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Signal Transmission Analysis of Burn-In Socket for Fine-Pitch Ball Grid Array Package

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Abstract

Signal transmission analysis is investigated for a burn-in socket of fine-pitch ball grid array (FBGA) package using a three-dimensional electromagnetic field simulation. The effects of different signal-ground pin assignments on its signal transmission characteristics are analyzed in this work. Also, its electric and magnetic fields are presented to evaluated their distribution intensity around the signal and ground pins. Its reflection and insertion losses are calculated to analyze the effects of the increase in the contact length. For a burn-in socket with a contact length of 3 mm, the 1-dB the insertion loss frequency is calculated to be 38 GHz. The calculation results for insertion loss and reflection loss show that the frequency characteristics of the burn-in socket are excellent, and that the burn-in socket is suitable for high-speed applications.

Keywords: *Burn-in socket, Signal transmission, Insertion loss, Reflection loss*

1. Introduction

Semiconductor chips are manufactured using various and complex processes, Because of manufacturing defects, it is necessary to determine whether the integrated circuit (IC) functions or not. Burn-in is a process in which semiconductors or electronic devices are operated repeatedly at elevated temperature and voltage prior to being placed into operation [1-2], and thus, initial failures in the semiconductor package will be detected by the burn-in test process [3]. A burn-in socket is an electromechanical component that provides a separable electrical interconnection between the semiconductor package and the printed circuit board (PCB) located on the test equipment. Figure 1 shows a cross-sectional view of a burn-in socket with an FBGA package. The electrical signals on the test board pass through the contact of the burn-in socket and arrive at the fine-pitch ball grid arrays (FBGA) package.

As the need for smaller outlines and higher performance has increased, the electrical packages have moved towards FBGAs as a technological solution for high-density interconnection. The FBGA package greatly increases the number of input/output pins within a given area. The technological need for smaller footprints has driven the development of packages with pitches less than 1.0 mm. These trends necessitate a burn-in socket with a high pin count and a fine pitch.

Research on development of the socket and contact structures for high-density packages with fine-pitches has been performed [4-6]. Changing the contact pitch between printed board side and FBGA package side has been studied for fan-out applications [4]. Fine pogo contacts surrounding by socket housing with low dielectric constant has been used widely for high-speed applications [5]. For wafer-level burn-in

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test, contact beam structure is proposed to apply 50 μm solder ball with pitch of 0.5 mm [6]. But, electrical characterization with change of signal-ground pin arrangement is not investigated. In this work, the signal transmission characteristics of a burn-in socket, such as insertion loss and reflection loss, are investigated.

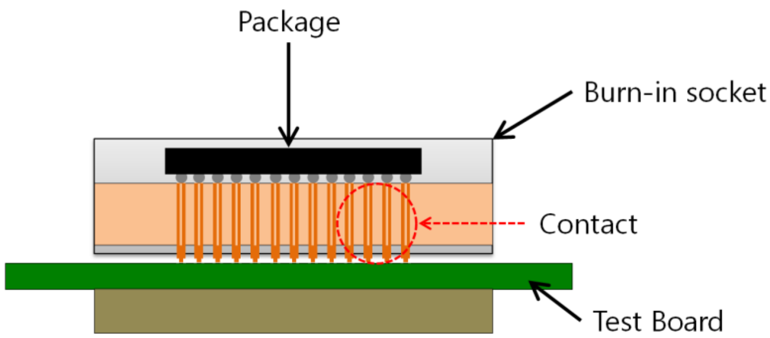


Figure 1. Cross-sectional View of the Burn-in Socket

2. Contact Structure

There are currently several contact structures for burn-in sockets, such as pinch-type contacts, microspring contacts, S-shaped contacts, and four-point crown tips. In this study, the pinch-type contact structure is investigated. Its three-dimensional model is shown in Figure 2. Two separated contacts pinch the ball from opposite sides and are combined at the far side. The contact has a length of 3.0 mm and is designed for a pitch of 0.35 mm.

Generally, burn-in tests are conducted at low frequencies such as 100 MHz. However, the operating frequency of the burn-in tests has increased gradually, following the trend of high-speed operation of electronic devices. In this study, the high-frequency characteristics of the socket are investigated using an electromagnetic simulation. The contact material used in the burn-in socket is beryllium copper and its housing material is polyetherimide. In the simulation, the electrical conductivity of beryllium copper and the dielectric constant of polyetherimide are 1.45×10^7 S/m and 3.5, respectively.

