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Review

Silver nanopaste: Synthesis, reinforcements and application

Ping Zhang *, Xiong Jiang, Peng Yuan, Haidong Yan, Daoguo Yang

School of Mechanical and Electrical Engineering, Guilin University of Electronic Technology, No. 1 Jinji Road, Guilin, Guangxi 541004, China

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A B S T R A C T

To meet the requirement of bonding power chips in microelectronic packaging, low temperature sintering silver (Ag) nanopaste appears to be the most interesting choice in several new attachment technologies. This opportunity is mainly attributed to its high electrical and thermal conductivities of the sintered joint, and its low elastic modulus and process temperature. Over the past decade, in order to improve the mechanical properties, electrical conductivity and thermal conductivity of sintered Ag nanopaste, the formulas for preparing Ag nanopaste were improved, and other materials also have been added into it to make a reinforced matrix. In this review, the material characteristics of Ag nanopaste under low temperature sintering are elucidated, including the progress in the synthesis of Ag nanoparticles, the preparation methods of Ag nanopaste and bonding performance of low temperature sintered Ag nanopaste. The effects of adding different types of reinforcing groups into Ag paste on the bonding properties of sintered Ag joints are discussed, such as carbon reinforced matrix, metal reinforced matrix and other reinforced materials. The recent applications of low temperature sintered Ag joints in power chips are summarized. In addition, the feasibility of preparing Ag nanopaste while adding additional enhancers will be discussed at the end of the paper.

Contents

* Corresponding author.
E-mail address: pingzhang@guet.edu.cn (P. Zhang).

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1. Introduction

Over the past decade, lead-free solder alloys have been widely used for die-attach material interconnections, which serves to attach a semiconductor die onto a substrate. The wide use of lead-free solder alloys is mainly due to the low cost and acceptable electrical conductivity [0.01–0.71 × 10^5(Ω cm)] and thermal conductivity [1–66 W/m K] [1]. However, with the rapid development of silicon carbide (SiC) and gallium nitride (GaN) devices, which have replaced Si technology, the devices could be operated at temperatures that exceeding 500 °C. These changes limit the applications of lead-free solder alloys because they can melt at an operating temperature below 315 °C, which could form a crack at the intermetallic layer between the solder and the metallized substrate [2,3]. In recent years, Ag nanopaste has become the most interesting choice for a new type of lead-free interconnection materials, which is because Ag nanopaste can be sintered at temperatures of 280–400 °C without the need for applying any pressure [4], and it can work at a higher temperature than the sintering temperature with enhanced bond strength. Moreover, Ag has a higher tensile strength (170 MPa) and Young's modulus (74 GPa) than other materials, which can prevent the mechanical properties of Ag nanopaste chip-attach materials from deteriorating in harsh environments. Based on these excellent mechanical properties, Ag nanopaste with higher bonding strength is expected to improve the reliability of die attach processing. In addition, the nanopaste does not undergo liquid-state transformation while sintering the Ag joint because die-shifting issues with porous structure do not occur, and it shows excellent electrical and thermal conductivity (approximately 2.6 × 10^5 Ω cm and 200 W/m K) [5], which are higher than other die attach materials. These are beneficial to providing superior electrical and structural connections as well as heat dissipation within the packaging. For example, sintered Ag nanopaste has been used to join insulated gate bipolar transistor (IGBT) assembly with high thermo-mechanical reliability [6,7]. Moreover, there has been a large number of studies on improving the sintered properties of Ag nanopaste in recent years, which is beneficial to solving the problem of the sintering density. The preparation methods and sintering processing of Ag nanopaste is shown in Fig. 1(a). It can be easily seen that the synthetic formula and sintering process affect the quality and sintering properties of Ag nanopaste, which is related to the application of sintered nanopaste. Therefore, this review mainly discusses on improving the performance of Ag nanopaste though adding reinforced materials.

