Available online at www.sciencedirect.com

ScienceDirect

Procedia Chemistry 19 (2016) 546 – 551

Procedia Chemistry

5th International Conference on Recent Advances in Materials, Minerals and Environment (RAMM) & 2nd International Postgraduate Conference on Materials, Mineral and Polymer (MAMIP), 4-6 August 2015

Effect of Sintering Cycle on Physical and Mechanical Properties of Open Pore Cell Copper Foam

A.A. Mahaidin[a,*], N. Abdullah[a], M. Mohammad[a], M.A. Omar[a], M.J. Suleiman[a], N.M. Zainon[a], M.A.N. Hadi[a], M.N. Abd Jalil[a], A.Z. Omar[a] and M.B. Mohd Hijazi[a]

[a]*Advanced Materials Research Centre (AMREC), SIRIM Berhad,*
Lot 34, Jalan Hi-Tech 2/3, Kulim Hi-Tech Park,
09000, Kulim, Kedah

Abstract

Poor thermal management leads to high LED junction temperature and give negative impacts to its life and performance. High temperature of LED junction has proven to produce less light and accelerate chip degeneration. Open pore cell copper foam provide good solution to the poor thermal management problem since it has higher surface area, thus increase surface emissivity and enhance thermal conductivity. In this study, copper foams were fabricated using metal injection moulding using potassium carbonate as space holder. The effect of sintering cycle on physical and mechanical properties were studied using two different sintering cycle which are 450-850°C and 450-850-950°C. It is found that sintered copper foams using 450°C-850-950°C sintering cycle has better mechanical properties in term of hardness and transverse rupture strength. It also exhibited higher porosity which is up to 33.9% compared to 33.1%, thus has higher surface area. This is proven by higher thermal conductivity exhibit by the specimen sintered using 450°C-850-950°C.

Peer-review under responsibility of School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia

Keywords: Copper foam; open pore cell; sintering-dissolution; potassium carbonate

1. Introduction

Light emitting diodes (LEDs) has become one of the main focus areas for general illumination in lighting industry due to its energy efficiency and long lasting light sources. Although LEDs commonly advertised to last between 50,000 to 100,000 hours, its life could be reduce to only few thousand hours when using in fixtures due to poor thermal management[1]. It is a major problem since poor thermal management will leads to high junction temperature which negatively affects the performance of the LED. Elevated junction temperatures have proven to

Peer-review under responsibility of School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia
doi:10.1016/j.proche.2016.03.051

cause an LED to produce less light (lumen output), less forward voltage and significantly accelerate chip degeneration by as much as 75% with an increase from about 100-135°C during regular use[2]. For regular LED fixtures using passive cooling, heat generated LED junction is conducted through heat sink and then dissipated to surrounding by natural convection and radiation. In general, aluminium is widely used as LED heat sink. Wrought copper, Cu is an alternative material to replace aluminium since it has higher thermal conductivity hence effectively dissipated heat better. However, the disadvantage of using wrought copper is that it has higher density than aluminium. Therefore, lightweight copper is needed for LED application. This problem can be solves using foaming technique.

Metallic foams or cellular materials are unique materials with controlled pore structure. Metallic foams have excellent physical and mechanical properties as well as thermal, acoustic, electric and impact absorbance properties[3,4]. It is a porous metal with high strength to weight ratio with good foam mechanical energy absorption during compression contributed by the ductility of copper[5,6]. It also offers several interesting features such as low density, high stiffness, high gas permeability and high thermal conductivity. Cu foam has attracted extensive research because of its great market potential in various fields such as catalyst, chemical engineering, energy and environmental protection. The excellent thermal and electrical conductivities of the copper foam are ideally suited for wide range of application such as heat exchanger and catalyst support.

Cu foam conventionally made by investment casting and powder metallurgy but these processes cannot produce near net shape product. For powder metallurgy process, space holder is used to produce open and close cell metal foam made by any sinterable materials. Lost carbonates sintering (LCS) process is one of the solid route technologies to produce open cell porous metals with controlled pore structures. LCS is a simple, low cost process and enables control over pore size and porosity. Porous metal parts are obtained by removing the carbonate particles from the sintered compact either by decomposition or dissolution. Sintering-dissolution process (SDP) is used when there are two phase precursors with one phase is water soluble. Manufacturing of Cu foam using powder metallurgy and dissolution process is considered as part of the development of eco-materials.

Other than limitation in producing near net shape product, another disadvantages of powder metallurgy is that the pore size and its distribution does not affect much on the mechanical properties due to the anisotropic nature of the foam produced by conventional powder metallurgy. This is because space holder particles were rearranged during compaction process leading to non-homogeneous distribution of Cu particles across the thickness[5]. Metal injection moulding (MIM) is one of powder metallurgy process used to produce complicated and near net shape parts. MIM combines the advantages of plastic injection moulding and versatility of conventional powder metallurgy process. MIM enable complex parts to be easily formed to form near net shape product. It is process with high design freedom and tolerance without the needs of secondary machining. For MIM process, polymer binder is added into the metal powder particles as the vehicle of flowability during the injection of green body prior to sintering. The binder is removed by debinding process.

In this study, open pore cell Cu foam is produced using MIM technique and SDP process to obtain the final specimen. Since SDP process was used, addition of carbonates is necessary to act as space holder for pore preform. Space holder selection is critical to ensure the formation of open cell and interconnected pores. NaCl is common salt/carbonate meanwhile Na_2CO_3 is an alternative to increase the interconnectivity of the pores. However, these carbonate especially Na_2CO_3, laminations were observed and lose its integrity after dissolution process[7]. As replacement for NaCl and Na_2CO_3, potassium carbonates (K_2CO_3) is suitable carbonates used as space holder as reported in several literature[3,4,5,8]. It is because K_2CO_3 has melting point above the normal sintering temperature of copper and soluble in water. Thus, uniform and homogeneous open cell can be achieved.