Environment Friendly Pb Free Interconnection Technology for Biomedical Devices

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Abstract – The environmental concerns and pending legislation have driven the action towards hazardous free electronics. Current biomedical investigations and reports reveal the increasing toxic levels caused by human lead exposure. Wider applications of biomedical electronics and on chip micro systems in clinical labs and day to day patient health monitoring demand intense activities to develop Pb free solders and packaging techniques for microelectronic devices. Isothermal solidification based interconnection technique is Pb free and the process steps to fabricate high stable bonding are environment friendly. This paper report the Au –Cu interconnects fabricated and tested in different environments.

Index Terms – Environmental friendly, Pb free technology, Human lead exposure, Isothermal solidification.

1. INTRODUCTION

The electronics is proving its valuable role to biomedical sciences. Use of microelectronic devices and chip level micro-systems is finding wider applications in diagnosis, curing and monitoring of health parameters of patients in day to day care and in hospitals. The successful implementations of electronic-tongue, electronic-nose and biomedical micro sensor systems; the development of lab-on-chip is the next target for microelectronics. Miniaturization is another objective of the scientists to explore the possibility of implantation of the device in human bodies. Reliable and toxic free interconnections on the devices are equally important to the development practice. In biomedical devices a variety of bonding methods and mediums are used to make the interconnection to the substrate and to bond the package to the external circuit.

Isothermal solidification [1-2] based bonding is an environment friendly and Pb free technique to produce high adhesion with an acceptable range of process temperature. The high process temperature during fabrication increases the cost due to greater rate of power consumption. Under this fact the isothermal solidification based interconnection technique is cost effective technique. With thermal and tensile strengths and good electrical conductivity of the bond produced and no use of toxicant gases and glues are the technology under research has scored advantages over other joining techniques. Au-Cu interconnections are fabricated with Indium interlayer. The results for strengths after intermetallic growth are reported in this paper. The reaction progress is analyzed under different parameters and plotted the curves for the same.

2. RELATED WORK

The demand for miniaturization with increased number of inputs and outputs on biomedical devices is challenging the performance of existing interconnection techniques. The Pb containing solders, epoxies and flux are not applicable in these devices due to given below ill effects of Pb on human health and skills;

- Behaviour irresponsive -Attention problems, distractibility and restlessness is commonly observed [3-6].
- Blood circulation system problems [4, 6-8].
- Cognitive development stopped-Intelligence Quotient (I.Q.) levels decrease [4-9].
- Foetal-Miscarriage probability increases, still birth and neonatal death [4, 10-12].
- Pituitary-thyroid endocrine system related problems [4-5].
- Hearing impairment; auditory sensitivity decreased [13].
- Problems in hand-eye coordination.
- Nervous system-Encephalopathy and other brain diseases [4, 8].
- Dizziness is most occurring after human ead exposure.
- Renal (kidneys) - Acute Nephropathy [14].

Beyond these worse effects Pb increases risk of early death from cancer disease [15], this increasing level of Pb in environment not only affects human being but also to the animals and the plants. The improperly disposed off old electronic devices produces lead oxides which contaminate the ground water [16]. These facts, environmental legislations and globally accepted green standards [17-18] indicate that the traditional packaging materials and techniques are found unsuitable for preserving our environment. New materials and packaging techniques with optimized characteristics and process parameters are the pre requisites for the Pb free biomedical electronics.

3. EXPERIMENT

The metals Au and Cu have wider applications in electronics and by studying the binary phase diagrams [19 - 20] these are chosen for present course of study. Au-In and Cu-In phase diagrams are of interest for fabricating high temperature stable Au-Cu joints at low temperatures. Au and Cu form intermetallic phases with Indium metal. High purity (99.999%) Indium has been used as interlayer metal. It melts at 429 K and intermetallic phase formation is achieved. These intermetallic phases are stable in a wide temperature range up to 975 K. Square shaped patterns of 2×2 mm^2 dimensions are printed with the DuPont Au thick film paste no. 4119 on 1×1 inch ceramic substrates using DEK printer. After a 18 - 20 minutes drying process these printed units are fired up to 1100 K temperature in the furnace. The post firing thickness measured with Light Section Microscope has been obtained in the range of 17-19.5μm.

A high purity Cu (99.999%) has been used for preparing Cu-metal sheet of 20μm thickness by pressure rolling, grinding and buffing. This Cu-sheet of constant thickness and polished surface is then cut into pieces to produce the Cu substrates for the bonding. Similarly high purity Indium (99.999%) foils of 10μm thickness are prepared. The In foil is sandwiched between the thick-film-Au pad and Cu-metal sheet with a ceramic substrate covering the top Cu layer.

The assembly is heated up rapidly to 453 K temperature in the load press apparatus under 0.6MPa pressure for different reaction times. With the progress of Au-In and Cu-In isothermal solidification reactions the high stable intermetallic phases (IP) are formed. The temperature is regulated with temperature controller and has a continuous measurement by a calibrated thermocouple.

The interconnect specimen are gone through 60 minute ultrasonic cleaning in methanol before capturing the optical and crystallographic images. The effects of changing environment on the mechanical and thermal properties are analyzed in this course of study. The fabricated samples are tested for 253 / 323 K thermal shock to predict the efficiency of joint in changing environments, during the biomedical investigations with automotive laboratory equipments. To ensure the biomedical applicability, interconnect specimens are stored in different humidity conditions for 240, 500 and 1000 hours. The fabricated samples are dipped in solutions of different pH ranging ± 0.5 points around the pH value of human blood.

