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Intercomparison of thermal diffusivity measurements on CuCrZr and PMMA

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The results of an inter laboratory comparison of thermal diffusivity measurements on two different materials, namely a copper alloy (CuCrZr) and a polymer (PMMA), are presented here. Both materials were selected with respect to their different thermal conductivity, since the copper alloy belongs to the family of good metallic conductors whereas the polymer is characterized by a low thermal conductivity. The measurements of the thermal diffusivity have been performed within a temperature range from RT to 500°C for the copper alloy and from RT to 100°C for the PMMA, respectively.

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1 INTRODUCTION

The thermal diffusivity is an important temperature dependent property which determines the time dependent heat flow in a large number of industrial applications but also in fundamental materials studies. Furthermore, it is directly related to the thermal conductivity, another important thermo-physical property which describes the heat flow within materials. Both properties can be converted into each other by considering the density and specific heat. Therefore, since the measurement of the thermal diffusivity is often easier and faster, the thermal conductivity of a material is frequently determined using its measured thermal diffusivity value multiplied by its density and heat capacity at a particular temperature.

For the laboratory intercomparison two different materials were selected: a copper alloy (CuCrZr) [1] and a polymer (PMMA). Both materials exhibit large differences in their thermal diffusivity and correlated thermal conductivity values. The CuCrZr-copper alloy belongs to the class of good metallic conductors with high electrical and thermal conductivity [2,3]. The PMMA polymer is a dielectric material with no significant electrical conductivity and a low thermal conductivity value [4,5]. Also, the optical properties are completely different since the copper alloy is opaque over a large wavelength range, whereas the PMMA exhibits a high transmission in the visible (VIS) and near infrared (NIR).

2 PARTICIPANTS AND MEASUREMENT METHODS

Participants	**Material**	**Measurement method**
AIT Seibersdorf	CuCrZr / PMMA	Laser Flash
BTU Cottbus	CuCrZr / PMMA	Laser Flash
DLR Köln	PMMA	Hot Disk
FZ Jülich	CuCrZr / PMMA	Laser Flash
IKTS Dresden	CuCrZr / PMMA	Laser Flash
KIT Karlsruhe	CuCrZr / PMMA	Laser Flash
Netzsch GmbH	CuCrZr	Laser Flash
ÖGI Leoben	CuCrZr / PMMA	Laser Flash
PTB Braunschweig	PMMA	Transient Hot Bridge
RWTH Aachen	CuCrZr/PMMA	Laser Flash
ZAE Bayern	PMMA	Laser Flash
DLR Stuttgart	CuCrZr/PMMA	Laser Flash

The total number of participants for this study was 12, whereas 11 laboratories delivered data for the polymer system PMMA and 9 labs measured the thermal diffusivity on the copper alloy CuCrZr.

3 SAMPLE DESCTRIPTION AND PREPARATION

The CuCrZr samples used in this study were manufactured starting from a bar shaped piece with a geometry of 35 × 35 × 1000 mm^3. The material was delivered by the company Zollern/Laucherthal. The composition given in mass-% was Cu-0.8Cr-0.08Zr.

The PMMA samples were delivered as plates by Evonik Röhm GmbH (Darmstadt, Germany). The plates (Plexiglas XT) were completely colourless and clear with a high optical transmission which was larger than 90% in the range of the visible wave length but with no transmission within the UV range.

4 MEASUREMENT AND EVALUATION

All measurements of thermal diffusivity of the Cu alloy were performed with the Laser Flash method. Also, nearly all measurements of the PMMA samples were done using the Laser Flash apparatus but with two exceptions where the hot disk or the transient hot bridge has been applied.

5 RESULTS

The results of the measured thermal diffusivity data of the CuCrZr alloy as a function of the temperature are shown in Fig.1. Each participating laboratory included one data set. The thermal diffusivity of the Cu alloy decreases nearly linearly with increasing temperature. Starting at a room temperature value of about (100 ± 4) mm^2/s the thermal diffusivity decreases to (90 ± 5) mm^2/s. Although each single data set shows a decreasing behaviour of the thermal diffusivity as a function of the temperature the evaluated temperature coefficients are different leading to larger spreading of the data at the maximum temperature of 500°C.

The thermal diffusivity data of PMMA as a function of the temperature of each participating laboratory are shown in Fig. 2. With the exception of one data set the temperature covered within this study was room temperature up to 100°C. Only one laboratory extended this range below room temperature down to –20°C.

Although the absolute values of the thermal diffusivity measured by different laboratories show a significant spread the slope with regard to the

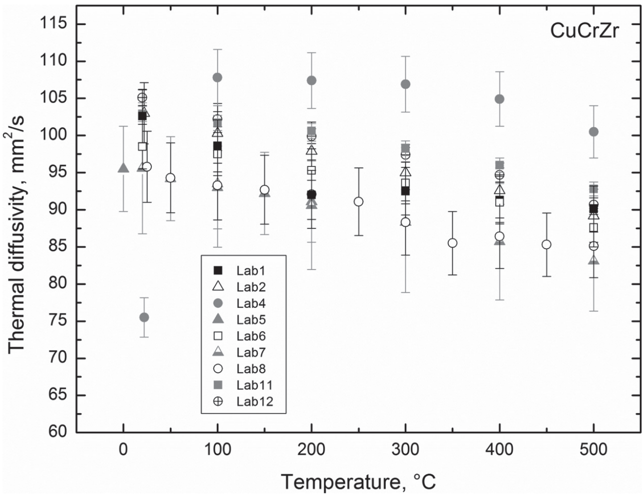

FIGURE 1
Thermal diffusivity data of the CuCrZr alloy.

