C/C COMPOSITE, CARBON NANOTUBES AND PARAFFIN WAX HYBRID SYSTEMS FOR THE THERMAL CONTROL OF PULSED POWER IN ELECTRONICS

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Introduction

Most electronic systems are subjected to a complex combination of internal and external transient thermal loads. The situation becomes even more conspicuous when the device experiences a sudden surge of power density, which can have detrimental effects on its components. A number of studies have been conducted in literature for the design of Thermal Control (TC) Units using a combination of Phase Change Materials and (PCMs) and Metal Fins or additives to counter the problem of transient heat loads [1-2]. This study proposes a TC system that utilizes paraffin wax, carbon nanotubes (CNTs) and Carbon-Carbon (C/C) Composites in a novel design configuration. Objective of this study is to demonstrate, the importance of using CNTs as an additive in paraffin wax and C/C composites as an efficient heat transfer enhancer, to improve the thermal performance of a TC Unit for protection against pulsed power loads in electronics.

Composite TC System Design

The Composite TC system consists of three PCMs arranged in series in a specific configuration selected according the previous work by the authors [3]. The multiple PCMs are doped with CNTs with an optimum volume fraction and are separated by two partitions and enclosed in a casing of high thermal conductivity C/C composite sheets.

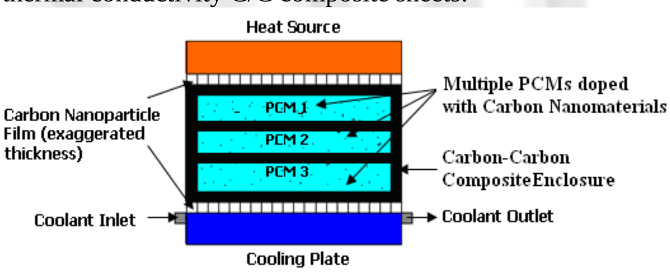


Fig. 1 Composite TC system with transient pulsed power

Fig. 1 shows a schematic for the composite TC system attached to a transient pulsed power heat source from the top with a coolant plate at the bottom and the left and right walls kept insulated.

Experimental Investigation:

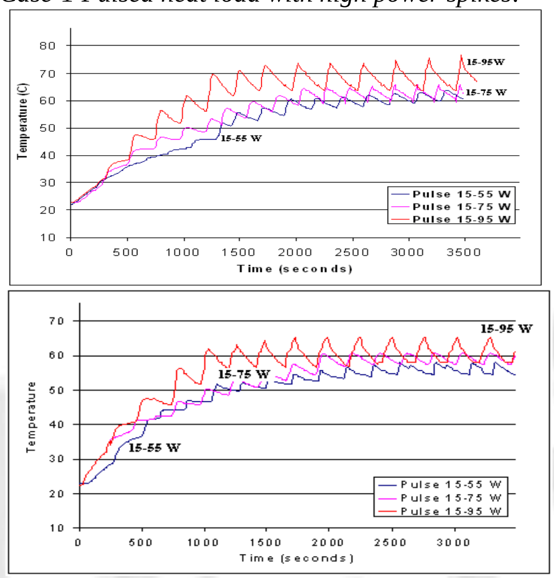
A test rig was designed and fabricated to analyze the composite TC system samples. Two types of samples each had three PCMs enclosed in C/C composite casing, sample-1 had three PCMs with similar and sample-2 had three PCMs with different melting points. The two sample types were tested for three cases, case-1) TC Composites without CNTs additives and CNTs Thermal Interface Sheet (TIS), case-2) TC Composites with only CNTs and case-3) TC Composites with both CNTs additives and TIS. For both TC Composite samples the bottom and side faces were kept insulated and following heat loads were applied to the top face,

(a) Pulsed heat loads with high power spikes (15W for 200 s followed by 55, 75 or 95 W for 30 s) (b) Pulsed heat loads in stand alone mode (ON period with 24, 36 and 48 W for 200 s with OFF period for 100 s).

