

Prototyping of a reliable 3D flexible IC cube package by laser micromachining

Richárd Berényi

Budapest University of Technology and Economics, Department of Electronics Technology, Goldman t. 3, 1111 Budapest, Hungary

ARTICLE INFO

Article history:

Received 20 October 2007

Received in revised form 5 February 2009

Available online 28 April 2009

ABSTRACT

A newly designed three-dimensional (3D) flexible circuit as a package with five IC chips has been invented, and the prototype of the 3D package using laser micromachining has been successfully demonstrated. Fabrication processes of the 3D package consist of (1) preparation of printed wiring on the flexible substrate, (2) selective polyimide material removing on contact pads using UV laser (3) component placing and soldering, and (4) preparation of bending windows by laser micromachining. The production of the so-called bending window is a unique application of laser material processing. These windows can be used in flexible circuits to define the exact position of deformation. It is done by reducing the thickness of the flexible substrate in a well-defined, narrow line. The unique feature of this newly developed package is the 2D design for a 3D structure. According to this design, 55% area reduction can be obtained without any designing and overheating problems, which usually occurs. Furthermore, the new 3D package design can simplify processes such as I/O redistribution, chip cooling, and package formation. It is proven that the mechanical integrity of the prototype 3D stacked package meets the requirements of the 85 °C/85% test.

© 2009 Elsevier Ltd. All rights reserved.

1. Introduction

As the complexity of electronic systems for portable electronic, aerospace, and military applications increases, more demands are placed on lightweight and compact packaging technologies. To meet these demands, the three-dimensional (3D) packaging technology is now emerging as a breakthrough of overcoming the limit of two-dimensional (2D) packages. When considering PWB efficiency, the ratio of total chip area to the area of package 20–90% efficiency can be obtained from the current MCM packages. However, 3D technology can provide more than 100% chip area/package area. Although 3D packaging technology can offer remarkable advantages, there are still a few hindrances for this technology to be extensively applied. Therefore, there is a need for a simpler and more cost-effective 3D packaging design and technology.

In the 3D system integration the easiest ways are package on package, system in package, and system on chip. These packages require 2D design and the ICs are placed close to each other or parallel in space. There is no micro-via interconnection, only bumping and bonding technologies. One of the first studies and working high interconnect 3D system in a package was that of Chandler et al. [1] solved the 3D design problem. An other, 3D-Stacked IC model was employed by IMEC in 2006, where the connections were realized by micro-vias. By Yole Development [3], the 3D trends are open for real stacked, connected 3D ICs. This solution is the best to shorten interconnect length, to improve electrical performances. This technique could integrate different functional

layers (RF, memory, logic, MEMs, etc.) with TSV (Through Silicon-wafer Vias) [4]. Unfortunately it has a disadvantages, these assemblies are using rigid materials with difficult design and the first 3D chip for application with TSV predicted only after 2010 [5].

In this study, a newly developed 3D flexible package design and the reliability of the package will be evaluated with a dramatic improvement in compactness resulting in five chips in a package capable for different functions with lower overall area needs and easy 2D design [6,7].

2. Laser ablation of polymers

Polymers are interesting materials for many different applications due to their unique mechanical, electrical, and processability properties. With its versatility, laser processing by selective ablation of surface patterns can be used to fabricate structures into flexible polymer substrates. This research is focused on the laser ablation process of polymers with UV laser pulses of the nanosecond pulse width.

The main outcome expected from our experiments is a 3D structure of the patterned or processed layers. The article is supposed to give answer for our application: industry needs to introduce lasers for direct processing of polyimide foils to achieve high-resolution patterning and controlled ablation of the substrate [2]. At the same time the flexible substrate is a multilayer structure: laminated and patterned copper areas increase the number of factors that influence the interaction by making the substrate inhomogeneous as far as its thermal conductivity is concerned [16].

E-mail address: richard.berenyi@ett.bme.hu

3. 3D packaging with bend-and-stay flexibles

When the composite structure, which is called a flex circuit, is bent, the metal is plastically deformed and gives a mechanical strength to the structure. The objective during bending makes certain that the metal can exceed the elasticity of the polymer to hold the final shape. There are two different paths: making the copper thicker may make etching a bit more difficult; it will also take longer to etch and will use more chemistry. An alternative to reduce the thickness of the polymer along a well-defined, narrow window is preferred. This “bending window” generation is a unique application of laser material processing. A bending window can be used to define the exact position of the bending edge as well as the radius and the angle of the deformation [10].