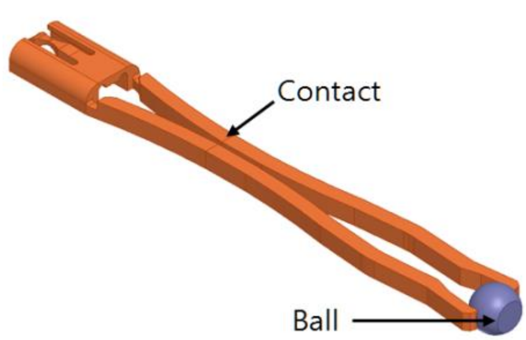


Figure 2. Three-dimensional Model of the Pinch-type Contact Structure

3. Signal Transmission Characteristics

In order to analyze signal transmission characteristics, S-parameters of the contacts with different pin assignment are calculated. Also, their insertion and reflection losses are investigated. It is known that impedance matching between the interconnected devices is critical in determining the signal transmission characteristics [7-9]. Generally, the characteristic impedance (Z_0) of electronic devices and components is designed to be 50 Ω to allow for more consistent signal transmission. Additionally, the fidelity of the electrical signals is significantly affected by the signal-ground pin assignments [10]. Therefore, the effects of the pin assignments on the signal transmission characteristics of the contact are performed with three-dimensional electromagnetic simulation (ANSYS HFSS).

A burn-in socket with nine contacts is modeled as shown in Figure 3. All contacts are assigned to be a signal pin, grounded pin, or floating pin. The signal transmission calculations are carried out under four assignment conditions (one grounded pin to four grounded pins), as shown in Figure 3. In other words, one signal-carrying pin is surrounded by several grounded pins, and the other contacts are assigned to be floating.

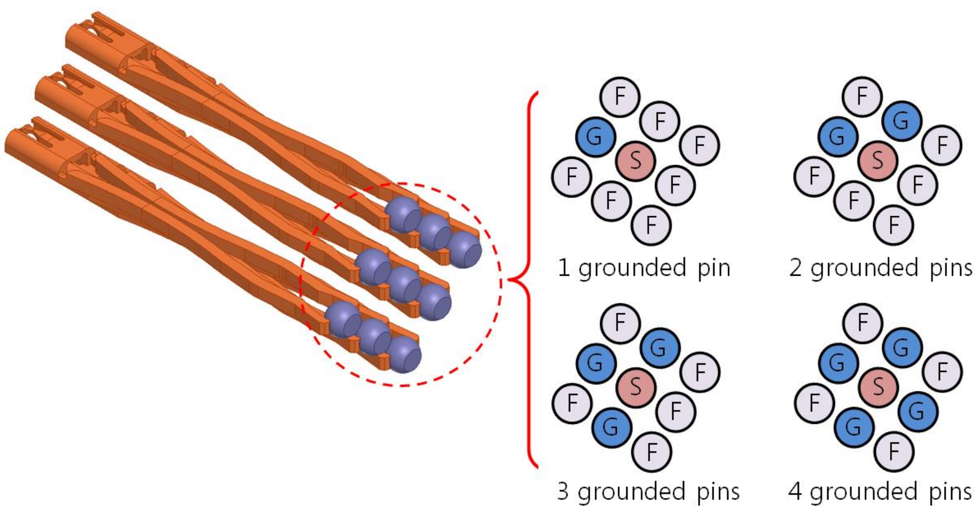
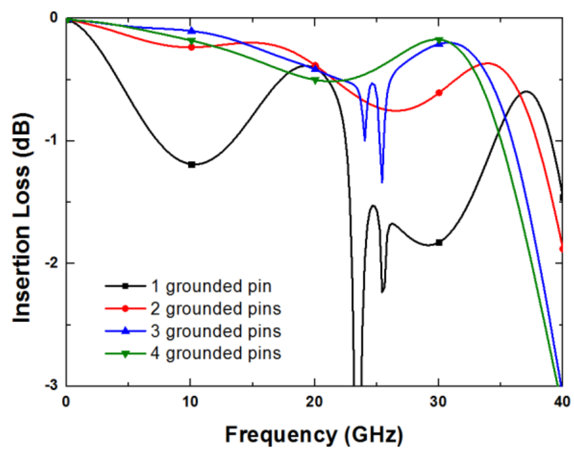


