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ScienceDirect

Control Engineering Practice 16 (2008) 685–696

CONTROL ENGINEERING PRACTICE

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An impact force compensation algorithm based on a piezo force sensor for wire bonding processes

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Received 26 August 2006; accepted 10 August 2007
Available online 25 September 2007

Abstract

Impact force control is a key factor in wire bonding processes affecting the overall quality of the product and productivity of the process. This paper presents an impact force compensation algorithm designed for gold wire bonding processes, which uses a piezo force sensor and contains a new algorithm design to reduce the impact force of the capillary when it contacts a silicon pad. This compensation algorithm was developed from an impedance model of the contact between the capillary and pad, and includes automatic drift cancellation calculations for the piezo force sensor. A flat-top impact force profile was achieved using this algorithm with the piezo force sensor attached to the *Z*-axis of the wire bonder. Tests were used to demonstrate that the proposed algorithm reduced the impact force dramatically, which is particularly important in fine pitch wire bonding processes.

Keywords: Impact control; Piezo force sensor; Contact detection; Force control; Wire bonding; Fine pitch

1. Introduction

The market trends of small consumer electronics such as cellular phones are very aggressive in the miniaturization of electronic packages. Ongoing demand for higher density and productivity of semiconductor packages is the main driving force for the development of precision assembly technologies in semiconductor processes. Recent trends in semiconductor assembly houses require 45-μm pad pitch wire bonding processes in the production line. Smaller pad sizes and finer pitches require various new techniques, such as micron-level control of the *xyz* system, more accurate current control of electronic flame-off devices, and especially impact moment control when the capillary tool tip contacts the pad or lead (Rooney, Nager, Geiger, & Shanguan, 2005).

Fig. 1 shows a 45-μm fine pitch gold wire bonding process. Gold wire bonding processes are thermosonic, which means that heat, ultrasonic energy, force, and time play important roles in the manufacturing process. The quality of the wire bonding is dependent on many subprocesses and material variables, such as the ultrasonic power, applied force, welding time, bond pad surface hardness, and interface temperature (Ding, Kim, & Tong, 2006).

Fig. 2 describes the movement of the capillary when it contacts a silicon pad. As the pad pitch decreases, the size of the free air ball (FAB) must also decrease, which degrades the ability to absorb an impact force. There are three major reasons why the impact force on the pad should be reduced to improve the quality of fine pitch wire bonding.

First, the impact force is directly related with the squashed ball size in the wire bonding process. If the impact force is too strong, the squashed ball becomes larger than the size of the pad, leading to a connection failure. In addition, it will not have proper bonding characteristics.

Second, a reduction in the impact force will increase the productivity of the entire wire bonding process by increasing the search speed. The search speed of the capillary must be much slower than that of a normal-sized pad in fine pitch wire bonding to reduce the impact force from the inertia of the *Z*-axis. A slow search speed for contact greatly increases the search time required for the contact. For example, a 10-mm/s search speed in an 80-μm search level will require approximately 8 ms for contact

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doi:10.1016/j.conengprac.2007.08.002

