半导体激光钎焊工艺参数对 QFP器件微焊点强度的影响

姚立华, 薛松柏, 王 鹏, 刘 琳
(南京航空航天大学 材料科学与工程学院, 南京 210016)

姚立华

摘 要: 采用 90W 半导体激光软钎焊系统对方形扁平式封装器件(QFP)进行了焊接试验研究, 并对不同激光输出功率下形成的 QFP结构焊点进行了力学性能比较。研究结果表明, 半导体激光软钎焊不仅能够大幅度地提高 SnAgCu钎料 QFP微焊点的抗拉强度, 而且也能够明显地改善 Sn-Pb钎料 QFP微焊点的抗拉强度。在相同的钎料成分下, 半导体激光输出功率直接影响 QFP焊点的抗拉强度, 研究结果可为提高 QFP微焊点强度和可靠性提供一个有效的解决方法。

关键词: 激光软钎焊; 方形扁平式封装器件; 抗拉强度
中图分类号: TG456 文献标识码: A 文章编号: 0235-360X(2005)10-90-03

0 序 言

方形扁平式封装器件(quad flat pack devices, 简称 QFP)由于具有高密度、高可靠性以及优良的电性能等诸多优点而在大规模集成电路中得到了广泛应用, QFP器件的焊点在实际应用中起着电气连接和机械连接的双重作用[1]。近年来, 由于 QFP引脚数量越来越多, 引脚间的间距也越来越小, 因此当 QFP器件经常处于温度循环负载中时, 常常容易引起焊点的开裂, 从而导致器件失效。

目前, QFP器件的焊接大都采用整体加热方式如热风对流、红外辐射及热板传导等方法, 虽然热风对流、红外辐射等再流焊技术已较为成熟[2], 但是细间距 QFP器件在这些整体加热方法中常出现大量桥连和开裂等缺陷。由于 QFP器件在使用中经常处于温度循环负载中, 长期的温度循环负载会在引脚处焊点产生周期性的应力应变, 从而导致焊点开裂[3], 因此如何提高 QFP器件焊点的力学性能, 成为人们关注的重点之一。

作者通过研究半导体激光软钎焊对 Sn63Pb37与 Sn96Ag3.5Cu0.5钎料对 QFP器件微焊点强度的影响, 分析了半导体激光工艺参数对 QFP焊点力学性能的影响因素, 可望对提高细间距 QFP器件的焊点可靠性提供有效的解决方法。

收稿日期: 2005-07-29

1 试验设备和材料及方法

1.1 试验设备

使用的 90W 半导体激光软钎焊系统由激光传输光路单元、半导体激光加热单元、六轴工作台、工业数字摄像机及数据采集和处理单元组成(如图 1所示)。它的工作原理是: 焊接时, 激光通过光学聚焦系统按照 2∶1的比例进行聚焦, 将直径为 400μm的激光聚焦为 200μm的激光束。调节工作台使激光束直接照射到焊接区域, 焊接区域器件引线和钎料吸收激光并转变成热能, 温度上升到一定温度值时, 钎料熔化并铺展、润湿欲焊工件。激光照射停止后, 焊接部位迅速冷却, 钎料凝固, 形成牢固可靠的

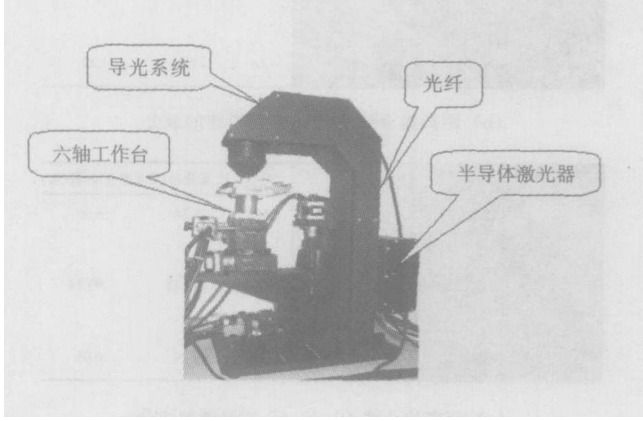

图 1 半导体激光焊接系统

Fig. 1 Diode laser soldering system

微焊点。

1.2 试验材料及方法

1.2.1 试验材料

(1)试验 PCB基板焊盘: Au/Ni/Cu三层结构和 Ni/Cu两层结构。

(2)焊膏成分: Sn63Pb37和 Sn96Ag3.5Cu0.5。

(3) QFP元器件: QFP48(四边引脚数各为 12)和 QFP100(四边引脚数各为 25)。

1.2.2 试验方法

采用红外再流焊机与 90W 半导体激光焊接系统分别对 3种组合试件进行了焊接, 具体试件组合方式如表 1所示。焊后采用日本 RHESCN公司生产的 STR-1000型微焊点强度测试仪测试 QFP焊点的抗拉强度, 分析对比其变化规律。

