学校编码：10384　　　　分类号______密级______
学　　号：20720131150103　　　　UDC______

厦门大学

硕　士　学　位　论　文

先驱体法制备自支撑硅氧碳复合薄膜散热基板及其改性与 LED 封装应用

Fabrication and Doping of Freestanding Si-O-C Composite Films by Precursor Method and Their Application in LED Devices Packaging

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论文提交日期：　2016 年 4 月
论文答辩日期：　2016 年 5 月
学位授予日期：　2016 年　月

答辩委员会主席：__________
评　　阅　　人：__________

2016 年 5 月

Fabrication and Doping of Freestanding Si-O-C Composite Films by Precursor Method and Their Application in LED Devices Packaging

A Dissertation Submitted to the Graduate School in Partial Fulfillment of the Requirement for the degree of Master Engineering

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May, 2016

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摘 要

LED 作为第四代光源，因其尺寸小、响应快、亮度高、节能环保等诸多优点展现出较广阔的应用前景。LED 向着高功率、高密度封装的方向发展，散热问题至关重要，散热效果差导致芯片结温过高、荧光粉量子产率降低、发光波长偏移及器件老化等问题。大功率 LED 散热主要集中在封装材料的研究、热界面材料的选择、封装结构的合理设计及冷却系统的优化等方面。而散热基板作为其重要封装材料，要求具有高绝缘性、高导热性、高平整性以及与芯片衬底匹配的热膨胀系数等特性。因此，本文主要针对封装材料中的高热导散热基板材料进行研究，主要工作如下：

首先，先驱体聚碳硅烷（PCS）经熔融纺膜、氧化交联、高温预烧、高温烧结工艺制得自支撑硅氧碳复合薄膜。该薄膜结构为微量 β-SiC 晶粒分散于无定形 SiO_xC_y 相和游离碳构成的基体中，其表面可生长热氧化层且具有致密度高、自支撑、热导率高、绝缘性好、与芯片衬底间无热膨胀与晶格失配问题等优点。因此，该薄膜较为适合用于大功率 LED 器件散热基板封装。

其次，采用丝网印刷工艺在自支撑硅氧碳复合薄膜表面设计高温银浆电极，通过 Chip On Board（COB）封装方式进行大功率 LED 器件封装，并测试其结温和热阻。研究结果表明以该复合薄膜基板封装的 LED 器件具有较低热阻和结温，对大功率器件散热能力的提高具有一定实际应用价值。

此外，借鉴先驱体法制备含异质元素 SiC 纤维提高热导率与热稳定性的经验，使用 Ti 和 B 元素对 PCS 进行掺杂改性，经熔融纺膜、氧化交联、高温预烧、高温烧结制得自支撑 SiC(Ti, B)陶瓷薄膜，并对其微结构及性能进行初探。研究结果表明，Ti 和 B 元素在薄膜中以 TiB_2 相的形式存在起烧结助剂和晶粒长大抑制剂的作用，促使高温烧结的自支撑 SiC(Ti, B)陶瓷薄膜具有较少缺陷和较小晶粒尺寸，防止粉化并保持着致密均匀结构及良好热稳定性。

关键词：大功率 LED；散热基板；复合薄膜；掺杂改性

Abstract

Light Emitting Diode (LED) as the fourth generation light source has presented several advantages over traditional light sources such as small size, fast response, high-brightness, long lifetime, energy-saving and environment-friendly. LED is also explored as one of the most outstanding solid-state light device and attracts more focuses and studies. Nowadays the power and package density of LED are tending to higher, so its heat dissipation is becoming more important. Much heat will cause serious defects on LED devices such as drift of light-emitting wavelength, decrease of fluorescence quantum yield, reduction of luminous efficiency and failure of devices. Studies related to the heat dissipation of high power LED devices covered many aspects including the improve of high thermal conductivity packaging materials, the reasonable design of packaging structure, the choice of thermal interface materials, and the optimizing of cooling systems. Heat dissipation substrates as crucial packaging materials should have high resistivity, high thermal conductivity, high smoothness and coefficient of thermal conductivity close to chip. Studies of this paper are aimed to prepare a kind of high thermal conductivity heat dissipation substrate materials, the main works are presented as follow:

