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Development of Heat sink from Aluminium Silicon Carbide for Electrical and Electronic Applications

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Abstract-
Heat sinks play a vital role in dissipating heat in electrical and electronic equipment. The heat sink device influences the overall efficiency, cost, and size of this equipment. Due to the development of the ever-evolving electronics market, new materials with a good thermal conductivity that can absorb and disperse heat away from high temperature and lightweight are sought for. As a result of this, searching for new materials with the tended properties to replace the traditional material is the focus of this work. The candidate materials choosing is aluminium silicon carbide composite because of its properties similar to the one needed for the heat sink. The aluminium silicon carbide composite was processed with different grits silicon carbide. Thereafter, additives with different oxide composition of calcium, zinc and chromium through the processing of stir and mechanical casting were used for the production of the samples. Nine samples in all were produced for the analysis and properties testing. The results show that density, electrical conductivity and thermal conductivity of produced samples are closely similar to the control sample. This preliminary result indicated that the developed heat sink sample could replace the traditional one.

Key words: Heat sink, aluminium, silicon carbide, calcium, zinc, chromium.

1. Introduction

Heat sinks are one of the simplest devices for dissipating heat from components and electronic devices, thus permitting controlling of the temperature of the components at optimum levels [1]. They are the instrument that improves heat dissipation from a hot surface involving moving from a heat-generation region to a cooled ambient in the form of air. Mostly, heat transfer through the interface amid the solid surface, and the coolant air is the leading phenomenon within the system, and the solid-air boundary depicts the most substantial obstacle for heat dissipation [2]. A heat sink drops this barrier generally by increasing the surface area that is in direct contact with the coolant. This permits more heat to be dispersed and decrease the device operating temperature. The main aim of a heat sink is to sustain the device temperature below the highest acceptable temperature stated by the equipment producer [3]. The rise in heat dissipation from microelectronic components and the decline in total form factors, thermal supervision becomes a relevant factor of electronic product design.

The performance reliability and life expectation of electronic instrument are inversely similar to the device temperature of the machine [4]. The connection amongst the reliability and the functional temperature of a distinctive silicon semiconductor device revealed that a decrease in the temperature matches the exponential increase in the reliability and life prospect of the device [5]. Moreover, extended life and reliability performance of a device can be realized by the effective controlling of the device operating temperature within limits agreed by the device design engineers [6]. Heat sinks are used to provide supplemental cooling that is required to prevent overheating of components. Cooling is intended to minimize the ambient temperature within a computer system, such as by removing hot air or cooling a particular part or small section. Nowadays, computers and operational devices are often formulated to lower the power consumed and the heating process agreeing to workload. However, more heat is generated by peripheral components that must be removed by cooling [7]. Following the ever-evolving electronics market development, materials used for previous heat sinks are no longer sufficient to meet the needs of heat removal. As a result of the limitations of these traditional heat sinks, there has been extensive research on new materials, mainly composites strengthened with fibre and particulates. The benefits of these new materials include higher thermal conductivities; controllable coefficients of thermal expansion (CTE); weight reductions; high strength and stiffness; and availability of net-shape fabrication processes. Sometimes, the new materials are inexpensive than the replaced ones. Thermal materials that are applicable in meeting the property requirements are copper, Aluminium and their alloys. Due to increased focus on miniaturization, ceramic materials (with CTE of between 3 - 7 × 10-6 K-1) are often used in conjunction with aluminium and copper for the production of substrates [8].

2. Experimental Methods

There are nine variations of heat sink material that were produced in the course of this work. The final composite of each sample comprises of discrete percentages of aluminium (Al) as a matrix and silicon carbide (SiC) of grits 3 µm (1200), 9 µm (600), 29 µm (320) and 45 µm (240) as reinforcement. Other substances acting as additives during production include powdered forms of zinc (Zn), calcium (Ca) and chromium (Cr). The aluminium ingots were sectioned using an electric cutting machine. A soluble oil was smeared as lubricant and coolant to mitigate the heat and metal distortion. The ingots were cut into nine differing weights for their respective samples, and SiC powder was measured according to percentage weight in the varying samples. The OHAUS Pioneer TM Model PA214 was used to accomplish this task. The powder was placed on a dish in a translucent airtight container of the weighing scale to avoid dust and air interference on the results. This process was repeated for powders of Zn, Ca and Cr. The AMMC was produced using the process of stir casting. The liquid metallurgy technique with optimum care was taken, and the standard procedure was followed to obtain the cast composites. The aluminium ingots were initially placed in a graphite crucible and were liquesced at 810 °C using a pit furnace. SiC powder was preheated to 700 °C for one hour to enable the silica content to retain its amorphous characteristic below 800 °C. Zn, Ca and Cr were also preheated before introduced into the vortex and stirring of the molten composite was accomplished for 10 minutes with a mechanical graphite stirrer at 400 rpm.

