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VIBRATION ANALYSIS OF FBGA SOLDER JOINTS OF THE MEMORY MODULE SUBJECTED TO HARMONIC EXCITATION

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ABSTRACT

Vibration analysis of Fine-pitch Ball Grid Array (FBGA) packages mounted on a Printed Circuit Board (PCB) subjected to harmonic excitation is performed by using finite element method (FEM). A finite element model of a memory module is composed of three main parts, packages, simplified solder balls and bare PCB. At first, natural frequencies and mode shapes of the developed model were confirmed experimentally. Secondly, the harmonic excitation experiment for the module was carried out at the first natural frequency of the memory module, and it was verified with the simulation by using mode superposition method at a constant acceleration.

1. Introduction

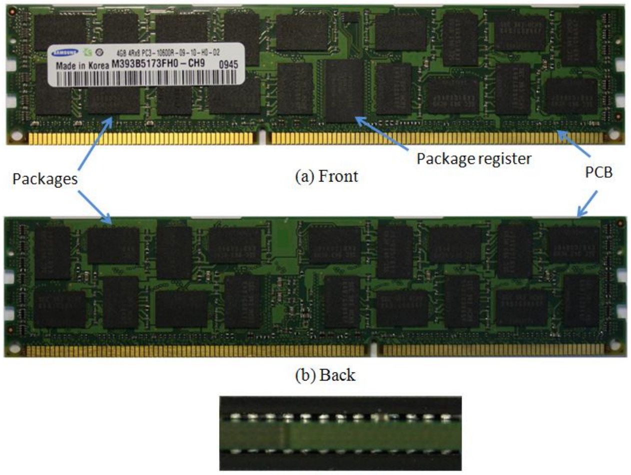
Memory module is a component composed of a number of packages mounted on a PCB. It is the one of the critical components used in the various applications such as Personal Computers (PCs), notebooks, workstations, servers, and so on. Packages are mounted on PCB by using a number of solder balls called Ball Grid Array (BGA). Solder balls are also used to provide electrical signals between chips in packages and PCB.

Memory modules are exposed to various kinds of vibration in the computer and during transportation, which may result in malfunction of products [1]. Reliability and performance of memory modules are standardized by Joint Electron Devices Engineering Council (JEDEC). Performance and life time of the memory modules are mostly depended on the solder joints. According to a report released by a semiconductor company, Solder Joint Crack (SJC) was approximately 40% of total failure. Therefore, it is very important to understand the dynamic behavior of memory module as well as the behavior of solder joint subjected to vibration. Several researches on memory module have been performed to meet the growing need of customer. Basaran and Chandaroy [2] presents a research based on a viscoplastic model to compute damage mechanics of Pb40/Sn60 solder alloys under different dynamic load conditions. They showed that the number of cycles to failure is reduced significantly when the dynamic load is applied with the thermal cycling.

Natural frequencies of the memory module have a great effect on the fatigue life of solder joint. This paper presents a finite element model of the memory module by using a finite element analysis tool, ANSYS and its response due to harmonic excitation of the memory module.

2. Analysis Model

A DDR3 SDRAM (Double-Data-Rate Three Synchronous Dynamic Random Access Memory) type memory module is shown in the Figure 1. The memory module is mainly composed of three components. One of the components is a bare PCB with a number of layers. The second component is the packages also shown in Figure 1.



(a) Front

(b) Back

(c) Solder joint

Fig. 1 A DDR3 SDRAM type memory module

There are the two kinds of packages composed of millions of Integrated Circuits (ICs) called the package and the package register. The other component is solder ball classified into sizes and package type they belong to. There are two types of solder ball used for the packages and the package register.

3. Method of Analysis

3.1 Finite Element Analysis

Finite element model of the memory module is presented in Figure 2. Components of the memory module were simplified due to complexity of structure. A bare PCB has a complex structure with number of layers composed of copper and FR4. The bare PCB can be assumed as a linear material here and is modeled as a solid element defined by eight nodes having three degrees of freedom at each node. Packages and solder balls are also simplified and modeled as solid element. Total number of element is around 151,000. In finite element model, packages and solder balls are connected by node sharing while nodes of solder balls and surface of PCB are connected by virtual connection.