Ag nanopaste was first to synthesized by Bai et al. in 2005, it has excellent sintering properties and bonding ability compared with traditional solder material [8]. To overcome the limitations of Ag

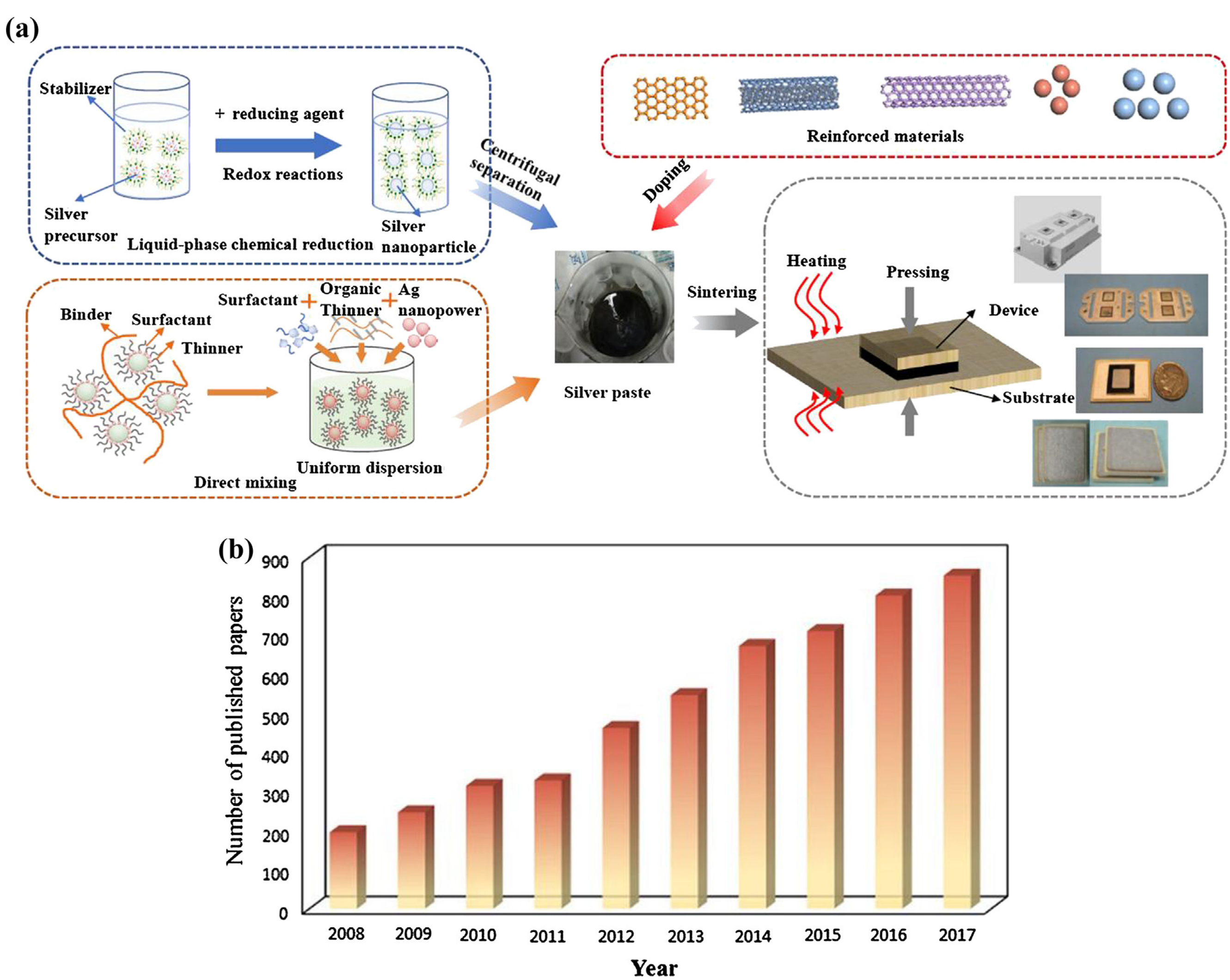

Fig. 1. (a) The formulation and processing of nano-Ag paste. (b) The number of paper published for the last decade using the keywords "the formulation and application of nano-Ag paste" as search using Google Scholar (until 31 December).