First of all, freestanding Si-O-C composite films were prepared by melt spinning the polycarbosilane (PCS) precursors. The whole procedure includes melt spinning, oxidation crosslinking, high temperature presintering and high temperature sintering. Microtructure of the composite films is β-SiC nanocrystals dispersed in the matrix of amorphous SiO_xC_y and free carbon. Thermal oxidation layer can grow on the surface of freestanding composite films with high density, high thermal conductivity and high resistivity. There are no serious lattice and thermal expansion mismatches between the composite films and chips. Thus, the freestanding Si-O-C composite films can be used as the heat dissipation substrates of high power LED devices properly.

Secondly, after screen printing high temperature silver paste electrode on the surface of freestanding Si-O-C composite films, high power LED devices with the

film substrates were packaged by the technology of chip on board. The received LED devices' junction temperature and thermal resistivity were tested. Results reveal that the high power LED devices packaged with freestanding Si-O-C composite film substrates have low junction temperature and small thermal resistivity, which suits for the application in the enhancement of high power LED devices' heat dissipation capability.

In addition, according to the experience of SiC fibers doped with heterogeneous elements to enhance their thermal conductivity and stability, a series of freestanding SiC(Ti, B) ceramic films were prepared by melt spinning the PCS precursors with B and Ti elements, The whole procedure also includes melt spinning, oxidation crosslinking, high temperature presintering and high temperature sintering. Microstructures and properties of freestanding SiC(Ti, B) ceramic films were studied.Results indicate that Ti and B elements exist in the ceramic films in the form of TiB_2 crystals and play both the roles of sintering aid and grain grow inhibitor during the high temperature pyrolysis sintering. They protect the freestanding SiC(Ti, B) ceramic films with good thermal stablility, little defects, small grain size, dense and homogeneouss structure from pulverization.

Key Words: High power LED devices; Heat dissipation substrate; Composite films; Dope

主要创新与贡献

本文针对当前大功率 LED 所存在的散热能力急待提高的问题，采用先驱体熔融纺膜法制得自支撑硅氧碳复合薄膜陶瓷基板，将其用于大功率 LED 封装，并借鉴先驱体法制备含异质元素 SiC 纤维提高热导率与热稳定性的经验，使用 Ti 和 B 元素对 PCS 进行掺杂改性，经熔融纺膜、氧化交联、高温预烧、高温烧结制得自支撑 SiC(Ti, B)陶瓷薄膜。本文主要创新性如下：

1. 采用先驱体熔融纺膜法制得自支撑硅氧碳复合薄膜陶瓷基板，对其结构及导热性能进行研究，该薄膜具有致密度高、热导率高、绝缘性好、表面可生长热氧化层等优点，结合丝网印刷工艺在其表面制作高温银电极后形成散热基板，并进行功率型 LED 器件的 COB 封装应用，为大功率 LED 的散热问题提出了一种新的解决方案。

2. 使用 Ti 和 B 元素对 PCS 进行掺杂改性，制得自支撑 SiC(Ti, B)陶瓷薄膜。阐明了氧化交联对自支撑 SiC(Ti, B)陶瓷薄膜的形成和性能的影响机制，并获得 B、Ti 元素在自支撑 SiC(Ti, B)陶瓷薄膜中的存在形式，即 Ti 和 B 元素在薄膜中以 TiB_2 相的形式存在并同时发挥着烧结助剂和晶粒长大抑制剂的作用，促使高温烧结的自支撑 SiC(Ti, B)陶瓷薄膜具有较少缺陷和较小晶粒尺寸，防止薄膜粉化并保持着致密均匀的结构及良好的热稳定性。

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