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Table 1: Produced Samples and constituents in percentage weight

Constituents	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Aluminium	100	78	78	78	78	90	90	90	90
Silicon Carbide 240	-	10	-	-	-	10	-	-	-
Silicon Carbide 320	-	-	10	-	-	-	10	-	-
Silicon Carbide 600	-	-	-	10	-	-	-	10	-
Silicon Carbide 1200	-	-	-	-	10	-	-	-	10
Calcium	-	3	3	3	3	-	-	-	-
Zinc	-	7	7	7	7	-	-	-	-
Chromium	-	2	2	2	2	-	-	-	-

Density, electrical conductivity and thermal conductivity were measured for all the samples. Density was calculated from the mass and volume measured in the analytical laboratory at the Department of Chemistry, Covenant University. Keithly Instrument Model 2400 was used to pass the current and voltage across the sample to be able to obtain conductivity and resistivity. This was conducted in instrumentation workshop in the Physics department. Thermal conductivity apparatus (EQUILAB) was used in measuring the thermal property.

3. Results and discussion

The produced samples were subjected to tests to obtain analytical values for comparison. The characterization of the samples was on their physical, electrical and thermal properties for analysis. The characteristics of the heat sink produced and the traditional material which was used as a control example are shown in Table 2.

Table 2: Produced samples and their properties

Constituents	**DENSITY (Kg/m^3)**	**ELECTRICAL CONDUCTIVITY ($s/m.e^7$)**	**THERMAL CONDUCTIVITY (W/mK)**
Sample A	2810	3.39	225
Sample B	3120	2.50	180
Sample C	2980	2.55	183
Sample D	2970	2.55	187
Sample E	2830	2.55	199
Sample F	2970	2.95	219
Sample G	2930	2.96	221
Sample H	2920	2.95	221
Sample I	2810	3.39	224

The electrical and thermal conductance of the composite materials was noticed to be lesser than that of the traditional aluminium-base metal—the electrical and thermal conductivity of the composite materials reduced with increase in particle sizes. The trend of electrical and thermal conductance of the composite materials was observed by [9] in their work. However, the low material density of AlSiC (approx. 3 g/cm^3) still makes it a proper material for weight-sensitive applications such as portable devices over traditional thermal management materials like copper-molybdenum, CuMo, (10 g/cm^3) and copper tungsten, CuW, (16g/cm^3) [10]. The grit size of 3 µm showed the most promise in use as a heat sink material with similar characteristics due to its small grit size, which presumably enabled better dispersion in the composite. Figure 1 shows the variation of density against the constituents. Figure 2 shows the electrical conductivity of heat sink from aluminum silicon carbide. Figure 3 shows the thermal conductivity of heat sink from aluminum silicon carbide. From Figure 1, the density of the reinforced aluminium silicon carbide on heat sink increases against the control sample A except sample I that have the same density as the control sample. The aluminium silicon carbide decreased the electrical conductivity of heat sink in Figure 2 from 3.39 to 2.50 s/m.e^7. It makes the capacity of the heat sink to conduct electricity because of the presence of silicon carbide in the heat sink. The thermal conductivity of heat sink from aluminum silicon carbide in Figure 3 decreased slightly and then rises as you increased the composition of silicon carbide in the sample.