Figure 3. Contact Model and Pin Assignment for Electromagnetic Simulation

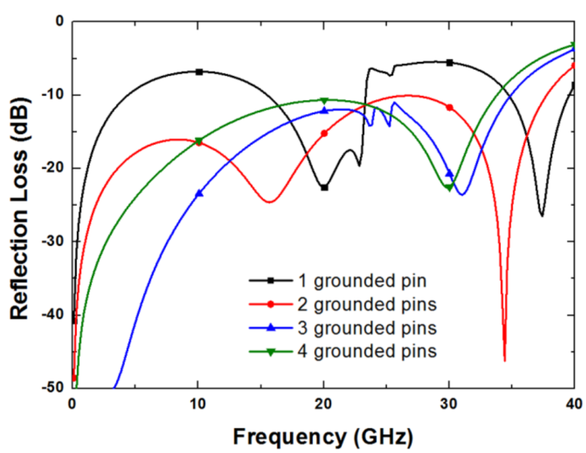
4. Result and Discussion

The effects of contact pin assignment on both the insertion loss and the reflection loss are presented in Figure 4. The calculations are carried out under four pin assignment conditions: one grounded pin, two grounded pins, three grounded pins and four grounded pins. Table 1 summarizes the frequency of the 1-dB insertion loss. The frequency of the 1-dB loss is calculated to be 7.3 GHz for one grounded pin, whereas the other pin assignments exhibit excellent results (namely, higher than 35 GHz). With the exception of the one-grounded-pin case, low reflection losses (less than -10 dB) are also obtained in most frequency ranges as shown in Figure 4 (b). Therefore, more than two grounded pins are necessary to obtain optimal high-frequency characteristics. These results verify that the contact pin assignment significantly influences the signal transmission characteristics of the burn-in socket and that one signal contact with two ground pins is the optimal pin assignment for high-frequency performance under these conditions.

Next, the effects of contact length on the signal transmission characteristics are investigated. In the previous simulation, the contact length was 3.0 mm; however, this length is increased to a maximum of 6 mm. The inset of Figure 5 (a) shows the contact with additional length from 0 mm to 3 mm. A simulation is performed with one signal-carrying pin and two grounded pins. Figure 5 shows the insertion loss and the reflection loss for the various contact lengths. As the total contact length varies from 3 mm to 6 mm, the insertion loss and the reflection loss exhibit different characteristics. At a length of 0 mm (total contact length of 3 mm), the 1-dB insertion loss frequency is calculated to be 38.0 GHz, as shown in Figure 5 (a). Table 2 summarizes the frequency response at the various contact lengths. As the length of the contact increases, the frequency of the 1-dB loss decreases.



(a)



(b)

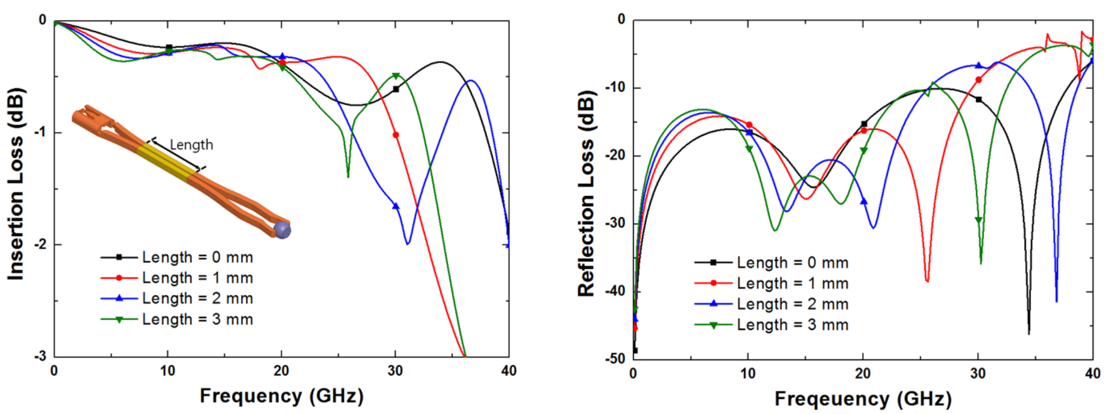
Figure 4. (a) Insertion Loss and (b) Reflection Loss for Different Pin Assignments

