UNIVERSITI TEKNOLOGI MARA

DEVELOPMENT OF POROUS COPPER BY POWDER COMPACTION

SITI ATHIRAH RASID

Thesis submitted in fulfilment
of the requirement for the degree of
Master of Science

Faculty of Mechanical Engineering

February 2019

ABSTRACT

The development of porous copper (Cu) as a heat sink has actively been researched in recent years due to some concern related to overheating of devices, particularly originated from alloys, towards lightweight, high surface area and a high performance (Hassani et al. 2012). One of the promising manufacturing techniques in producing porous structure is Powder Metallurgy (PM) incorporated with space holder material (SHM). In this study, to obtain porous Cu, three types of SHM which are potassium carbonate (K_2CO_3); 355-500 µm, natrium chloride (NaCl); 200-300 µm and polymethylmethacrylate (PMMA); 450 µm-1 mm were used together with Cu powder. The usage of SHM is to help in obtaining the required pore size and was used with the composition of 50:50%, 40:60% and 30:70% of volume fraction. The impact of volume fraction of SHM were investigated. The mixtures of Cu powder with different SHM were compacted into a green part with pressure of 2 tonne and 60 seconds holding time. The process continues with sintering in high vacuum tube with different temperature depending on the SHM that was used. After the sintering process, subsequent dissolution process is carried out to remove the SHM with distilled water in between 40 ^{o}C- 60 ^{o}C. Lastly, the samples were tested by using Heat Conduction Apparatus to obtain the result of thermal conductivity. The result shows that thermal conductivity of the sample is decreased as the volume fraction of SHM is increased. The microstructure of porous Cu was evaluated via SEM. It was observed that K_2CO_3 as a SHM worked successfully on porous Cu where pore structure developed exhibited open and highly inter-connected rather than NaCl and PMMA as a SHM. The results of the study show that porosity and pore size in the porous Cu give an effect on the performance of thermal conductivity results and successfully improve the problem of overheating at the junction of semiconductor. Other than that, for SHM of K_2CO_3, three different sizes of particles were used; 355 µm, 355-500 µm and 500 µm. From the study, the observations are the heat flow of the samples increases while the thermal conductivity of the samples decreases with increasing of porosity. In conclusion, it is possible to produce porous Cu through PM technique, with the recommendation of using 50% volume fraction of SHM with particle range size of 355 µm.

ACKNOWLEGEMENTS

In the name of Allah, the most Gracious, the Most Merciful

All praises and thank to Allah

Alhamdulillah I am very grateful to Allah for providing me the blessings and faith throughout my life. I am very pleased to thank all those who have made this work possible. This dissertation has been performed under the guidance and supervision of my advisor, Dr. Muhammad Hussain Ismail who was not only my academic advisor, but also he is my counsellor and my second supervisor, Associate Prof. Dr. Aidah bt Jumahat.

To my collaborators at Sirim Amrec Berhad, my experimental results could not have been accomplished without the help of all staffs in Structural Material Programme, AMREC, SIRIM Berhad especially towards Encik Mazlan Mohammad, Encik Bakri and Encik Zahid. I express my utmost gratitude for collaborating on this research and for all the materials and machines support provided. This dissertation would not have been possible without their willingness to work with me. I am thankful for all their sincere help and advice.

I would like to share my happiness at this moment with my husband, Muhammad Afiq Mokhtar who taught me how to overcome obstacles, to fight against the circumstances, to be generous and to always keep a positive mind. Without his unconditional love, it would not have been possible for me to complete this dissertation. Finally, I would like to express heartfelt gratitude and love to my father, Tuan Haji Rasid Daud, my mother, and my sisters, Amirah, Norawaida and Farhana and friends for their love, encouragement and support. Alhamdulillah.

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Background

The development of copper (Cu) heat sink in thermal management applications (TMA) has been actively researched in recent years due to significant concern related to overheating of devices, particularly those made from aluminium (Al) based alloys. The overheating issue leads to problems such as reducing the efficiency of overall system performance and leading to failure of devices to function properly. It has been estimated that 55% failure in most electronics power devices are due to thermal effects (Ling et al. 2014).

Continuous and rapid development of electronic devices today have partly improved the problems, but the improvement has not met the desired industrial requirements of heat sink and heat spread out. It is observed that technology has been driven to focus on the development of lightweight material in terms of strength and weight while improving heat transfer. All issues related to thermal management application are optimised simultaneously which is also known as tackling the diversity issues of thermal management applications. Generally, thermal properties of thermal management application can be categorized according to heat transfer mechanisms, flow arrangement, surface compactness, heat dissipation, and transfer process (Terry 2005).

In the industry so far, two approaches have been implemented to address the TMA problems where both approaches emphasize on addressing the heat sink by considering the materials used and the structure. It is noticed that, honeycomb structure has been recommended due to the advantages of its light weight and simple assembly, and also it introduces cost reduction. Another approach is by creating highly interconnected and open porous structure in the TMA. In such a way, large surface area for heat transfer is created and eventually improving the overall system performance. One of the main concerns in creating a good lightweight component is the optimum processing technique that could produce homogenous and controllable porous structure. Several manufacturing routes have been investigated in producing porous structure ranging from metal casting incorporated with injection gas, powder metalling with