CARBON BLACK FOR THERMAL AND ELECTRICAL CONTACTS

Chia-Ken Leong and D.D.L. Chung
Composite Materials Research Laboratory
University at Buffalo
State University of New York
Buffalo, NY 14260-4400, U.S.A.

Introduction

Thermal contacts, as that between a heat sink and a microprocessor, are critical to heat dissipation from microelectronics. Electrical contacts are central to electrical interconnections in electronic packaging. Both types of contacts may be improved by the use of an interface material applied between the mating surfaces. The interface material must conform to the topography of the mating surfaces, in addition to being very thin (just thick enough to fill the valleys in the topography of the mating surfaces). Furthermore, thermal or electrical conductivity of the interface material helps. This paper is focused on the development of interface materials in the form of pastes. By the use of compressible particular agglomerates, namely carbon black, highly conformable and spreadable pastes have been developed. The carbon black pastes provide even higher thermal contact conductance than solder or commercial thermal pastes containing silver or ceramic particles, and even lower electrical contact resistivity than commercially available silver paint.

Thermal contact improvement

With the miniaturization and increasing power of microelectronics, heat dissipation has become critical to the performance, reliability and further miniaturization of microelectronics. Heat sinks, which are made of materials of high thermal conductivity, are commonly used for heat dissipation from microelectronics. In order for the heat sink to be well utilized, the thermal contact between the heat sink and the heat source should be sufficiently good [1,2]. A thermal fluid or paste is commonly applied at the interface to enhance the thermal contact [3]. The fluid or paste is a material that has high conformability so that it can conform to the surface topography of the mating surfaces, thereby avoiding air gaps (which are thermally insulating) at the interface. The fluid or paste must also be highly spreadable, so that the thickness of the paste after application is small.

By using carbon black (30 nm particle size) as the solid component, thermal pastes that surpass tin-lead-antimony solder and commercial thermal pastes (with submicron silver or ceramic particles) in the effectiveness as a thermal interface material have been attained, as evaluated by measuring the thermal contact conductance across copper mating surfaces [4]. The thermal contact conductance reaches 30 x 10^4 W/m^2.°C for carbon black pastes, but is only 20 x 10^4 W/m^2.°C for solder and is only up to 21 x 10^4 W/m^2.°C for commercial thermal pastes containing submicron silver and/or ceramic particles. The thermal paste has thickness less than 25 μm. Graphite particles, diamond particles, nickel particles, carbon nanofiber and single-walled carbon nanotubes are all less effective than carbon black. The high effectiveness of carbon black is attributed to its compressibility, which was also measured in this work. Compressibility results in high conformability and spreadability. Conformability and spreadability are even more important than thermal conductivity in governing the performance of a thermal paste. Polyethylene glycol (PEG) and butyl ether, both containing dissolved ethyl cellulose for helping solid particle dispersion and suspension, are effective vehicles for the thermal pastes. The PEG-based pastes are better for use above 100°C, due to superior thermal stability.

Electrical contact improvement

Electrical contacts are needed for electrical interconnections in electronics. They can be in the form of pressure contacts (i.e., contacts made by the use of pressure to hold the mating surfaces together) and pressureless contacts, which are made without pressure by the use of an electrically conductive joining medium, such as solder, silver epoxy and silver paint. A particularly common form of pressure contact involves the use of clips to provide the pressure. The advantage of a pressure contact lies on the ease of disconnection and reconnection, as needed during the use of the electronics. In fact a pressure contact is referred to as a separable interconnect [5]. In contrast, disconnection is not convenient for non-pressure contacts, as it may require heating or the application of a considerable mechanical force.

Pressure and pressureless electrical contacts were comparatively evaluated by measuring the contact electrical resistivity between copper mating surfaces using the carbon black pastes described above. Pressure electrical contacts with contact resistivity 2 x 10^{-5} Ω.cm^2 have been attained [6]. In contrast, a pressureless contact with silver paint as the interface materials exhibits a higher resistivity of 3 x 10^{-5} Ω.cm^2 or above. A pressureless contact with colloidal graphite as the interface material exhibits the same high contact resistivity (1 x 10^4 Ω.cm^2) as a pressure contact without any interface material. However, pressureless contacts involving solder exhibit lower contact resistivity than carbon black pressure contacts.

References

[1] Wolff EG, Schneider DA. Prediction of thermal contact resistance between polished surfaces. Int J Heat & Mass Transfer 1998;41(22):3469-3482.

[2] Ouellette T, de Sorgo M. Thermal Performance of heat transfer interface materials. Proc. Power Electronics Design Conf., Power Sources Users Conf., Cerritos, CA 1985:134-138.
[3] Vogel MR. Thermal performance for a miniature heat sink cooled by microPCM slurry. Proc. Int. Intersociety Electronic Packaging Conf., Adv. in Electronic Packaging, American Society of Mechanical Engineers, New York, NY 1995;10-2:989.
[4] Leong C-K, Chung DDL. Carbon black dispersions as thermal pastes that surpass solder in providing high thermal contact conductance. Carbon 2003;41(13):2459-2469.
[5] Kshonze K, Syrett BA, Khalil R. 23rd Annual Connector and Interconnection Technology Symposiu 1990;191-198.
[6] Leong C-K, Chung DDL. Pressure electrical contact improved by carbon black paste. J Electron Mater 2004;33-3:203-206.