表 1 焊接试件结构

Table 1 Structure of soldering samples

试件编号	试件组合方式(元器件+钎料+焊盘结构)
1	QFP100+ Sn96Ag3.5Cu0.5+Au/Ni/Cu
2	QFP48+ Sn63Pb37+Ni/Cu
3	QFP48+Sn96Ag3.5Cu0.5+Ni/Cu

2 试验结果与分析

2.1 激光工艺参数对微焊点强度的影响

当钎料成分、PCB基板焊盘及 QFP元器件确定后, 则焊接后的焊点性能就由焊接温度与焊接时间所决定[4]。但是在半导体激光焊接过程中, 焊接区域的温度是很难准确控制的, 因此采用控制激光焊接速度和激光输出电流两个参数来控制焊点形态和焊点的各项性能[5]。

表 2数据表明, 如果焊接速度、钎料成分和 QFP元器件确定后, 当选取不同的激光加热工艺参数进行焊接时, QFP微焊点的抗拉强度具有较大的差别。

图 2反映了激光输出电流与 QFP微焊点抗拉强度之间的关系, 当激光输出电流达到一定值时, QFP微焊点的抗拉强度达到最大值, 如果电流继续升高, 抗拉强度反而会下降。其原因是由于在连续扫描的方式下工作时, 8.8A的输出功率, 使 QFP的钎焊温度达到最佳状态, 此时激光束的照射可以使钎料完全润湿 QFP的引脚, 钎缝组织细密[6], 钎料与基板和元器件端头的相互作用最大, 因此抗拉强度达到最高。继续升高电流, 激光输出功率过大, 钎缝区组织粗大, 因此抗拉强度明显地下降。

2.2 两种焊接方法的微焊点强度对比试验结果

有研究表明[7,8], 各种成分的 Sn-Pb钎料(不含其它元素, 如 Sb, Bi等)的抗拉强度等力学性能均较 Sn-Ag-Cu钎料低, 但从表 3中可以看出, 半导体激光焊接软钎焊能够明显地提高 Sn-Pb微焊点的抗拉强度, 使其达到红外热风再流焊焊后 Sn-Ag-Cu微焊点的抗拉强度水平。

表 2 激光连续加热试件微焊点抗拉强度试验结果

Table 2 Results of tensile strengths of micro joints with laser continuous heating

强度测定值 σ_b MPa)	激光输出电流 I/A				
试件编号	8.6A	8.8A	9.0A	9.2A	9.4A
1	49.18	80.85	63.43	54.88	30.16(已过烧)
2	53.01	84.06	63.79	56.26	24.19(已过烧)
3	55.06	90.38	70.78	52.83	基板击穿
4	57.02	85.97	65.70	50.92	基板击穿
5	58.53	85.04	61.96	62.76	基板击穿
6	52.88	82.90	64.68	60.45	基板击穿
7	48.78	90.29	61.70	48.55	基板击穿
8	56.31	93.68	71.32	52.34	基板击穿
9	47.13	91.45	58.93	56.62	基板击穿
平均值	53.10	87.18	64.68	55.06	-

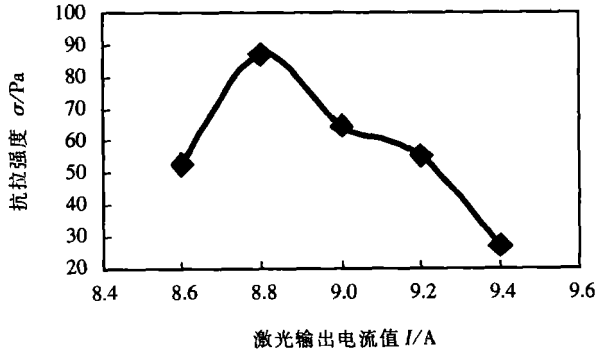

图 2 激光输出电流与 QFP焊点抗拉强度之间的关系

Fig. 2 Relation between output currents of laser and tensile strengths of QFP micro joints