Results and Discussion

Transient Maximum Junction Temperature (MJT) values were plotted for the two samples for the three cases when subjected to the two varying power conditions.

Case-1 Pulsed heat load with high power spikes:

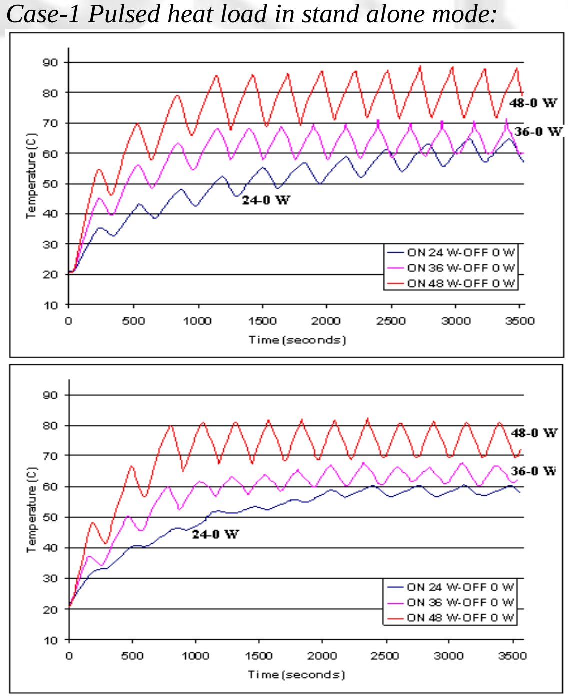


Sample-1

Sample-2

Fig. 2 Maxim. junction temp. (case-1) with high power spikes

Case-1 Pulsed heat load in stand alone mode:

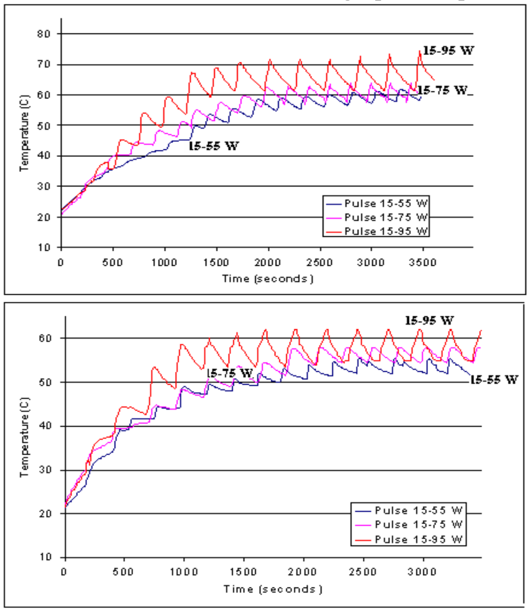


Sample-1

Sample-2

Fig. 3 Maxim. junction temp. (case-1) stand alone mode

Case-2 Pulsed heat load with high power spikes:

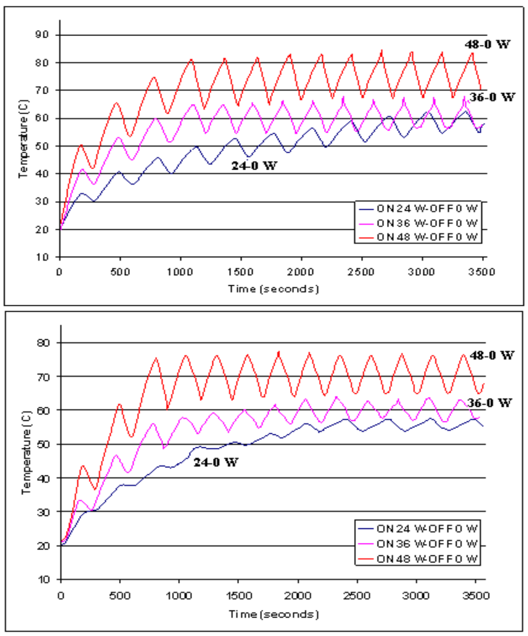


Sample-1

Sample-2

Fig. 4 Maxim. junction temp. (case-2) with high power spikes

Case-2 Pulsed heat load in stand alone mode:

