Application Brief

SII

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Specific Heat Capacity Measurements Using DSC I

- The Principles of Specific Heat Capacity Measurements and an Example Using Epoxy Resin -

1. Introduction

DSC can measure the specific heat capacity (Cp) of even small quantities relatively easily.

While explaining the principles of specific heat capacity measurement, this brief presents results of a measurement accuracy test in which duplicate measurements of sapphire were performed and examples of applications with epoxy adhesive and IC packages (epoxy resin and filler).

2. Principles of Specific Heat Capacity Measurements

Figure 1 shows an example of acquiring specific heat capacity using DSC. The measurements conditions for the sample, the reference (a sample with a known specific heat capacity) and the empty pan were the same. The specific heat capacity of the sample was calculated by equation 1 from the DSC data obtained (a, b, and c in Figure 1).

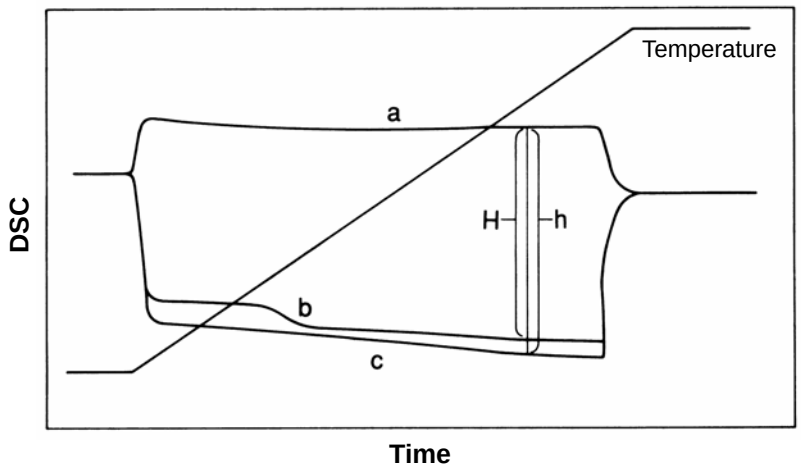

Figure 1 DSC measurement of specific heat capacity
a : empty pan
b : sample
c : reference

$$Cps = \frac{H}{h} \cdot \frac{mr}{ms} \cdot Cpr \quad \cdots\cdots \quad 1$$

Cps : Cp of sample
Cpr : Cp of reference
ms : Weight of sample
mr : Weight of reference
H : Difference of sample and empty pan
h : Difference of reference and empty pan

3. Results

3-1 Accuracy of the Specific Heat Capacity Measurements

Figure 2 shows the results for four repeated measurements of a 30mg sapphire sample. The vertical axis is the difference of the measured and literature values. The variation of the repeated measurement was within about 2%.

Table 1 shows the average values (avg), standard deviations (SD), literature values and deviations from the literature values. Comparisons with literature values show that the accuracy of the average of the four specific heat capacity measurements was within 1%.

It is assumed that it is best to perform DSC measurements of specific heat capacity with samples and reference that have roughly same the heat capacity. To confirm this, measurements were performed with the heat capacity of sapphire at 65%, 99% and 175% of the heat capacity of the reference. The results in Table 2 confirm that the measurement accuracy was highest for the 29.68mg sample, the condition where the heat capacity of the sample and the reference were roughly equal.

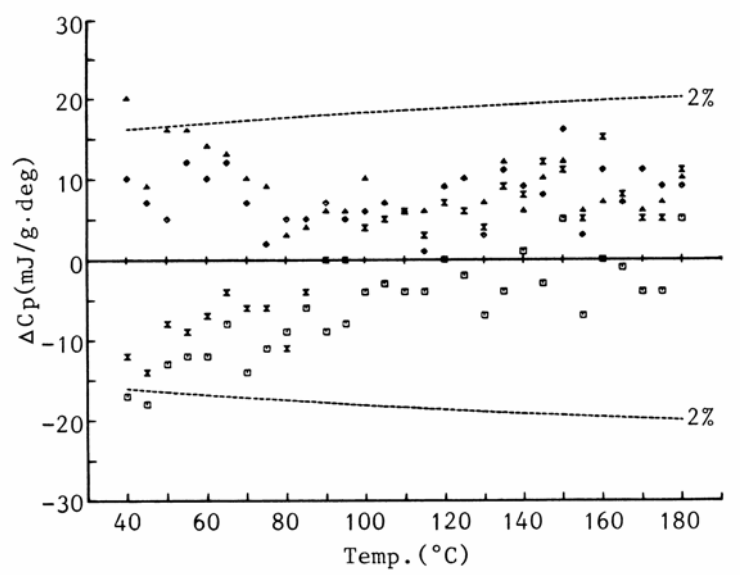

Figure 2 Results for repeated measurements of sapphire
ΔCp = Cp (literature value) - Cp (measured value)
Sample weight : 29.7mg
Heating rate : 10℃/min

Table 1 Repeated measurements (n=4) of the specific heat capacity of sapphire

Temp.(°C)	avg. (J/g･deg)	SD	C.V. (%)	Literature value (J/g･deg)	Deviation (%) from literature value
40	0.806	0.018	2.2	0.806	0.0
60	0.844	0.012	1.4	0.843	-0.1
80	0.874	0.008	0.9	0.877	-0.3
100	0.912	0.006	0.7	0.908	-0.4
120	0.941	0.005	0.5	0.935	-0.6
140	0.965	0.004	0.4	0.959	-0.6
160	0.989	0.006	0.6	0.981	-0.8
180	1.007	0.007	0.7	1.001	-0.6