比较表 3和图 3的抗拉强度数据, 可以看出, 采用半导体激光焊接, Sn-Ag-Cu钎料焊点与 Sn-Pb钎料焊点的抗拉强度都有明显提高, 并且两者的提升幅度相当接近, 在 25%左右, 特别是对于 100引线的 QFP元器件来说, 其抗拉强度的提高幅度更大, 达到 50%以上。

进一步分析还可以看出, 半导体激光软钎焊微

焊点的力学性能相对于红外热风再流焊焊点普遍有所提高，尤以细间距无铅钎料激光焊点的力学性能最为优异，其微观机制有待进一步的研究，这一问题的深入研究，对提高细间距 QFP微焊点强度和可靠性将提供理论指导和技术支持。

表 3 微焊点强度试验对比结果

Table 3 Comparisons of micro joints strength

焊接方式	红外再流焊			激光软钎焊		
抗拉强度	试件编号			试件编号		
测定值 MPa	I	II	III	I	II	III
1	49.18	46.82	58.01	80.85	58.49	69.36
2	46.95	52.12	59.56	84.06	71.81	72.70
3	45.70	45.48	61.43	90.38	56.53	79.74
4	54.92	52.03	63.52	85.97	62.23	72.79
5	52.43	47.44	60.94	85.04	60.63	70.79
6	54.48	51.81	61.96	82.90	59.42	76.62
7	49.80	52.70	62.19	90.29	70.92	85.97
8	53.86	43.61	58.27	93.68	54.61	72.12
9	51.67	46.15	63.34	91.45	61.61	64.99
平均值	51.01	48.69	61.03	87.18	61.78	73.99

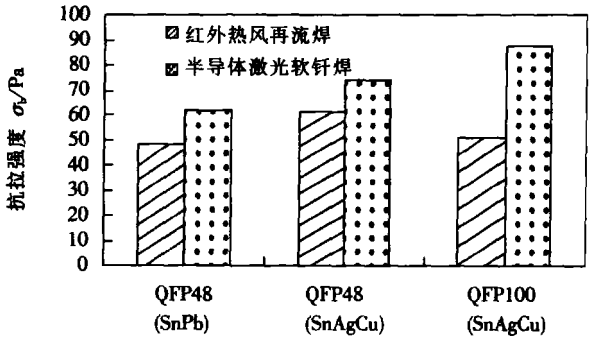

图 3 抗拉强度平均值

Fig. 3 Average of tensile strengths of micro joints

3 结 论

(1) 半导体激光输出功率直接影响 QFP焊点的抗拉强度。半导体激光无铅微焊点的力学性能相对于红外热风再流焊无铅微焊点普遍提高了 25%左右，尤以细间距无铅钎料激光微焊点的力学性能提升最为显著，平均提高了 50%以上。

(2) 半导体激光软钎焊不仅能够改善无铅微焊点的抗拉强度，也能够大幅度地提高 Sn－Pb微焊点的抗拉强度，平均可提高 25%左右。

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作者简介：姚立华，女，1976年 11月出生，硕士研究生。主要研究方向为微电子焊接技术及无铅钎料研究。发表论文 1篇。

Email: ylh0306110@yahoo.com.cn

Abstract One technological problem about the weak combination of interface between Cr plating layer and substrate which was strengthened by plasma had been put forward according to the application state of under serious ablation and erosion by hot chemical airflow. The technology using distransfer plasma to heat the steel workpiece with Cr plating layer at high speed was used to strengthen interface bonding between Cr plating layer and substrate. The principle of strengthening with plasma was introduced in this paper and the process experiment of strengthening with plasma arc was carried out. The experimental results measurement and analysis show that the metallurgical bonding has occurred between Cr plating layer and substrate and the strengthening of interface bonding between Cr plating layer and substrate is improved remarkablely.

Keywords plasma beam; plating layer; interface strengthening; metallurgical bonding

Study on strength of soldered micro joints of QFP devices HU Yong-fang[1], XUE Song-bai[1], YU Sheng-lin[2] (1. College of Materials Science & Technology, Nanjing University of Aeronautics & Astronautics, Nanjing 210016, China; 2. 14th Research Insitute, China Eletronics Technology Group Corporation, Nanjing 210013, China). p78 - 80

Abstract Tensile strength of the quad flat pack (QFP) devices were determined by STR-1000 Joint Strength Tester and compared with the joints soldered with different pitches and different solder compositions QFP and SOP (small outline package). The results indicate that for the same solder compositions, the wider the pitch is, the larger the pulling force is, i.e. the higher the tensile strength is. The tensile strength of soldered joints of QFP with pure lead is higher than that of eutectic solder and as well and as higher than that of eutectic solder itself.