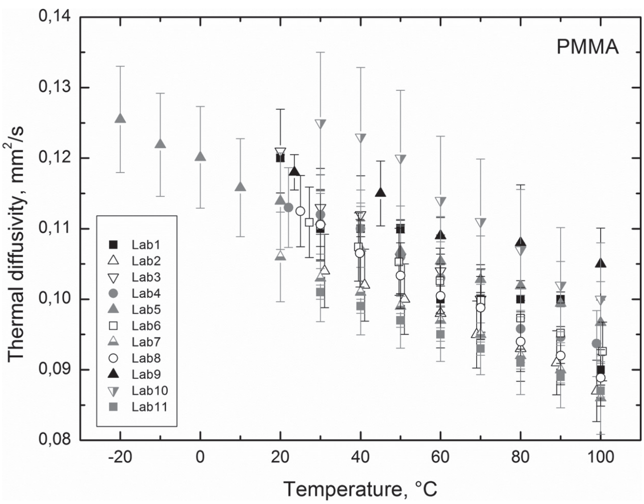

FIGURE 2
Measured thermal diffusivity data of PMMA.

temperature appear to be nearly identical. The thermal diffusivity decreases with a slope of $-2.7 \cdot 10^{-4}$ $mm^2/(s \cdot K)$ as function of temperature within the temperature range of RT to 100°C. The additional data below room temperature measured by only one laboratory confirm this result.

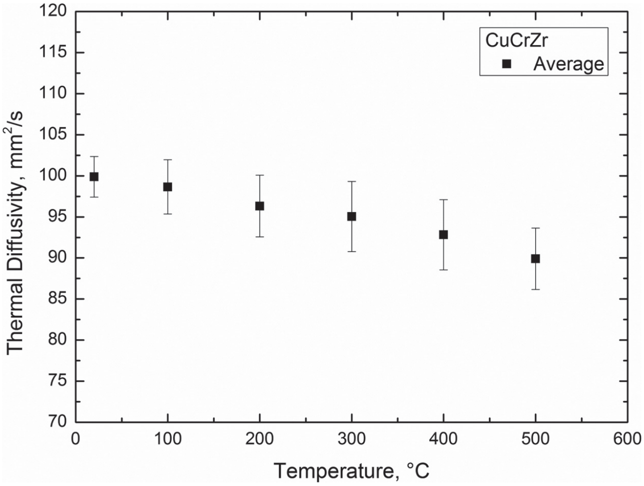

FIGURE 3
Mean values of the thermal diffusivity for the Cu-alloy.

6 DISCUSSION

Based on the data sets delivered by the contributing laboratories mean values of each material system were calculated. For the copper alloy CuCrZr the average values of the thermal diffusivity as a function of the temperature are shown in Fig. 3. The diffusivity values decreases with increasing temperature nearly linearly starting at about (100 ± 2.3) $mm^2\ s^{-1}$ at room temperature to a value of (90 ± 3.7) $mm^2\ s^{-1}$. Over the measured temperature range a relative expanded uncertainty (K = 2) of about 3.7% was estimated.

The mean diffusivity values of the polymer system PMMA are shown in Fig. 4, which were only calculated for the temperature range from RT to 100°C. The values below room temperature, which were delivered by one participant, were not included in this calculation. The thermal diffusivity decreases from (0,114 ± 0,0035 mm^2/s) at room temperature to (0,093 ± 0,0040 mm^2/s) at 100°C. Over this temperature range a relative expanded uncertainty (K = 2) of about 3,8 % was estimated. Although the temperature covered within this study extends beyond the glass temperature of the amorphous PMMA at around 80 °C no effect of the "softening" on the thermal transport parameter can be observed in the averaged data set.

7 CONCLUSION

The specific objective of this inter laboratory comparison was to consider materials with either high or very low thermal conductivity/diffusivity. This

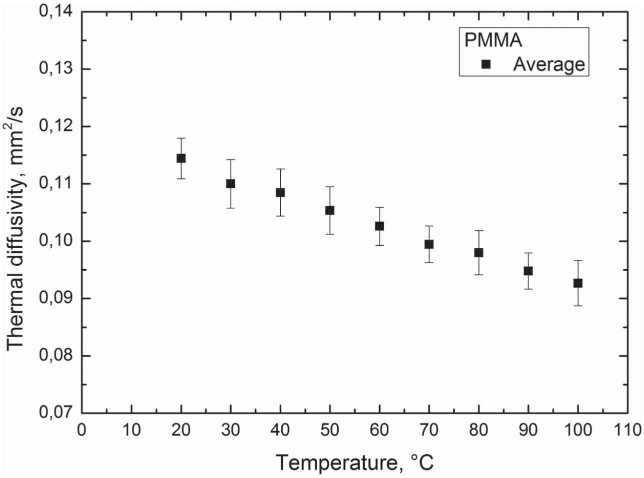

FIGURE 4
Mean values of the thermal diffusivity of PMMA.

intercomparison delivered thermal diffusivity values for the polymer system PMMA and for the Cu-alloy CuCrZr with relative uncertainties of less than 4% and about 4–5%, respectively. A further reduction of the measurement uncertainties might be possible by a restriction of the temperature range used in future studies in order to avoid an irreversible thermal treatment of the material [2,5].

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