4. RESULTS AND DISCUSSIONS

By Optical inspection it has been observed and reported that partial quantity of Indium out flow in molten state and remain stacked around the reaction zone. This highlights the importance of accurate estimation of interlayer thickness to ensure complete consumption of the low melting metal Indium. The surface asperities, uneven pressure and creation of different temperature zones at the interface during reaction progression are responsible for discontinued surface growth.

The isothermal solidification reaction leads to IP formation by solid-liquid inter diffusion. It is reported after the experiments that thermal shock tests and storage at higher temperatures causes further solid-solid diffusion and the joint strength increases. The intermetallic compositions remain unaffected of humidity and the interconnection samples analysis show no change in strength and melting temperature during humidity test. The specimens fabricated show good resistance against corrosion due to the presence of high anti-corrosive Au in the Cu rich and Indium rich IP.

When Compared after the measuring thermal stabilities with the fabrication temperatures, the un-bonding temperatures are found vary high than that of the fabrication temperature. Therefore the application of isothermal solidification based interconnection technique is safe for chip level packaging and extension on an biomedical electronic assembly.

The tensile strengths of the specimen fabricated for variety of process parameter settings have been measured and presented as function of these parameters. Tensile strength of the isothermal solidification based interconnection increases with the reaction growth in the range 15 – 60 MPa. The effects of change in process parameters like interlayer thickness, temperature and pressure on the ultimate tensile strength (UTS) of Au-In-Cu interconnection are given in Figures 1 - 3.

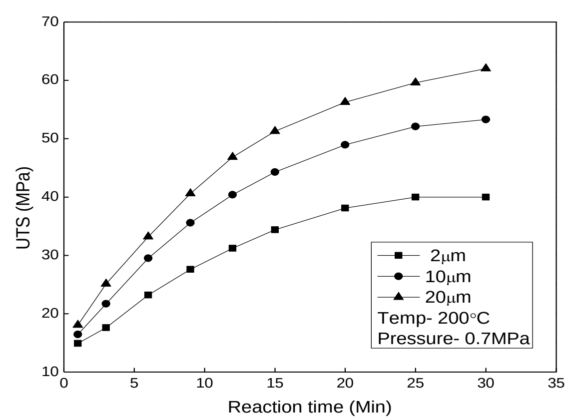

Fig. 1 The effect of interlayer thickness on UTS of Au-In-Cu interconnection

The results show that variation in UTS for different thickness values are symmetric and vary from 14 to 62 MPa. By increasing the interlayer thickness the interconnection zone thickness increases which in turn results in higher tensile strengths of the interconnection.

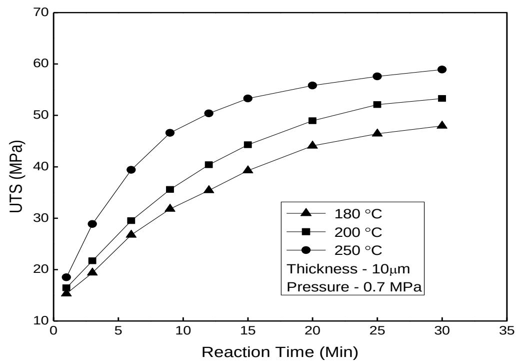

Fig. 2 The effect of process temperature on UTS of Au-In-Cu interconnection

Temperature is the most important parameter in isothermal solidification process. The isothermal solidification process becomes faster for higher temperatures.

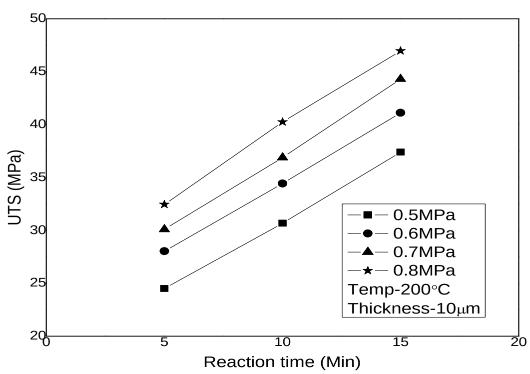

Fig. 3 The effect of pressure on UTS of Au-In-Cu interconnection

Pressure is an important parameter of isothermal solidification based interconnection technique. Optimum pressure is required in order to obtain maximum joint strength. UTS values obtained for different pressures at constant temperature and reaction time give that increment in pressure results in higher bond strength [Fig.3]. It is observed and reported that pressure reduces the size of surface asperities which in turn increases the contact area between joining surfaces by reducing the number of voids at subsequent bonding stages.

Similar variations, with the process parameters, in UTS values have been observed in the other joining compositions. The Au-In-Cu interconnection shows the highest UTS of 62 MPa, specimen fabricated at 200 ºC process temperature for 30 min reaction time with 20 µm thickness under 0.7 MPa pressure.

5. CONCLUSION

The use of Pb in electronics particularly in biomedical devices and body implants is causing immense problems to human health. Development of Pb free electronics for biomedical applications is demanding utmost preference to avoid the risks of exposure to Pb in patient care, clinical tests and hospitals.

The isothermal solidification based packaging technology offer the possibility to develop stable interconnections without using toxic metal Pb. This innovative technique is cost effective in fabricating joints of good adhesion quality.

The environment test results performed for package specimens reveal that this technique is suitable for body implantable devices and automotive biomedical instrumentation.

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