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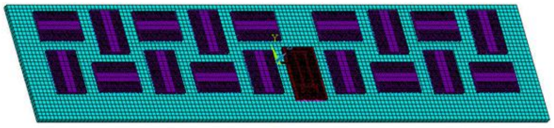
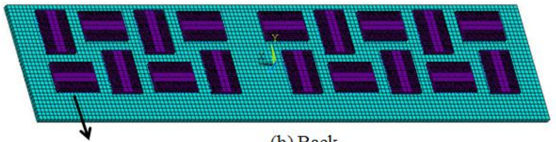


(a) Front



(b) Back

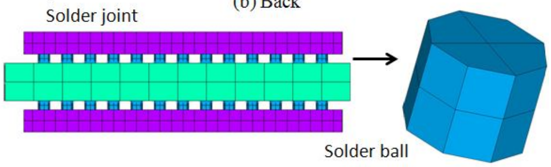


Fig. 2 Finite element model of a memory module

4. Results and Discussion

4.1 Free vibration analysis and experiment

Modal analysis of finite element model of memory module is performed by using ANSYS. The natural frequencies and the mode shapes are obtained for the free boundary conditions.

Experimental modal testing with free boundary conditions is performed to verify the proposed simulated results. An impact hammer is used to excite a memory module. The responses on the memory module are measured from 35 points by using a laser doppler vibrometer (sensor) and PULSE 3560C (signal analyzer). The mode shapes are measured by using the STAR modal system.

Table 1 shows the comparison between the undamped simulated and experimental natural frequencies of a memory module with free boundary conditions (BCs). Figure 3 shows the comparison between the simulated and experimental mode shape of vibration mode 1 of the memory module. The simulated results match with experimental one.

Table 1 Simulated and measured natural frequencies (*f*) of a memory module with free BCs

Mode number	Simulation *f* [Hz]	Experiment *f* [Hz]	Error [%]
Mode 1	266.03	262	1.51
Mode 2	742.4	716	3.56
Mode 3	819.98	790	2.44

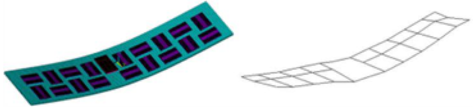


Fig. 3 Comparison of the first vibration mode between the simulation and the experiment

4.2 Harmonic Excitation Analysis of the Memory module and Experiment

The response of a memory module subjected to harmonic excitation was investigated by using mode superposition method. Finite element model of memory module was coupled rigidly from two shorts and one long side of the PCB with a nodal mass to present base excitation. The fundamental frequency with these BCs is calculated as 891 Hz. Harmonic excitation is applied to the nodal mass with constant 20 G level at the resonance frequency.

Experiment of a memory module due to harmonic excitation was carried out to verify the simulation results by measuring response on a package shown in Figure 4. Three sides of memory module were fixed to jig mounted on the top of the shaker. The acceleration variation of the shaker and response on the package was measured simultaneously. The simulated magnitude and frequency of the package matches with the measured one.

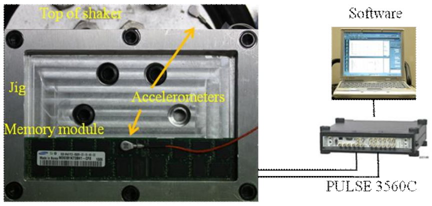


Fig. 4 Experimental setup for acceleration measurement

Figure 5 shows the acceleration variation of simulated and experimental result in time and frequency domain.

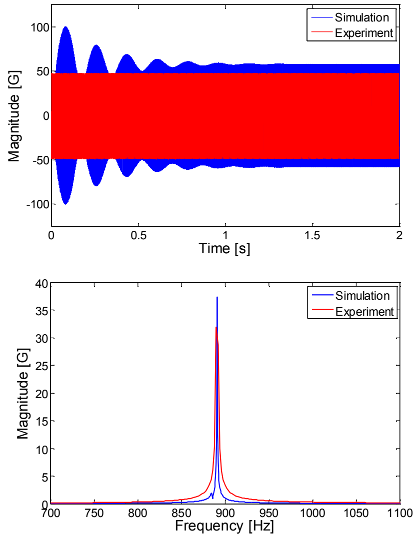


Fig. 5 Response on the package to harmonic excitation

5. Concluding Remark

This paper presents a finite element model of a memory module developed by a commercial simulation tool. Simulation results obtained by ANSYS are in the good agreement with experimental ones. The accuracy of the model is also verified by a forced vibration analysis. This research also shows that a method of simplification of the complex structure can be used to obtain reasonable results. This research will be extended to predict the fatigue life time of a memory module subjected to vibration.

References

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[2] Basaran C, Dhandaroy R., 1998, “Mechanics of Pb40/Sn60 Neareutectic Solder Alloy Subjected to Vibration”, Applied Math. Modelling, vol.22, pp.601-627.