STUDY OF INTERFACIAL REACTION DURING REFLOW SOLDERING OF Sn Sn-Ag-Cu LEAD-FREE SOLDERS ON BARE COPPPER AND IMMERSION SILVER SURFACE FINISHES

NURFAZLIN BINTI ABU HASSAN

UNIVERSITI TEKNOLOGI MALAYSIA

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ABSTRACT

Due to increasing environmental and health concerns related to the toxicity of traditional tin-lead solders, lead-free solders appear as promising replacement for the eutectic solder alloy in flip chip technology. Then a surface finish is designed to protect the copper surface against oxidation as well as provide a diffusion barrier against rapid diffusion between the liquid tin in the solder alloy and copper. In this research, an investigation has been carried out to investigate the effect of multiple reflow and solder bump size during soldering between three types of lead-free solders which are Sn-3.0Ag-0.5Cu, Sn-3.8Ag-0.7Cu and Sn-4.0Ag-0.5Cu on Copper and Immersion Silver (ImAg) surface finishes. Two different solder ball sizes were used; 200 μm and 700μm, and the solder joints were subjected to three reflows at the same temperature. The IMC's formed were characterized in terms of thickness, morphology and composition. From the research findings, it was observed that solder bump size, which also relates to solder volume, has a significant effect on the formation of intermetallics thickness in the solder joint. The mean thickness of the intermetallics for smaller solder balls was found to be thicker than the bigger solder balls. ImAg produced thinner IMC's compared to copper surface finish. However, these IMCs grew thicker and changed their morphologies when exposed to multiple reflow, but the compositions were more or less the same. For the Cu surface finish, Cu_6Sn_5 intermetallic compounds with scallop morphology are formed at the solder/ surface finish interface.

ABSTRAK

Berkaitan peningkatan isu-isu alam sekitar dan masalah kesihatan berhubung pada toksik semulajadi dari pateri plumbum , aloi pateri tanpa plumbum, iaitu Sn-4Ag-0.5Cu telah wujud sebagai salah satu calon terunggul untuk menggantikan aloi eutektik Sn-Pb dalam teknologi penyambungan *flip chip*. Kemudian kemasan permukaan diperlukan untuk melindungi permukaan kuprum daripada pengoksidaan dan ia juga membentuk lapisan penghalang dari resapan mengejut antara atom-atom timah dalam logam pemateri dengan kuprum. Dalam projek ini, kajian dijalankan untuk memeriksa kesan *reflow* berganda dan saiz bebola pateri semasa pematerian antara tiga jenis aloi pateri tanpa plumbum; Sn-3.0Ag-0.5Cu, Sn-3.8Ag-0.7Cu dan Sn-4Ag-0.5Cu dengan kemasan permukaan Cu dan rendaman *silve* (ImAg).Dua jenis saiz bebola pateri digunakan iaitu 200 µm dan700µm, dan sambungan pematerian ini dilakukan reflow sebanyak tiga kali pada suhu yang sama. Sebatian antara logam yang terbentuk dikaji dari segi ketebalan, morfologi dan komposisi. Daripada kajian, didapati saiz babola pateri banyak mempengaruhi pembentukan IMC. Ketebalan purata IMC untuk bebola pateri bersaiz kecil didapati lebih tebal berbanding bebola pateri bersaiz besar. Manakala kemasan permukaan memperlahankan kadar tindak balas antara logam pateri dan substrat. ImAg menghasilkan IMC yang paling nipis berbanding Cu. Walaubagaimanapun, IMC ini menjadi semakin tebal dan berubah dari segi morfologi apabila didedahkan kepada *reflow* berganda, tetapi komposisinya adalah lebih kurang sama. Untuk Cu, sebatian antara logam yang terbentuk adalah Cu_6Sn_5 dengan bentuk siku keluang (*scallop*) di lapisan antara logam pemateri dengan kemasan permukaan.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In the current industrial world, soldering has become indispensable for the interconnection and packaging of virtually all electronic devices and circuits. The fast changing technology and increasing miniaturization of electronic devices place challenge for obtaining reliable and successful component joints. This is another reason which has pressed the researchers to investigate and develop the novel solder materials to meet the requirements and a goal of the modern day solder interconnects. Almost all the potential lead-free solder materials are high Sn-containing alloys, including the most promising Sn-Ag-Cu (SAC) alloy of eutectic composition.

During the soldering process, the metallization layer of the printed circuit board (PCB) or the component pins react with Sn in the solder to form an intermetallic compound (IMC) layer at the metallization/solder interface. Although the formation of the IMC layer is desirable for good wetting and necessary bonding, an excessively thick layer is detrimental to the health and reliability of solder joints. The problem arises due

to the brittle nature of the IMC which makes it prone to mechanical failure even at low loads. A thicker IMC layer would also increase the heterogeneity in the physical properties of material across the joint. Therefore, the growth rate of the IMC layer and subsequent dissolution of the metallization (substrate) must be under control during soldering.

Thus, reliability issues are usually closely related to the solder joints intermetallic compounds. During reflow soldering, due to the high temperature conditions, a reaction will usually occur between the solders and the surface finish layers which in turn forms layers of intermetallic compounds at the interface of the solder joints. These intermetallic compounds are required for the formation of solder joint. However, excessive thickness of IMCs will embrittle the solder joint due to its hard and brittle properties in nature. Therefore, study and characterization on the IMCs formed are essential in order to achieve a good and reliable solder joint.

1.2 Objectives of the research

The main objectives in this research are as follows:-

The intent of this study is first to examine the effect of multiple reflow on interfacial reactions (IMC) during soldering between Sn-Ag-Cu Solders and Cu and ImAg finishes. The secondary objective is to examine the effect of Cu and Sn contents in SAC solder on the interfacial reactions on Cu and ImAg surface finishes and lastly to investigate the effect of solder bump size (solder volume) on the formation and growth of the intermetallics between the various surface finish and different lead-free solders.

1.3 Scope of Research

Solder joints in the present work are produced by doing multiple reflow until three times numbers of reflow soldering between immersion silver and bare coppers as surface finishes with three types of lead free solders (SAC305, SAC3.807 and SAC405) which having diameter of around 200µm and 700µm. Characterization is done on the IMCs to determine their compositions and morphologies, and the IMC thickness for all specimens is also measured.

1.4 Structure of Thesis

This thesis comprises eight chapters. The first chapter is the introduction. The objectives and scopes of this thesis are also clearly stated in this chapter. Chapter two to five are the literature review. Chapter two is a detailed introduction of electronic packaging. Chapter three discusses the different types of surface finish systems. In chapter four soldering basics, solder alloys, fluxes and soldering techniques are reviewed. Towards the end of literature review in this study is chapter five which is a, intermetallic compound formation at the interface of solder joints. In chapter six, a detailed experimental methodology is presented to give a better idea of how samples and specimens are prepared based on the most recommended procedures. Chapter seven contains the results and discussion obtained from the experimental work. The final chapter, chapter eight, includes a set of conclusions drawn based on the results and discussion conducted and also recommendation for future work.

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