrical resistivity increases almost linearly with increasing temperature. The succeeding cooling cycles for nearly all measured alloys show that after resolidification the electrical resistance remains higher than in the heating cycles (see also Fig. 5). This may be attributed partly to a change in the microstructure, but will be discussed later.

5. CALCULATION OF THERMAL CONDUCTIVITY

One objective of this investigation was to determine the thermal conductivity from the electrical resisitivity measurements by using the Wiedemann–Franz law, which describes the relationship between the thermal conductivity λ and electrical conductivity $\sigma = 1/\rho$ for metals:

$$\lambda/\sigma = LT \qquad (2)$$

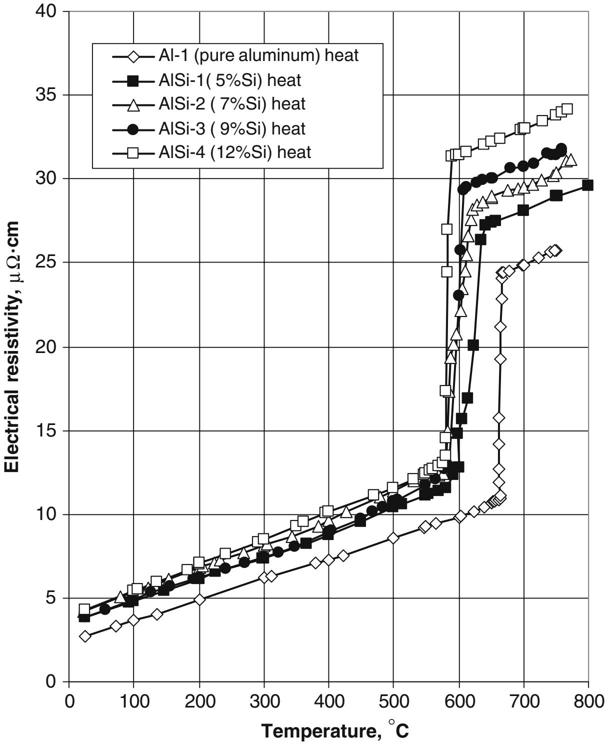

Fig. 3. Electrical resistivity of pure aluminum and binary AlSi alloys (heating curves).

L is the Lorentz number, which depends on the type of metal and also to some extent on its temperature, and T is the absolute temperature (in K). Above the Debye temperature and especially near the melting temperature, the Lorentz number is close to the Sommerfeld value L_0, which is determined theoretically from the Boltzmann constant κ and the electron charge e:

$$L_0 = 1/3\pi^2(\kappa/e)^2 = 2.445 \times 10^{-8}\,\mathrm{V}^2 \cdot \mathrm{K}^{-2} \tag{3}$$

As an example, we have calculated the thermal conductivity of pure aluminum from our electrical resistivity measurement results (vernier calliper results, heating cycle, cooling cycle) by using Eq. (2) with the theoretical Sommerfeld value (Eq. (3)). The results are shown in Fig. 6. For comparison the recommended thermal conductivity data of Touloukian [10] based on the results from many laboratories, are included. It is evident

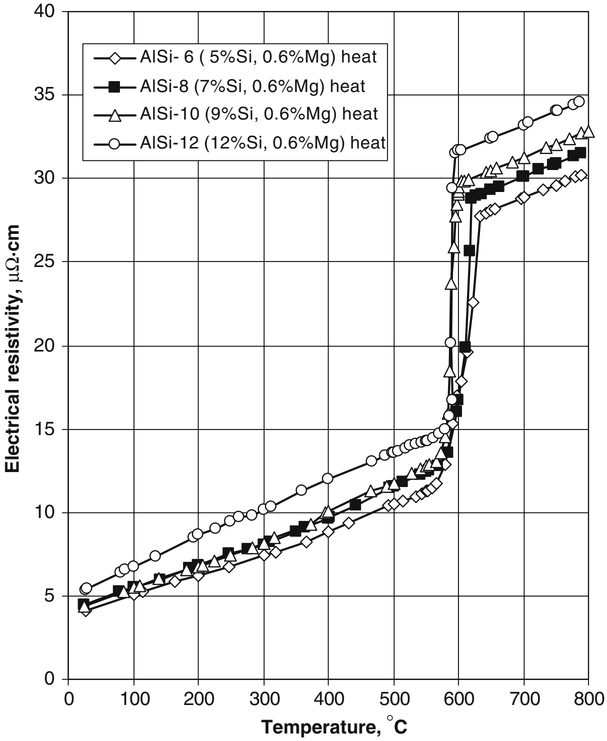

Fig. 4. Electrical resistivity of ternary AlSiMg alloys with 0.6 mass% Mg (heating curves).

