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The effect of the inclination angle on the transient performance of a phase change material-based heat sink under pulsed heat loads

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Motivation and tasks

- **How is transient performance of a PCM-based heat sink affected by simply tilting it?**

- Design and construction of a test-rig for an inclined PCM-based heat sink with adjustable inclination angle from horizontal to vertical conditions

- Testing on the transient performance of the PCM-based heat sink at various inclination angles under pulsed heat loads

Experimental setup

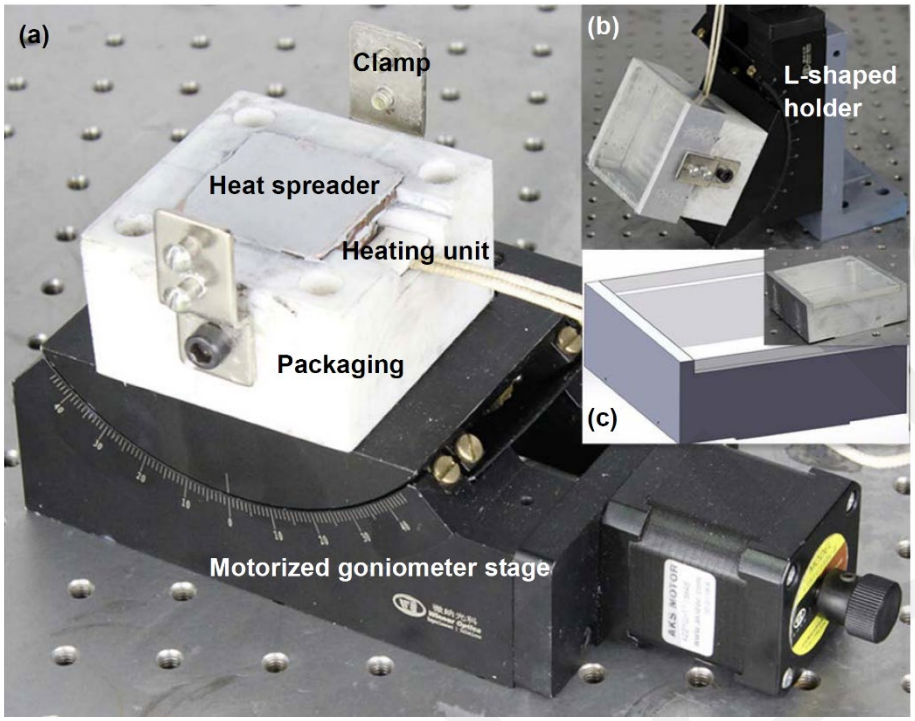

Fig. 1 Photographs of the experimental setup positioned horizontally on a table (a) and mounted vertically on a L-shaped holder (b), and schematic diagram of the heat sink (c) (the inset is a photograph of the heat sink)

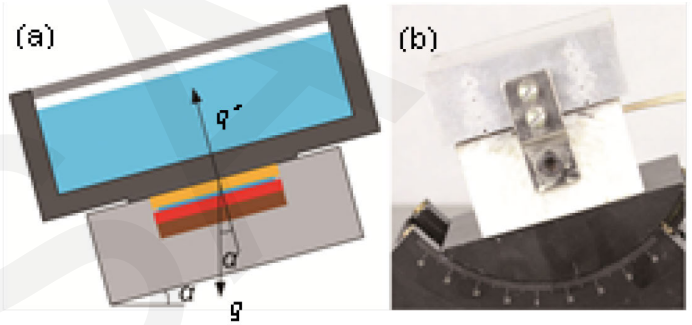

Fig. 2 Schematic diagram of the PCM-based heat sink showing the definition of the inclination angle (a) and

Table 1 Surface heat fluxes and heating durations of the two heat loads exerted

Q (W)	Current (A)	Voltage (V)	q'' (W/cm^2)	Time (min)
19.54	3.02	6.47	1.22	50
39.30	9.14	4.30	2.46	23