Table 1. Effects of Pin Assignment on the Frequency of the 1-dB Loss

Pin assignment	1 grounded	2 grounded	3 grounded	4 grounded
f_{-1dB} (GHz)	7.3	38.0	36.0	35.0

An important factor in determining the signal transmission characteristics of the burn-in socket is the impedance matching at 50 Ω. It is known that impedance mismatch increases reflection noise and degrades signal transmission quality. Therefore, the characteristic impedance (Z_0) of the socket is evaluated using an electromagnetic simulation (with ANSYS Q3D). Table 2 lists the value of Z_0, inductance and capacitance of the socket. The inductance and capacitance of the socket increase gradually with contact length. However, Z_0 remains almost constant as the contact length increases. Therefore, the reduction in the 1-dB insertion loss frequency is caused by increased resistive losses due to the increase in contact length. These results indicate that a burn-in socket with a relatively short pinch-type contact can be used in high-speed test applications.

The electromagnetic field distributions of one signal-carrying pin surrounded by two ground pins are investigated in Figure 6. In this analysis, the remaining pins are assigned to be floating. Figure 6 (a) shows the cross sectional distributions of the electric field in the middle of the contact along its length and Figure 6 (b) shows the magnetic field of the contacts. Both fields are distributed intensively within a region confined between the signal pin and the two ground pins. These field distributions show that the electromagnetic signal propagates well along the contact.

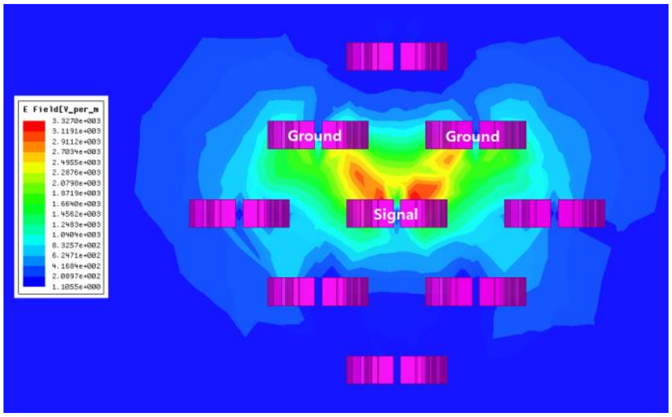


(a) (b)

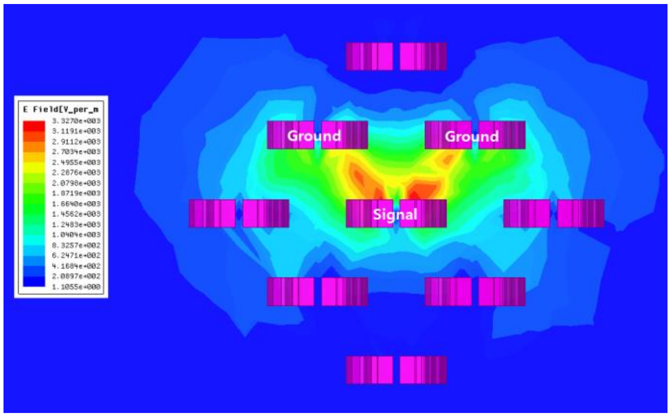
Figure 5. (a) Insertion Loss and (b) Reflection Loss for Different Contact Lengths

Table 2. Effect of Contact Length on the Frequency Response and Characteristic Impedance

Length (mm)	0	1	2	3
f_{-1dB} (GHz)	38.0	30.0	26.2	25.4
Inductance (nH)	1.09	1.30	1.58	2.00
Capacitance (pF)	0.31	0.35	0.42	0.52
Z_0 (Ω)	59.3	60.9	61.3	62.0



(a)



(b)

Figure 6. (a) Electric Field Distribution and (b) Magnetic Field Distribution of the Contacts

5. Conclusion

The signal transmission characteristics of a burn-in socket with pinch-type contacts are investigated. Additionally, the effects of signal-ground pin assignment and increased contact length are analyzed using electromagnetic simulation. The frequency of the 1-dB insertion loss is calculated to be greater than 35 GHz for all ground pin assignments, with the exception of one grounded pin. In this paper, it is verified that the short pinch-type contact is effectively able to improve the high-frequency characteristics of the burn-in socket and can, therefore, be utilized in high-speed testing applications.

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