that at room temperature the thermal conductivity calculated from the electrical resistivity is about 13% higher than Touloukian's recommended data. However, with increasing temperature the difference becomes smaller, and above the Debye temperature (about 120°C for pure Al), it is reduced to less than 2.5%. This is in accordance with Binkele and Brunen [11], who measured both the electrical resistivity and thermal conductivity and found deviations between measured and calculated thermal conductivities (with the Sommerfeld value) of less than 4% at 127°C and less than 1% above 227°C. Measurements of the thermal conductivity had been performed also on an aluminum alloy (AlSi7Mg0.4) up to 400°C. Thermal conductivities calculated from the electrical resistivity of specimen AlSi-8 (7 mass% Si, 0.6 mass% Mg) differed from earlier measured thermal conductivities by about 2% below 100°C and by less than 1.5% above 100°C. Therefore, it could be stated that for aluminum and the aluminum alloys

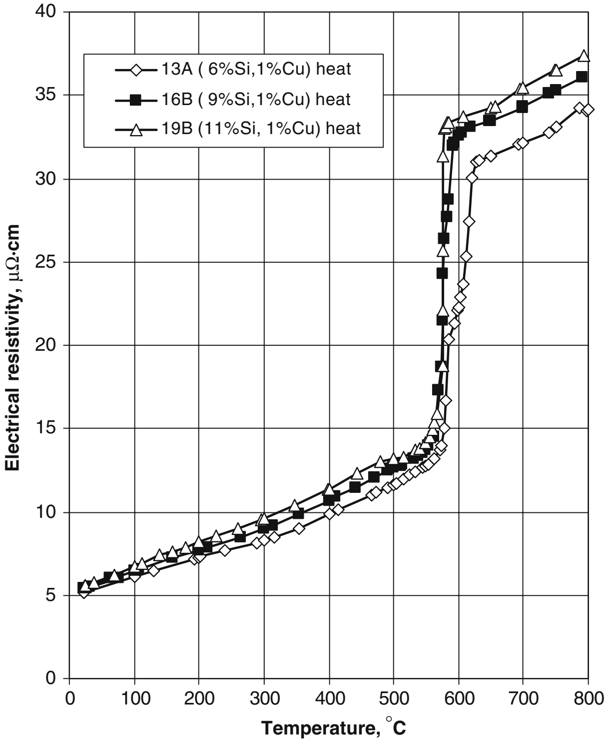

Fig. 5. Electrical resistivity of ternary AlSiCu alloys with 1 mass% Cu (heating curves).

investigated here the determination of the thermal conductivity from the electrical resistivity using the Sommerfeld value is valid within about 1–3% at temperatures above ~200°C. This is in accordance with measurements of Overfelt et al. [5] on three aluminum alloys. They showed that in the solid state the Lorentz number L is about 5% below the Sommerfeld value L_0 and is equal to the Sommerfeld value in the liquid state.

Also from Fig. 6, it could be seen that for pure aluminum the thermal conductivity during cooling is the same as measured in the heating cycle, whereas for nearly all alloys the measured electrical resistivity during the cooling cycle was higher than that during heating (see Tables I–III), i.e., the thermal conductivity remained lower after resolidification, as shown in Fig. 7 for the AlSi-1 binary alloy (5 mass% Si) as an example. Measurements after resolidification with the vernier calliper confirmed the measurement in the crucible when using the same gauge length of

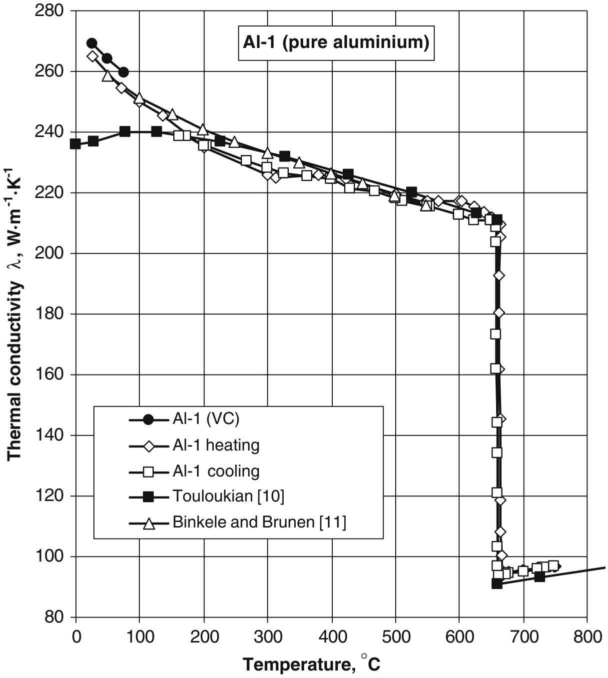

Fig. 6. Calculated thermal conductivity of pure aluminum (heating and cooling cycles) compared to measured data from literature.

