D. Challenging Solders for Microjoints: Developments in the Field of Active Solders and Transient Liquid Phase Systems

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Introduction

Microsystem engineering is one of the world's key technologies for the coming decade. From electronics to aerospace, from chemistry to optics, from biology to medicine, nowadays microsystems are used in many fields of the science and technology. A broad contribution to the enormous success of the challenging field of microsystem engineering has been given from the manufacture and the continuous development of new materials, which offer the possibility to assembly hybrid, namely non-monolithic, microstructures able to combine the different carachteristics of metallic and ceramic materials.

On this account, the joining technique plays a crucial role in microsystem engineering. The joining technologies used at present in the microsystems field impose strong restrictions on the process concerning, e.g., the number of suitable bonding materials or their use at higher temperatures. In order to overcome these limitations, two innovative bonding technologies have been considered in this study: Transient Liquid Phase (TLP) Bonding and Active Soldering. Both joining techniques are successfully applied in the macrotechnique for joining dissimilar materials. From the field of macrosystems they have been transferred into microtechnology and specifically adapted to the requirements of the microstructures.

In order to reach this goal, new filler metals have been developed, evaluated and characterized with regard to fundamental parameters for the microsystems. A constant optimisation and modification of these materials has been carried out, according to the specific requirements of the microstructures being joined like, e.g., a low process temperature. The developed filler metals work in a temperature range of 200°- 400°C. This low field of joining temperatures enables the decreasing of thermal stresses, which can occur during the cooling phase of the bonding process. Moreover, the use of a vacuum or an inert atmosphere is not required, since the joining process can be carried out in an air atmosphere and without flux.

Procedure

New developments have been performed for the active solder Sn4Ag4Ti0,1Ga0,1Ce, which has been investigated in a previous study. An optimisation of the ductility of the joint has been carried out. The presence of titanium as active element in the alloy has, in fact, the negative effect of undesired, hard intermetallic phases being formed in the joint, which can worsen its mechanical properties.

Moreover, thorough investigations have been carried out by means of Electron Energy Loss Spectroscopy (EELS) in order to study the wetting mechanism of this active solder. The joint between two silicon substrates, which were bonded by means of the active solder Sn4Ag4Ti0,1Ga0,1Ce has been examined.

Concerning the TLP systems, the research activity has been extended from binary to ternary solder systems, with the goal of reaching a lower field of process temperatures. In this study the ternary systems CuSnIn, CuSnBi and CuInBi have been considered. The mechanical characteristics of the new alloys have been investigated and correlated with the intermetallic phases formation in the joint.

Results and Discussion

The optimisation of the amount of titanium in the active solders allows the reduction in the amount of surface intermetallic phases in the solder alloy Sn4Ag4Ti0,1Ga0,1Ce. It was proved that gallium in an active solder with a SnAg matrix does not contribute to the growth of intermetallic phases, but opposite conclusions have been reached for titanium and cerium. With a reduction of these two last elements to 0.05 wt.%, the amount of intermetallic phases could be reduced from 15.8 % to less than 1 %, without significant changes in the wetting characteristics and mechanical properties.

The wetting mechanism of the active solder Sn4Ag4Ti0,1Ga0,1Ce has been investigated by means of EELS analysis. The presence of titanium compounds, like oxides as well as silicates, which should prove the occurrence of a reaction zone at the joint surface, has been scanned on the silicon substrate. The EELS spectra revealed the absence of titanium compounds. Pure titanium settled on the silicon in the joining zone and the bonding area was wetted by the soldering filler metal matrix.

The aim of the investigation of ternary TLP systems was to reach low joining temperatures. In order to reach this goal, binary alloys with a melting temperature in a range of 80°– 140°C have been used as low melting solders. A strong influence of the joining zone morphology on the mechanical characteristics of the joint has been observed. With joining process times up to 15 s, a mechanical strength up to 40 MPa could be achieved. With a decrease of less than 5 s in the joining time, stable joints could not be reproduced.

Conclusions

New innovative filler metals for active soldering and TLP bonding processes have been developed, investigated and characterized. The developed solder systems present several significant characteristics: low joining temperatures, reductions of thermal stresses, use of air atmosphere and absence of flux during the joining process, bonding of similar and dissimilar materials.

The wetting mechanism of the investigated active solder Sn4Ag4Ti0,1Ga0,1Ce has been attributed not to a chemical reaction, but to a mechanical interlocking, which is due to the activation of the boundary surface by means of ultrasonic treatment. The decreasing of titanium and cerium amount in this active solder results in a reduction of the intermetallic phases and, consequently, in a increase of the ductility.

The ternary Transient Liquid Phase systems CuSnIn, CuSnBi and CuInBi show a low range of joining temperatures. The morphology of the joint has been investigated and correlated with its mechanical characteristics.