Journal of ELECTRONIC MATERIALS, Vol. 42, No. 3, 2013
DOI: 10.1007/s11664-012-2354-5

Effects of Solvents in the Polyethylene Glycol Series on the Bonding of Copper Joints Using Ag_2O Paste

SHINYA TAKATA,[1,3] TOMO OGURA,[1] EIICHI IDE,[2] TOSHIAKI MORITA,[2] and AKIO HIROSE[1]

1.—Division of Materials and Manufacturing Science, Graduate School of Osaka University, 2-1 Yamadaoka, Suita 565-0871, Japan. 2.—Hitachi Research Laboratory, Hitachi Ltd., 7-1-1 Omika, Hitachi 319-1292, Japan. 3.—e-mail: s-takata@mapse.eng.osaka-u.ac.jp

The effects of reducing solvents on the bonding process using silver oxide paste in a copper joint were investigated. Three solvent types were tested: diethylene glycol (DEG), triethylene glycol (TEG), and polyethylene glycol (PEG). The strength of the joints was assessed by fracturing, which occurred at the interface of the copper oxide layer and the copper substrate in DEG and TEG samples and at the bonded interface in the PEG sample. Analysis of the samples revealed that, in the DEG and TEG samples, the copper substrate was oxidized during the bonding process, which compromised the shear strength of the joints. In contrast, the PEG sample exhibited nonuniform sintering of the silver layer while retaining good shear strength. It was found that the combination of DEG and PEG produced optimum shear strength in the copper joint, as PEG suppressed the growth of copper oxide and DEG promoted the formation of a dense sintered silver layer. The bonding strength achieved was higher than that of the gold-to-gold joint made using standard Pb-5Sn solder.

Key words: Ag nanoparticles, Ag oxide, reducing solvent, shear strength, Cu joint

INTRODUCTION

Public concern regarding the environmental impact of heavy metals has grown significantly in recent decades. In 2006, the Restriction of Hazardous Substances (RoHS) directive came into effect, regulating the use of detrimental substances including heavy metals (Pb, Hg, Cd, etc.) commonly used to manufacture electronic products.[1] As a result, the electronics industry has developed lead-free solder for joining together metal components, such as Sn-80Au.[2–5] However, the use of a noble metal makes this solder rather costly, and alternatives to Pb-5Sn and Pb-10Sn high-temperature solders have not yet been established.

Simultaneously, improvement of energy efficiency has become a top priority, and much attention is focused on developing semiconductor devices for power conversion in hybrid cars and bullet trains as a strategy for reducing energy usage. Silicon carbide (SiC) has emerged as an attractive power device material, as it possesses the characteristics of low loss, high withstand voltage, and high heat resistance, which permit the reduction of the volume of the semiconductor without decreasing the power. It is expected to be widely applied in hybrid and battery-powered cars because of its excellent performance at high temperatures.[6–8] Unfortunately, at operating temperatures over 200°C,[9] solders experience thermal degradation and remelting causes deterioration in strength. Therefore, there is a critical demand for new packaging materials that are lead-free and exhibit improved thermal reliability.

To address these issues, we previously proposed a bonding process using silver metallo-organic nanoparticles.[10–13] Each particle is covered with organic

(Received May 15, 2012; accepted November 4, 2012; published online December 11, 2012)