50 mm as during the crucible measurement; but when keeping the bottom voltage tap at its position and moving the upper voltage tap to smaller gauge lengths of 40 or 30 mm, the conductivity increased. This indicates a locus-dependent thermal conductivity, possibly caused by segregation during resolidification. This segregation may occur because there is a small temperature gradient in the specimen and the cooling rate is low, so resolidification starts at the bottom of the vertically installed specimen (see Fig. 2) and slowly moves upward. Another reason for the lower conductivity may have its origin in the low solidification producing a microstructure, which differs from the original one, or in the forming of porosity in the material during the solidification process which might be different at various positions in the specimen. These effects shall be examined by evaluating micrographs of the resolidified specimens.

The influence of the constituents of the alloy on the electrical resistivity or on the thermal conductivity is shown in Fig. 8, where the thermal conductivity of the binary AlSi alloys is plotted vs. the Si-content for some

Table I. Electrical Resistivity of Pure Aluminum and Binary AlSi Alloys

Sample No.	Al-1	AlSi-1	AlSi-2	AlSi-3	AlSi-4
Si (mass%)	0	5	7	9	12
Density $(\mathrm{g \cdot cm^{-3}})$	2.698	2.682	2.676	2.662	2.650
Temperature	Electrical resistivity ρ $(\mu\Omega \cdot \mathrm{cm})$				
	Heating cycle				
25°C	2.71	3.85	4.17	3.89	4.25
75°C	3.28	4.53	4.91	4.61	5.07
100°C	3.64	4.85	5.32	4.92	5.41
200°C	4.92	6.16	6.80	6.25	7.01
300°C	6.19	7.39	8.12	7.43	8.47
400°C	7.30	8.76	9.59	8.92	10.16
500°C	8.61	10.39	11.41	10.73	11.54
550°C	9.26	11.14	12.22	11.77	12.44
600°C	9.82				
650°C	10.64				
Solidus	663°C	580°C	577°C	579°C	577°C
ρ_S	10.92	11.36	12.45	12.67	13.00
Liquidus	666°C	642°C	629°C	613°C	596°C
ρ_L	24.10	27.25	28.43	29.54	31.44
ρ_L/ρ_S	2.21	2.40	2.28	2.33	2.42
650°C		27.38	28.91	30.02	32.20
700°C	24.87	28.11	29.50	30.72	32.97
750°C	25.76	28.93	30.39	31.42	33.80
	Cooling cycle				
750°C	25.76	28.85	30.39	31.42	33.27
700°C	24.99	28.12	30.37	30.77	32.62
650°C		27.36	29.31	29.96	32.06
600°C				28.96	31.70
Liquidus	662°C	628°C	618°C	600°C	584°C
ρ_L	24.38	27.10	28.64	28.96	31.44
Solidus	658°C	550°C	564°C	546°C	566°C
ρ_S	11.17	14.55	14.69	14.84	18.03
ρ_L/ρ_S	2.18	1.86	1.95	1.95	1.74
650°C	10.70				
600°C	10.02				
550°C	9.33	14.55	14.30		17.25
500°C	8.66	13.39	13.11	13.80	15.64
400°C	7.33	11.56	11.27	11.98	13.23
300°C	6.14	9.77		9.92	11.16
200°C	4.90	8.02		8.46	9.09
100°C		6.19		6.29	6.96
25°C				4.70	