- Inclination angle: 0 to 90 deg
- Heating power: 20 and 40 W

Transient temperature rise

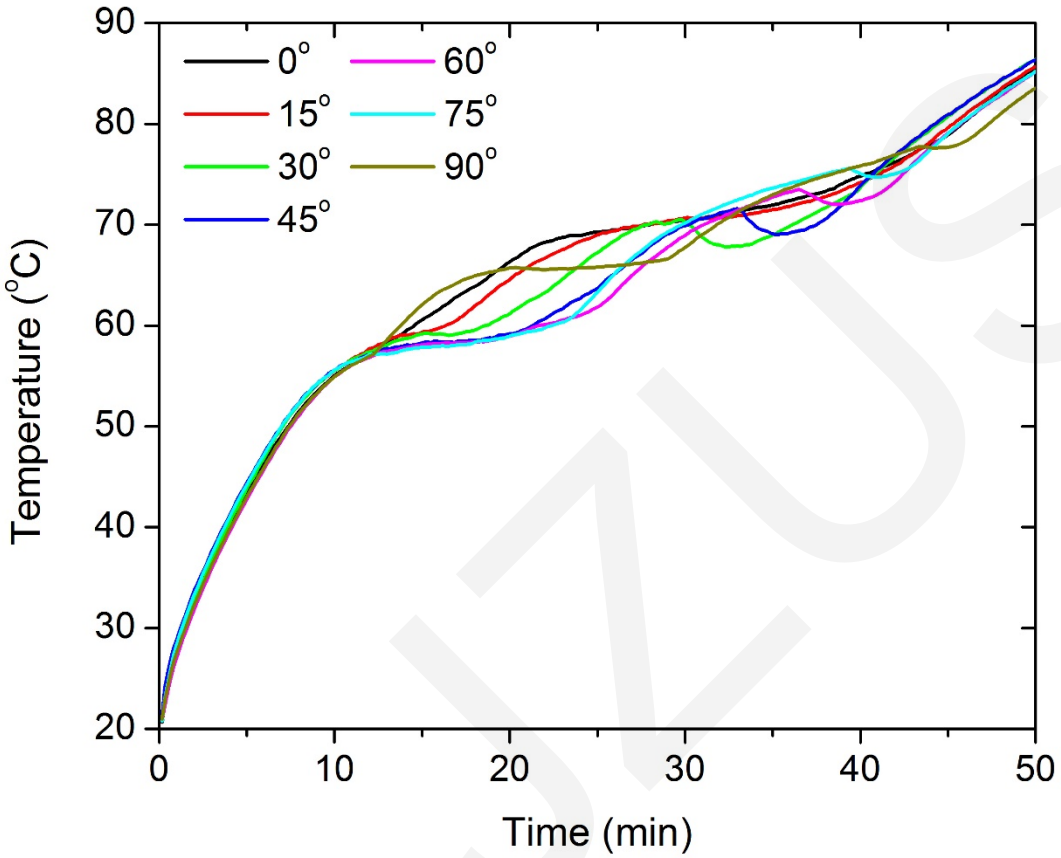

Fig. 3 Transient temperature rises at the center of the round copper plate for the heat sink operated at various inclination angles under the heat load of 20 W

