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Thermal and gas flow characterization of a fluxless Si solder bonding oven

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ABSTRACT

In this paper the technology of the "Linn" type Si fluxless solder bonding oven and the thermal and gas flow characterization of the oven are discussed. This oven is used for fixing silicon chips on metal substrates with high temperature solder bonding process. The solder is applied in a foil form which is placed between the Si chip and the metal substrate. This does not contain any flux, therefore a reducing agent has to be applied to avoid the oxidation of the joints during the soldering process. In this technology the reducing agent is the forming gas which is a mixture of 10 vol.% H_2 and 90 vol.% N_2. The key factors of this soldering process was studied; the suitable temperature (350–370 °C for 13–15 min) and the adequate H_2 concentration (8–10 vol.%). A detailed 3D gas flow model of the Linn oven was prepared which is based on the finite volume model (FVM) method. The gas flow circumstances using the basic and a hypothetic oven setting were compared by simulations applied the ANSYS–FLUENT system. The gas flow model was verified by the measurements of the temperature, the H_2 concentration and the pressure inside the oven. Furthermore the heating ability of the oven under full load was characterized by the change of the heating temperature and the time coefficient of the heating.

1. Introduction

Various bonding methods were reported for silicon die bonding applications, such as anodic bonding, direct bonding, and intermediate layer bonding which includes glass-frit bonding, thermocompression bonding, eutectic bonding, solder bonding, and adhesive bonding [1–5]. For all of the mentioned bonding methods elevated temperatures are required for bonding silicon wafers, except for the room temperature adhesive bonding with the use of organic and inorganic conductive compositions [6,7] which possesses low bonding strength and nonhermeticity.

From the above discussed die bonding technologies this paper deals with the special field of die soldering when the soldering is fluxless and carried out between 300 and 400 °C. The originality of the die soldering is the simplicity of this technology since the process temperature is relatively lower than in case of the other mentioned bonding methods and vacuum, high voltage or high pressure is not needed. In addition the reliability and quality of this type of joints [8,9] are very high. Usually the applied solder alloys are AuGe, NiAu and SnPb [10,11]. Due to the directive of lead-free soldering in the EU and the temperature sensitive applications the solder bonding with lower process temperature is a strongly researched field, the applied solder alloys are AuSn and SnAg between 250 and 300 °C [12–15]. In addition alloys with extremely low melting temperature (under 250 °C) are investigated such as SnBiAu, InAg and InSn [16–18].

The aim of this research was the thermal and gas flow characterization of the "Linn" type fluxless solder bonding oven [19] which operates between 300 and 400 °C. The oven is used for fixing Si and SiC dies on metal substrates. During the investigations 96Pb/4Sn solder alloy was used at 365 °C. The solder is placed between the Si die and the metal substrate in a foil form before the soldering process. The soldering foil does not contain any flux, therefore a reducing agent has to be applied to avoid the oxidation of the joints during the process. In this case the reducing agent is the forming gas [20] which is a mixture of 10 vol.% H_2 and 90 vol.% N_2. It is sometimes called a "dissociated ammonia atmosphere" due to the reaction which generates it:

$$2NH_3 \rightarrow 3H_2 + N_2 \quad (1)$$

Forming gas is used as an atmosphere for processes that need the properties of hydrogen gas without the explosion hazard. The forming gas is also widely used in silicon and thin film technology for passivation [21,22].

The process area of the oven is 8 m long, 0.24 m wide and 0.08 m high. The main parts of the oven are the following (Fig. 1): (1) entrance trapdoor; (2) entrance vent hood; (3) entrance gas blocks; (4) entrance dilute N_2 intake; (5) heater zone; (6) forming gas intake; (7) cooling zone; (8) cooling N_2 intake; (9) exit dilute N_2 intake; (10) exit vent hood; (11) exit gas blocks; (12) exit trapdoor. The vent hoods contain funnels with 80 mm diameter

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