Table II. Electrical Resistivity of Ternary AlSiMg Alloys

Sample No.	AlSi-6	AlSi-8	AlSi-10	AlSi-11	AlSi-12
Si (mass%)	5	7	9	12	12
Mg (mass%)	0.6	0.6	0.6	0.3	0.6
Density ($g \cdot cm^{-3}$)	2.669	2.666	2.659	2.640	2.642
Temperature	Electrical resistivity ρ ($\mu\Omega \cdot cm$)				
			Heating cycle		
25°C	4.10	4.43	4.42	4.87	5.20
75°C	4.76	5.17	5.19	5.76	6.13
100°C	5.03	5.47		6.07	6.73
200°C	6.25	6.83	6.71	7.62	8.63
300°C	7.41	8.07	8.18	9.24	10.12
400°C	8.83	9.66	10.07	11.27	11.96
500°C	10.55	11.55	11.76	13.01	13.57
550°C	11.25	12.42	12.75	13.40	14.27
Solidus	567°C	569°C	567°C	569°C	580°C
ρ_S	11.71	12.75	13.08	13.73	14.96
Liquidus	634°C	621°C	599°C	609°C	590°C
ρ_L	27.79	28.83	29.05	31.61	31.55
ρ_L/ρ_s	2.37	2.26	2.22	2.30	2.11
650°C	28.08	29.29	30.46	32.27	32.40
700°C	28.85	30.12	31.27	35.24	33.21
750°C	29.60	30.90	32.08	37.64	34.03
800°C	30.37	31.70	32.86	39.26	34.74
			Cooling cycle		
750°C	29.67	30.95	32.17	35.38	34.10
700°C	28.88	30.14	31.40	33.97	33.14
650°C	28.08	29.37	30.60	33.11	32.35
600°C			29.78	31.94	31.52
Liquidus	624°C	609°C	596°C	576°C	579°C
ρ_L	27.51	28.63	29.70	31.37	31.15
Solidus	538°C	542°C	549°C	548°C	545°C
ρ_S	12.78	13.98	15.02	18.23	16.98
ρ_L/ρ_S	2.15	2.05	1.98	1.72	1.83
500°C	12.03	12.87	13.64	16.48	15.74
400°C	10.35	10.97	11.65	14.03	13.39
300°C	8.60	9.24	10.15	11.80	11.07
200°C	6.82		8.07	9.54	9.08
100°C	5.38			7.35	7.00
25°C	4.09	4.68	4.91	5.69	5.17

Table III. Electrical Resistivity of Ternary AlSiCu Alloys

Sample No.	AlSi-13	AlSi-15	AlSi-16	AlSi-17	AlSi-18	AlSi-19	AlSi-21
Si (mass%)	6	6	9	9	9	11	11
Cu (mass%)	1	3	1	2	3	1	3
Density ($g \cdot cm^{-3}$)	2.748	2.783	2.730	2.747	2.765	2.710	2.755
Temperature	Electrical resistivity ρ ($\mu\Omega \cdot cm$)						
				Heating cycle			
25°C	5.17	5.61	5.36	5.57	5.73	5.55	5.95
75°C	5.84	6.30	6.09	6.30	6.47	6.34	6.74
100°C	6.09	6.58	6.43	6.75	6.74	6.74	7.23
200°C	7.28	7.86	7.70	8.17	8.22	8.18	8.60
300°C	8.26	8.86	9.00	9.31	9.32	9.61	9.98
400°C	9.83	10.56	10.70	11.05	11.04	11.39	11.78
500°C	11.63	12.55	12.64	12.77	13.03	13.16	13.49
550°C	12.78			13.78		14.19	
Solidus	563°C	538°C	545°C	550°C	536°C	550°C	531°C
ρ_S	13.17	13.38	13.50	13.78	14.39	14.19	14.03
Liquidus	626°C	611°C	595°C	602°C	598°C	580°C	580°C
ρ_L	31.03	31.27	32.16	32.67	32.84	33.10	33.36
ρ_L/ρ_S	2.36	2.34	2.38	2.37	2.28	2.33	2.38
650°C	31.37	31.98	33.47	33.34	33.58	34.26	34.24
700°C	32.16	32.71	34.29	34.11	34.25	35.47	34.98
750°C	33.07	33.38	35.27	34.82	34.96	36.50	35.67
800°C	34.11	34.12	36.28	35.50	35.71	37.49	36.34
				Cooling cycle			
750°C	33.18	33.43	35.17		35.02		35.70
700°C	32.21	32.72	34.14	34.11	34.34	35.31	35.00
650°C	31.38	32.05	33.26	33.41	33.61	34.53	34.31
600°C			32.44	32.62	32.75	33.79	33.59
Liquidus	616°C	603°C	597°C	593°C	586°C	575°C	568°C
ρ_L	30.71	31.29	32.40	32.34	32.54	33.42	33.19
Solidus	541°C	530°C	537°C	536°C	533°C	543°C	539°C
ρ_S	16.59	18.22	17.89	18.06	18.71	19.59	19.06
ρ_L/ρ_S	1.85	1.72	1.81	1.79	1.74	1.71	1.74
500°C	14.85	17.20	16.52	16.73	17.18	18.03	17.10
400°C	12.87	14.67	14.11	14.22	14.46	15.31	14.41
300°C	11.39	12.89	12.45	12.17	12.67	13.33	12.50
200°C	9.50	11.04	10.54	10.20			10.48
100°C		8.84					8.44
25°C	6.20	7.32		6.82	7.12	6.41	6.91