Keywords tensile strength; quad flat pack (QFP); eutectic solder

Reliability of CBGA soldered joint under thermal cycling XUE Song-bai[1], HU Yong-fang[1], YU Sheng-lin[2] (1. College of Materials Science & Technology, Nanjing University of Aeronautics & Astronautics, Nanjing 210016, China; 2. The 14th Research Insitute, China Eletronics Technology Group Corporation, Nanjing 210013, China). p81 - 83

Abstract Thermal fatigue life of ceramic ball grid array (CBGA) devices under thermal cycling conditions was presented in -55℃ ~ 125℃. Failure mechanism of the soldered joints including the germinating position and expanding direction of the cracks were observed and analyzed by optical microscopy. Results show that the crack in soldered joints germinats in the borderline all around the outmost solder balls. With the increasing of thermal cycling times, the cracks expand from the borderline of outmost solder balls to the ball center along the interfaces. It is found that the germination and expanding of the micro-cracks are caused by highly concentrated stress and strain as well as interaction between thermal cycling and creep.

Keywords thermal fatigue life; BGA; crack; thermal cycling

Low cycle fatigue property of TA5 titanium alloy welded joint YAN Keng, ZHANG Pei-lei, JIANG Cheng-yu (Province Key Lab of Advaued Welding Technology, Jiangsu University of Science and Technology, Zhenjiang, Jiangsu 212003, China). p84 - 86

Abstract The low cycle fatigue property of TA5 Titanium alloy welded joint with different reinforcement was investigated. The result shows that the increasing of weld reinforcement decreases the low cycle fatigue life of welded joint when the TA5 titanium alloy welded joint is working in the strain value is less than 0.35%. When the strain value is higher than 0.35%, the rule is not obvious. In high stress strain condition, the low cycle fatigue life of TA5 Titanium alloy welded joint is under the circulatory hardening and in low stress strain condition, its circulatory hardening property is not obvious. The expression of the circulatory stress strain of welded joint and the low cycle fatigue life of its smooth sampling were shown.

Keywords titanium alloys; welded joint; low cycle fatigue

Microstructures and properties of 7A52 aluminum alloy welded joint by twin wire welding YU Jin, WANG Ke-hong, XU Yue-lan, LIU Yong (Department of Materials and engineering, Nanjing University of Science and Technology, Nanjing, 210094, China). p87 - 89

Abstract 7A52 aluminum alloy was welded by using 5A56 filler with twin wire gas shielded arc welding. The mechanical properties and microstructure of welded joint were studied. The results show that the weldability of 7A52 aluminum alloy is good. The weld zone is the weakest in welded joint due to effects of chemical components of filler and crystallization process. Therefore twin wire gas shielded arc welding of medium and thick 7A52 aluminum plate can obtain excellent welded joint.

Keywords 7A52 aluminum alloy; twin wire gas shielded arc welding; welded joint; microstructure

Effect of diode laser parameters on tensile strength of QFP micro joints YAO Li-hua, XUE Song-bai, WANG Peng, LIU Lin (College of Materials Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China). p90 - 92

Abstract Soldering technology for quad flat pack devices (QFP) were studied by means of 90W diode-laser soldering system and the mechanical properties of micro-joints of QFP were compared with different laser power. Results indicate that diode laser soldering can obviously improve both the tensile strength of the joints with Sn-Ag-Cu solder and the strength of the joints with Sn-Pb solder. The diode laser output power directly influences the tensile strength of the micro-joints of QFP with the same solders. These results will provide a good method for improving the

strength and reliability of fine pitch QFP devices.

Keywords: laser soldering; QFP; tensile strength

Effects of temperature and coatings on wettability of Sn-Ag-Cu lead-free solder WANG Xu-yan[1], XUE Song-bai[1], YU Sheng-lin[2], ZHU Xiao-jun[2] (1. College of Materials Science & Technology, Nanjing University of Aeronautics & Astronautics, Nanjing 210016, China; 2. 14[th] Research Insitute, China Eletronics Technology Group Corporation, Nanjing 210013, China). p93 – 96

Abstract: By means of wetting balance method, the wetting time, wetting force and the effects of soldering temperature on wettability of Sn-Ag-Cu lead-free solder were tested under the conditions of two temperatures and three substrates. The results indicate that the higher temperature remarkably improves wettability of lead-free solder on substrate. The wetting time of Sn-Ag-Cu lead-free solder on Cu substrate is close to that of Sn-Pb solder, and the wetting force is greater than that of Sn-Pb solder at 260℃. The wetting time of Sn-Ag-Cu lead-free solder on Ni/Au and SnBi coatings are obviously shorter than that on Cu substrate, and the wetting time of Sn-Ag-Cu solder on three substrates are decreased by 34% ~ 67% compared with that of Sn-Ag-Cu at 235 ℃.