Transient temperature rise

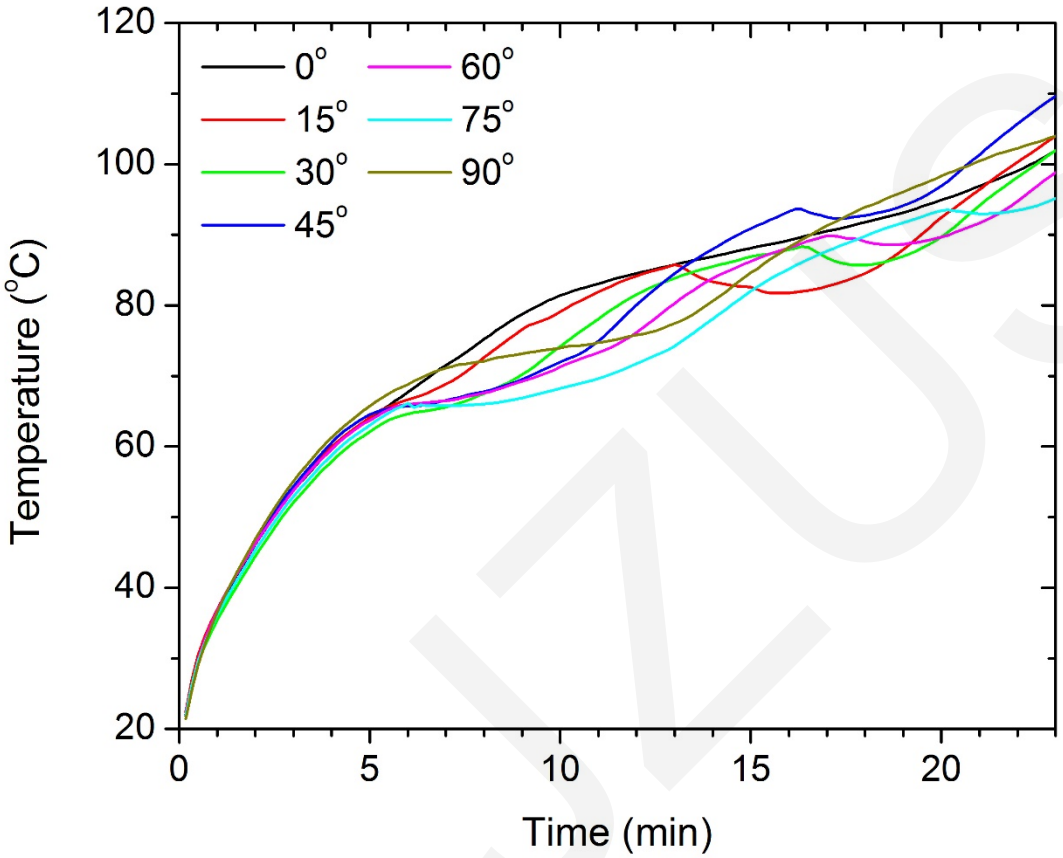

Fig. 4 Transient temperature rises at the center of the round copper plate for the heat sink operated at various inclination angles under the heat load of 40 W

Time-averaged thermal resistance

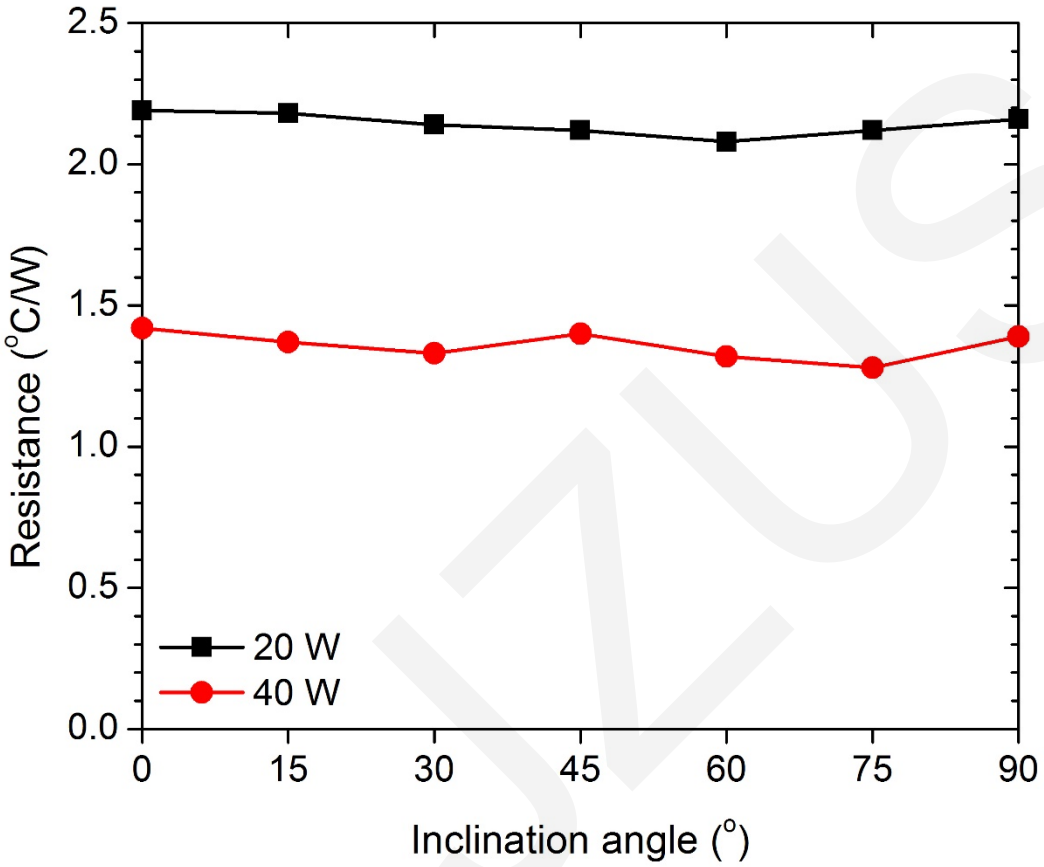

Fig. 5 The time-averaged effective thermal resistances of the PCM-based heat sink over the operation durations of the two heat loads at various inclination angles