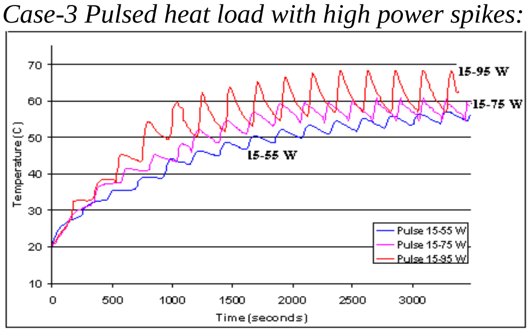


Sample-1

Sample-2

Fig. 5 Maxim. junction temp. (case-2) stand alone mode

Case-3 Pulsed heat load with high power spikes:



Sample-1

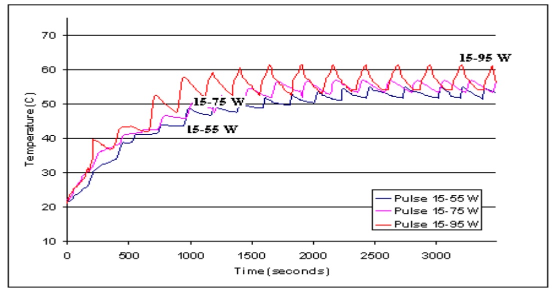


Fig. 6 Maxim. junction temp. (case-3) with high power spikes

Case-3 Pulsed heat load in stand alone mode:

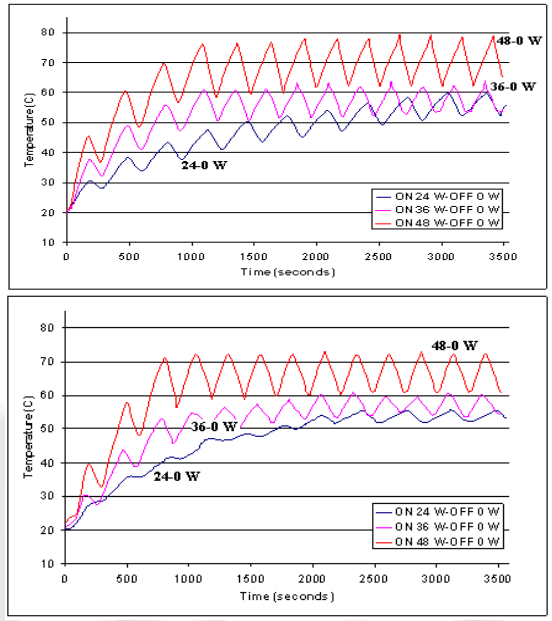


Fig. 7 Maxim. junction temp. (case-3) stand alone mode

The MJT values for sample-2 are lower than sample-1 for all three cases. For both the high power spikes & stand alone mode conditions equilibrium state is reached earlier with dampened spike heights for sample-2 as compared to sample-1 due to its greater melting rate latent energy storage. The MJT values are reduced by 2-6 °C for both samples for case-2 compared to case-1. However, the reductions in MJTs for case-3 are 15-20 °C as compared to case-1. This clearly emphasizes the greater heater transfer ability and thermal control achieved by both samples by using CNTs as an additive and as a thermal interface material.

References

[1] Py X, Olives R, Mauran S. Paraffin/porous graphite-matrix composite as a high and constant power thermal storage material. Int. J. of Heat and Mass Transfer. 2001; (44): 2727-2737.

[2] Krishnan S, Garimella SV. Thermal management of transient power spikes in electronics, phase change energy storage or copper heat sinks.Heat and Mass Transfer. 2004; 126(3): 308–316.

[3] Shaikh S, Lafdi K. Effect of multiple phase change materials slabs configuration on thermal energy storage. Carbon. 2005; 47(15): 2103-2117.