Table 2 Specific heat capacity measurement results for different sapphire weights

Temp. (°C)	19.20mg		29.68mg		50.25mg	
	measured (J/g·deg)	Deviation (%) from literature	measured (J/g·deg)	Deviation (%) from literature	measured (J/g·deg)	Deviation (%) from literature
40	0.800	-0.7	0.795	-1.4	0.797	-1.1
60	0.851	0.9	0.843	0.0	0.835	-0.9
80	0.888	1.3	0.877	0.0	0.862	-1.7
100	0.929	2.3	0.912	0.4	0.901	-0.8
120	0.966	3.3	0.942	0.7	0.928	-0.7
140	0.989	3.1	0.966	0.7	0.949	-1.0
160	1.017	3.7	0.989	0.8	0.968	-1.2

Reference weight : 29.71 mg

3-2 Measuring the specific heat capacity of epoxy adhesives

Both Figure 3 and Table 3 show the specific heat capacity measurement results for an epoxy adhesive. Figure 3 plots the specific heat capacity versus the temperature and shows the change process of specific heat capacity. The large increase of specific heat capacity between 70°C and 90°C is due to the glass transition of the epoxy. Table 3 lists the specific heat capacity values by temperature.

3-3 Measuring the specific heat capacity of IC packages

Both Figure 4 and Table 3 show the specific heat capacity measurement results for the IC package, which is filled with epoxy resin (approximately 20%) and other inorganic material. The specific heat capacity of the IC package was likely lower than the epoxy adhesive because specific heat capacity of inorganic material is lower than the resin.

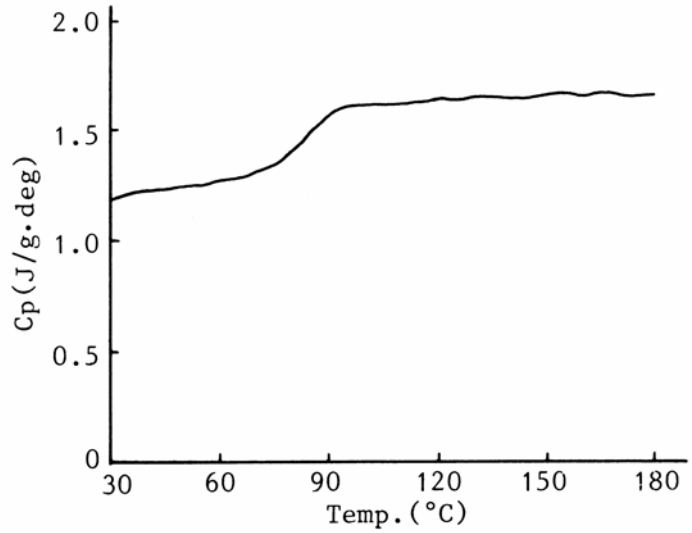

Figure 3 Specific heat capacity results for epoxy adhesive
Temperature interval for Cp calculation : 5 °C

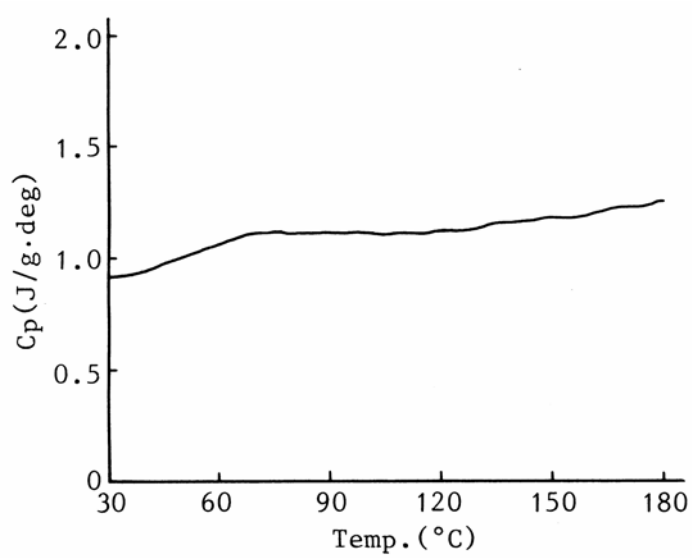

Figure 4 Specific heat capacity results for IC package
Temperature interval for Cp calculation : 5 °C

Table 3 Cp for epoxy adhesive and IC package

Temp. (°C)	Cp (J/g·deg)	
	Epoxy adhesive	IC package
30	1.188	0.910
35	1.210	0.923
40	1.228	0.941
45	1.231	0.968
50	1.245	1.000
55	1.254	1.029
60	1.274	1.058
65	1.282	1.090
70	1.310	1.111
75	1.340	1.112
80	1.408	1.105
85	1.499	1.116
90	1.575	1.112
95	1.609	1.111
100	1.614	1.109
105	1.615	1.102
110	1.621	1.110
115	1.628	1.107
120	1.642	1.118
125	1.633	1.122
130	1.650	1.130
135	1.651	1.155
140	1.645	1.160
145	1.647	1.167
150	1.660	1.181
155	1.665	1.178
160	1.652	1.188
165	1.675	1.207
170	1.660	1.220
175	1.651	1.221