Time-averaged thermal resistance

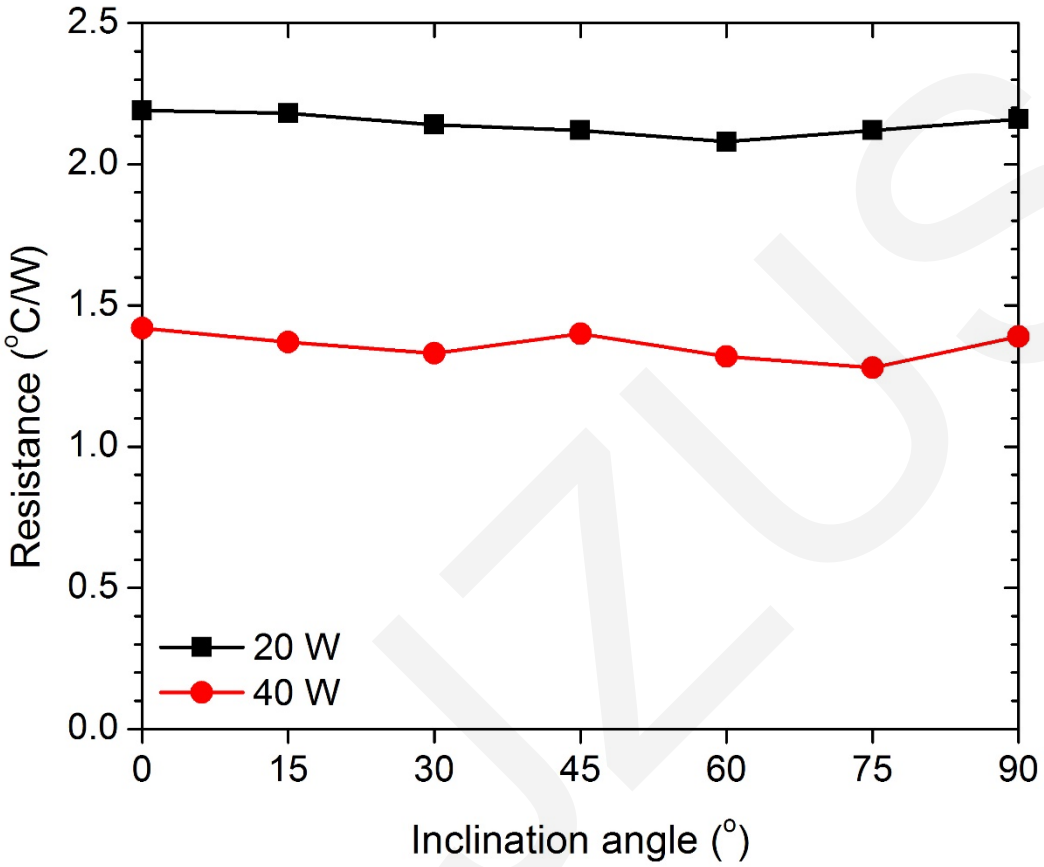

Fig. 5 The time-averaged effective thermal resistances of the PCM-based heat sink over the operation durations of the two heat loads at various inclination angles

Extended operation time

Table 2 Measured operation times of the PCM-based heat sink at different inclination angles for *Q*=20 W below the set point of 75 °C

α (°)	Operation time (s)	Relative extension (%)
0	2420	–
15	2470	2.1
30	2450	1.2
45	2450	1.2
60	2550	5.4
75	2510	3.7
90	2310	–4.6

Table 3 Measured operation times of the PCM-based heat sink at different inclination angles for *Q*=40 W below the set point of 75 °C

α (°)	Operation time (s)	Relative extension (%)
0	480	–
15	520	8.3
30	620	29.2
45	670	39.6
60	710	47.9
75	800	66.7
90	680	41.7

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Conclusions

- It was shown that by facilitating natural convection, the temperature rises for the inclined cases were greatly suppressed during the initial stage of the melting phase, regardless of the heat load exerted.

- For a given combination of heat load and maximum allowable temperature of the electronic device being cooled, the maximum operation time may be extended by simply inclining the heat sink.