Keywords: lead-free solder; wettability; coatings

FEM analysis of stress and strain in CBGA solder joint with different size under thermal cycle HU Yong-fang[1], XUE Song-bai[1], YU Sheng-lin[2] (1. College of Materials Science & Technology, Nanjing University of Aeronautics & Astronautics, Nanjing 210016, China; 2. 14th Research Insitute, China Eletronics Technology Group Corporation, Nanjing 210013, China). p97 – 100

Abstract: The components of CBGA was simplified into 2-D model of finite element analysis for the stress and strain of soldered joint, and the finite element method was used to simulate the distribution of stress and strain of three kinds of CBGA components (0.76 mm, 1.0 mm and 1.3 mm) under thermal cycle, and calculate the maximum of stress and strain. The results show that the reliability of CBGA components with 0.76 mm diameter is the best and the analysis indicates the finite element simulation is suitable for studying reliability of all kinds of soldered joints in packaging of microelectronics.

Keywords: CBGA; stress; strain; FEM analysis

Effect of process parameters and interlayer on properties of 1420 Al-Li alloy diffusion bonded joint CHEN Wen-hua, QIN Zhan-yan, SHEN Yi-fu (College of Materials Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China). p101 – 104

Abstract: The feasibility of diffusion bonding of 1420 Al-Li alloy under certain technical conditions was investigated in this paper. The microstructure, fracture morphology and microhardness of the joints were studied. The results show that the excellent metallurgical bonding can be obtained through the sufficient diffusion of atoms near the joint boundaries by using the reasonable processing parameters. The welded joint with homogenous microstructures can be obtained by using the copper as the interlayer material. When the nickel is used as interlayer material, the intermetallic compounds are formed by diffusion, which can improve the strength of the joints.

Keywords: 1420 Al-Li alloy; diffusion bonding; interlayer

Effect of CPGA gullwing lead size on reliability of soldered joints WU Yu-xin, XUE Song-bai, HU Yong-fang (College of Materials Science & Technology, Nanjing University of Aeronautics & Astronautics, Nanjing 210016, China). p105 – 108

Abstract: Finite element method was used to study the stress distribution in soldered joints of CPGA gullwing lead. Results indicate that the innerside of soldered joint underside is the weakest position where the stress is relatively concentrated, so it is easily to be destroyed. The relationships between different sizes of gullwing lead and the max stress in soldered joints were calculated and the thermal stress distribution in soldered joints was analyzed with different sizes of gullwing lead experienced alternating thermal effects. Results show that the stress distribution is affected by the size of gullwing lead. With the increasing of lead's thickness, the stress will increase in soldered joints. With the increasing of lead's height, the stress in soldered joints will increase firstly and then decrease, which has a maximum value. With the increasing of lead's length contacted with solder pad, the stress in soldered joints will decrease firstly and then increase, which has a minimum value.

Key words: finite element method; gull wing lead; soldered joint; stress

Water cleaning technology for surface mounted components soldered with Sn-Ag-Cu solder WANG Xu-yan[1], XUE Song-bai[1], WANG Hai-song[1], YU Sheng-lin[2] (1. College of Materials Science & Technology, Nanjing University of Aeronautics & Astronautics, Nanjing 210016, China; 2. 14th Research Insitute, China Eletronics Technology Group Corporation, Nanjing 210013, China). p109 – 112

Abstract: Simulative specimens and SMC soldered with layer resistances were cleaned by SMT-450-LD SMT water cleaning system, and the results indicate that the layer resistance mounted on FR4 by Sn-Ag-Cu no cleaning solder paste is clean and the residua concentrateion on PCB surface is about 1.9 μg/cm^2, which met the requirement of MIL-STD-2000 (the residua concentrateion on PCB surface should be less than 5.7 μg/cm^2). Cleaning parameters such as cleaning temperature and cleaning time have great effects on the cleaning result.

Keywords: water cleaning; surface residue; ionic concentration; Sn-Ag-Cu solder paste