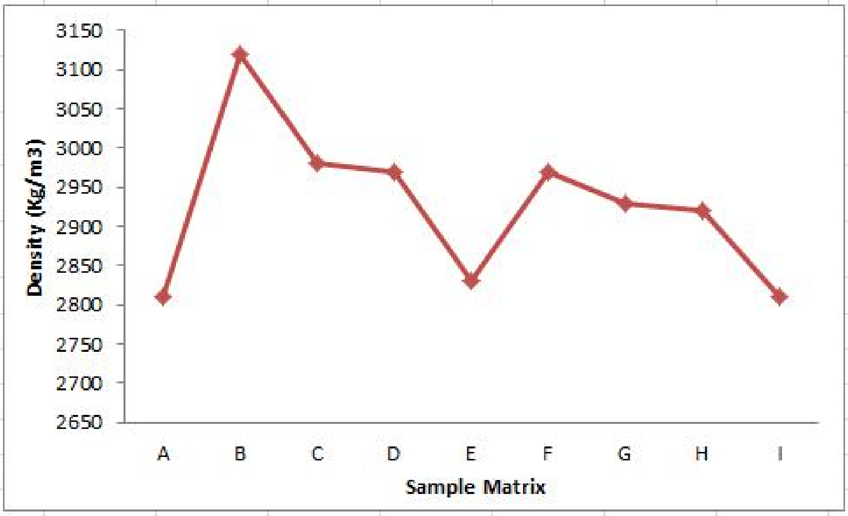

Figure 1: Density against the constituents

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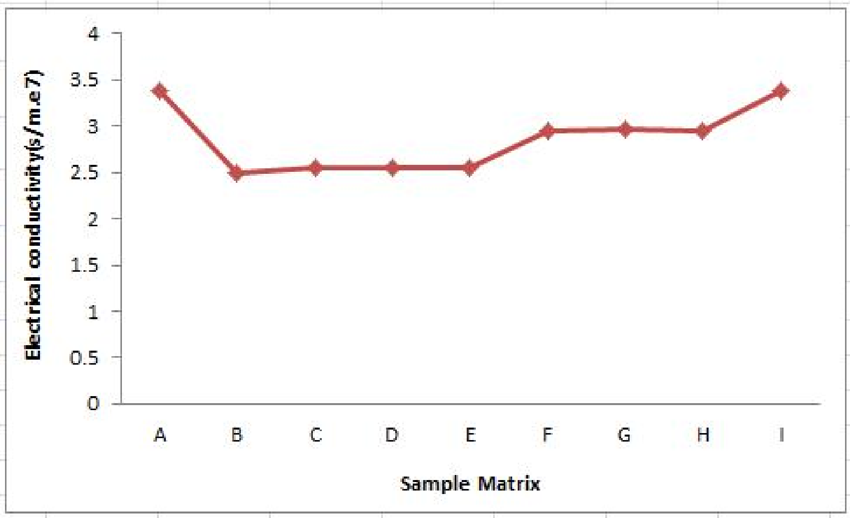

Figure 2: Electrical conductivity of heat sink from aluminium silicon carbide

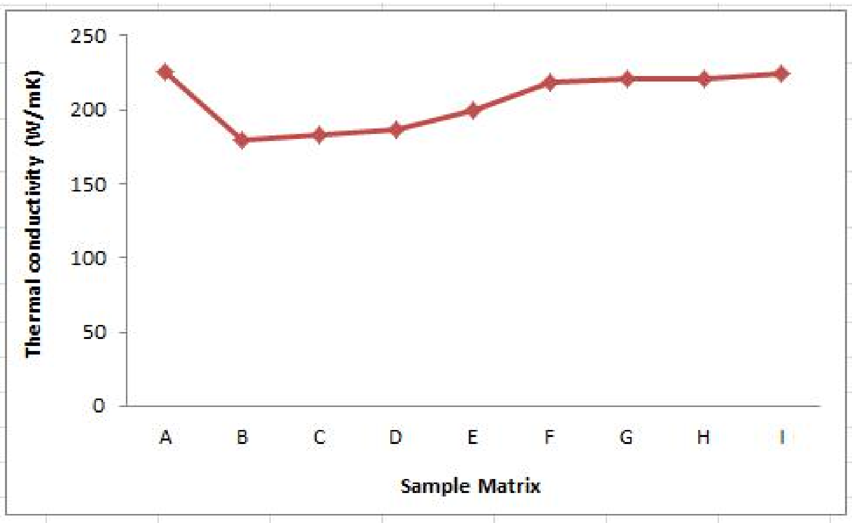

Figure 3: Thermal conductivity of heat sink from aluminium silicon carbide

4. Conclusions

The development of heat sink from aluminium silicon carbide for electrical and electronic applications after proper production was examined. The result from the produced samples is promising in using them for heat sinks applications. These are certain because the main properties of traditional heat sink materials have similar results from the produced samples. It was seen that the effect of aluminium silicon carbide gave substantial improvement toward the standard quality of produced heat sink. A lower thermal conductivity of 180 W/mK was obtained in sample B with a slightly lower conductivity of 2.5 s/m.e^7 improvement of over the control samples. In conclusion, the use of aluminium silicon carbide is crucial for application in electrical and electronic equipment.

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