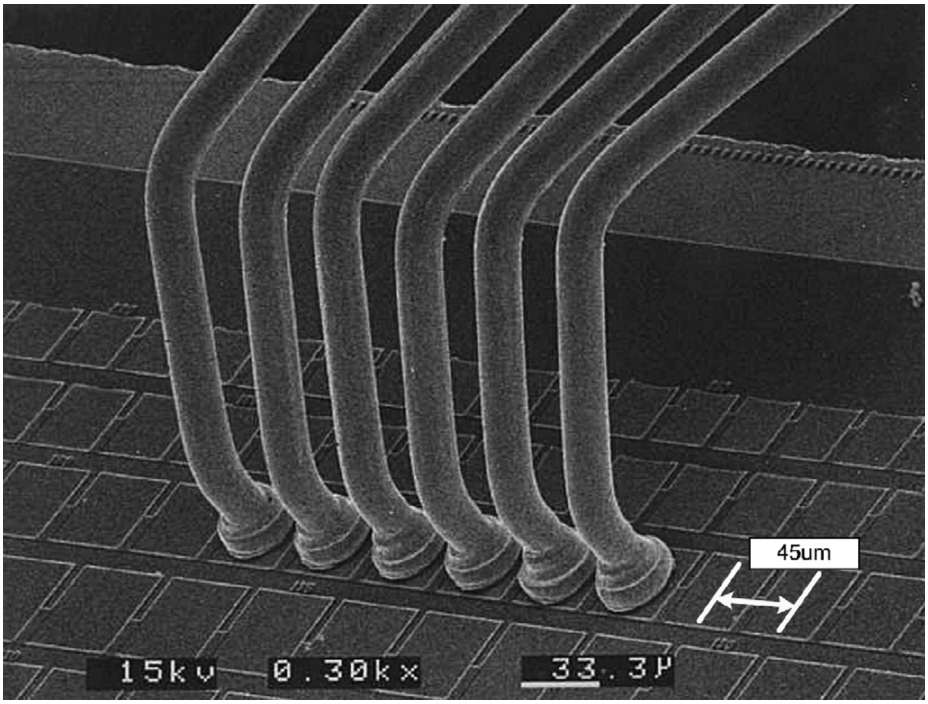

Fig. 1. A 45-μm pad pitch gold wire bonding process.

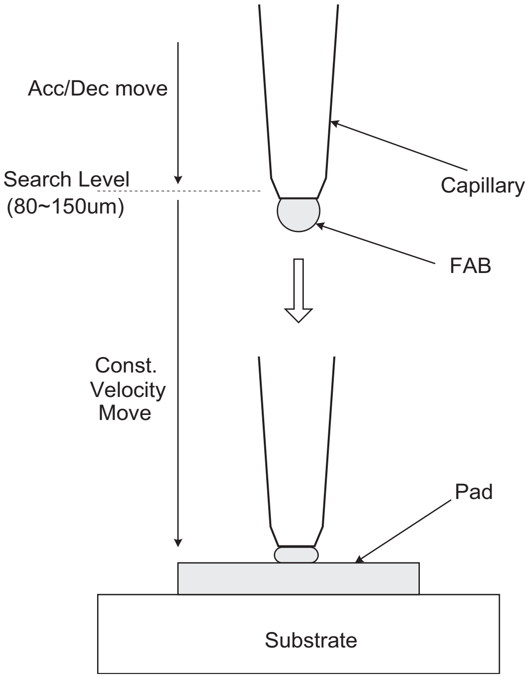

Fig. 2. Capillary with FAB contacts on the pad.

searching. However, if the speed must be decreased to 5 mm/s to reduce the impact force in the fine pitch case, the searching time will double to 16 ms for each contact. Chips usually have hundreds of pins and therefore their production units per hour (UPH) will be greatly affected by the search speed. The cost–time effectiveness is one of the most important issues in semiconductor manufacturing systems (Zafra-Cabeza, Ridao, Camacho, Kempf, & Rivera, 2007).

Third, the bonding quality will improve if the impact force is reduced. If the impact force is too great, the size of the squashed ball will instantly become too large and the ultrasonic generator (USG) will not be able to ensure an adequate amount of time to produce the intermetallic layer of the bonding surface. In addition, all bonding processes should have certain margins in their parameters for control of the mass production lines.

The measurement of the impact force exerted on a capillary tip during bonding is not an easy task because of the sensor location and various vibration noises. The location of the piezo sensor and electrode pattern greatly affects its sensitivity and measuring frequency (Chiu, Chan, Or, Cheung, & Liu, 2003). Recently, a special double beam force sensor was designed to provide force feedback in wire bonding processes (Yin, Zhou, Chen, Hu, & Lin, 2006).

Control of the impact force between two objects has been extensively researched in robotic control problems (Yoshikawa, 2000). In robotic application, usually both position control and force feedback are required for a given task. The main approaches for this type of problem are hybrid force control and impedance control. In the hybrid control strategy, a combination of motion control along one subspace and force control along another subspace is used (Raibert & Craig, 1981). Yoshikawa proposed a dynamic hybrid approach (Yoshikawa, 1987), and a nonlinear coordinate transform method was developed by McClamroch and Wang (1988). In the impedance force control strategy, it does not use both motion and force trajectories; rather, it controls the motion and force using the relationship between interactive forces and the position of the manipulator (Hogan, 1985).