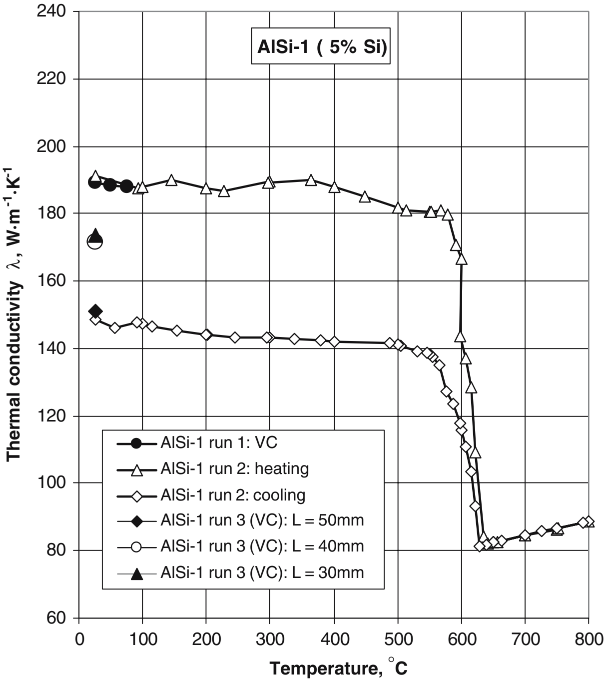

Fig. 7. Calculated thermal conductivity of AlSi with 5 mass% Si (heating and cooling cycles).

distinct temperatures. In the solid state the thermal conductivity decreases with increasing Si amount, but with a discontinuity, which disappears in the liquid phase. After resolidification, this discontinuity becomes smaller.

6. CONCLUSIONS

The determination of the thermal conductivity of metals in the range of the melting temperature by measuring the electrical resistivity has been remarkably improved especially by eliminating the error source caused by contamination of insulating components with condensing metal vapor. These measurements and an analysis of converting electrical resistivity results to thermal conductivity values, led to a total uncertainty below 6% at a statistical expansion (coverage) factor of $k = 2$. Investigations of binary AlSi-alloy samples in the range below the eutectic mixture show that with increasing Si-content the thermal conductivity decreases both in the solid and liquid states. The "mushy" temperature range becomes

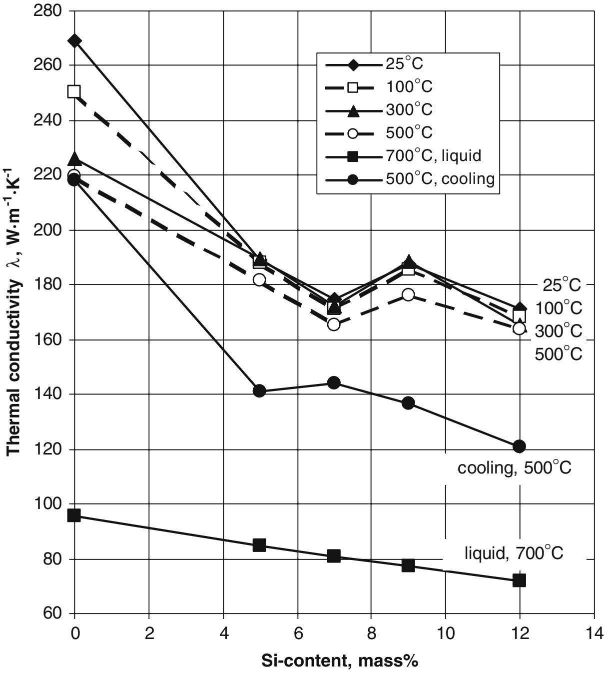

Fig. 8. Influence of Si-content on the thermal conductivity of binary AlSi-alloys.

smaller with increasing Si-content, and the conductivity values in the solid state have changed after resolidification. They are up to 25% lower after resolidification. The reasons are based on changes of the material which shall be investigated by macro- and micro-scale material analyses.

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