4. Experimental results

To overcome the 3D design limitations, an alternative bend-and-stay approach that is based on bending technology using laser-processed bending windows is proposed. This design can be done in 2D, then the PWB can be bent to a 3D object. Packaging efficiency can be high because five pieces of ICs can be built together as a cube formation, as shown in Fig. 1. The total area for 5 IC (QFN, μ BGA) would be $5 \times 16 \text{ mm}^2$, using this package type it is reduced to 36 mm^2 (45%). This package size obtained with 5 mil line width. The working prototype prepared with 10 mil line width.

If the applied number of the ICs or other characteristic heat dissipating components were higher than five, another geometrical arrangement, like tetrahedron, octahedron, or cubo-octahedron could be used instead of the simplest cube.

In this package, the heat dissipating ICs are close to each other, and they cannot dissipate heat easily. For this reason, all the ICs in the package are connected to an internal heat distribution cube, which can dissipate the energy using heat pipe technology. The ICs can easily contacted with, Intek TCG thermal transfer compound which is formulated with select poly-dimethyl siloxane fluid in combination with metallic oxide fillers to provide superior thermal conductivity.

Predicting the temperature distribution inside the package is always a significant part of the design. The following simulation (Fig. 2) has been made by Comsol Multiphysics heat transfer module. At stationary state, the maximum temperature concluded at 69°C , at the bottom side.

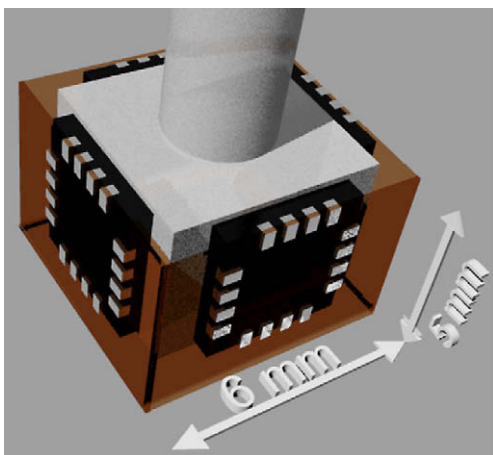


Fig. 1. 3D solution for IC arrangement (black: IC, grey: IC pads, brown: polyimide). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

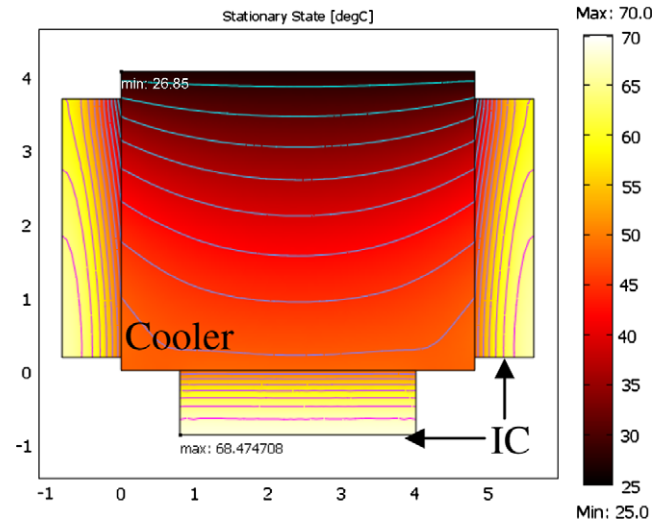


Fig. 2. Thermal simulation of a package (cube: heat sink, cylinder: heat pipe).

The components in the package are connected to the copper wiring with micro-vias [15]. As the copper wire lies in the outer surfaces, it can easily be connected to any other packages or circuit modules.

The application of bend-and-stay flexible-printed circuit boards to the unique 3D circuit module construction requires dimensionally very precise and well-controlled bending technology. It is also important to avoid mechanical degradation of the materials; therefore, the bending process must not cause excessive deformation. This is the reason for investigating the possible application of laser-processed bending windows.

5. Bending window opening by laser processing

In the experiments, a one-sided DuPont Pyralux flexible substrate was involved (FR9150R). The thickness of the insulation layers of the sample was $125 \mu\text{m}$.

The material removing process is a simple step-by-step work where the material is removed layer by layer, moving the laser beam in parallel lines. The whole ‘V’ shape is roughly $40 \mu\text{m}$ wide (Fig. 3) [8,9].

6. Multilevel laser machining

Investigation on the different geometrical forms of bending windows has proved that the application of a single ‘V’ form window for 90° bending is not reasonable (Fig. 4).

Bends over 90° place the greatest stress on formed areas. To decrease the mechanical stress, bending with distributed parameters was used. The bending is not concentrated at one point.



Fig. 3. Cross-section of ‘V’ form bending window, where the cut almost reached the copper layer.

Download English Version:

<https://daneshyari.com/en/article/549626>

Download Persian Version:

<https://daneshyari.com/article/549626>

[Daneshyari.com](https://daneshyari.com)