DEVELOPMENT OF LEAD-FREE SOLDERED 3D STRUCTURES

Michal Nicák
Doctoral Degree Programme (1), FEEC, BUT
E-mail: xnicak00@stud.feec.vutbr.cz

Supervised by: Josef Šandera
E-mail: sandera@feec.vutbr.cz

ABSTRACT

This paper describes design, construction and some test results of lead-free soldered three-dimensional structures based on combination of stacked thick-film Al_2O_3 or LTCC and FR-4 substrates. These various substrate configurations are realized in two ways, at first by lead-free solder bumps made by solder paste stencil printing, and at second by bumps using combination of paste and solder balls. This three dimensional technology offers great potential to very compact embedded structures which may include as hybrid integrated circuits (HIC) well as non-conventional applications (sensors, attenuators etc).

1. INTRODUCTION

Main goal of this work is development of method for design and implementation of a workable soldered 3D structure. The first step was definition and design of the simple 3D structure based combination of stacked Al_2O_3 and FR-4 substrates, connected together with solder bumps by use lead-free solder paste only, and the paste in combination with two types of balls, classic and solid-core solder balls. Usage of solder paste printed through extremely thick stencil is a new approach for TFT technology. We also tried to build multi-substrate structure (Fig. 1) with through-holes in alumina.

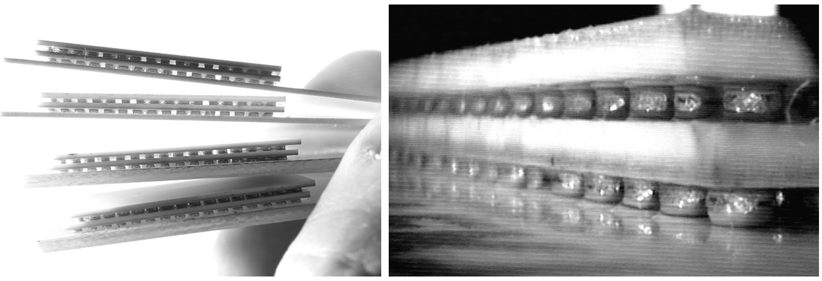

Fig. 1: Final soldered 3D stacked substrates

This can lead to cheap and compact base for devices like sensors connected with embedded thick film HIC´s, chips or SMD in one small package. This paste application allows assembling the whole structure together and then reflow everything together in one step by the use of vapor phase oven. Some results are being used as a base for further development of universal package fabricated using LTCC materials and various interconnection methods including solder paste bumps or solid-core soldering balls.

2. EXPERIMENT SETUP

As first step organic and alumina test substrates were designed (Fig. 2). Organic substrates were ordered and alumina-based substrates were fabricated by standard thick film technology using ESL AgPd conductive paste.

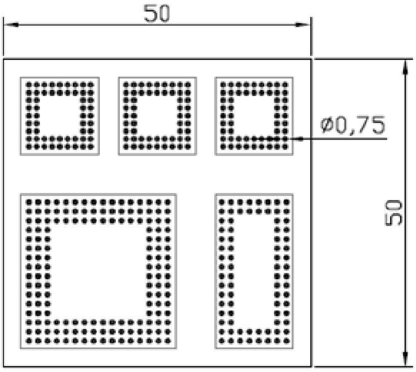

Fig. 2: Overall design of the base substrate, dimensions in millimetres

We also used CNC drill to prepare special stencil 550µm thick containing apertures with 0.8mm in diameter, which enabled us to print enough paste on substrates as shown in Fig. 3.

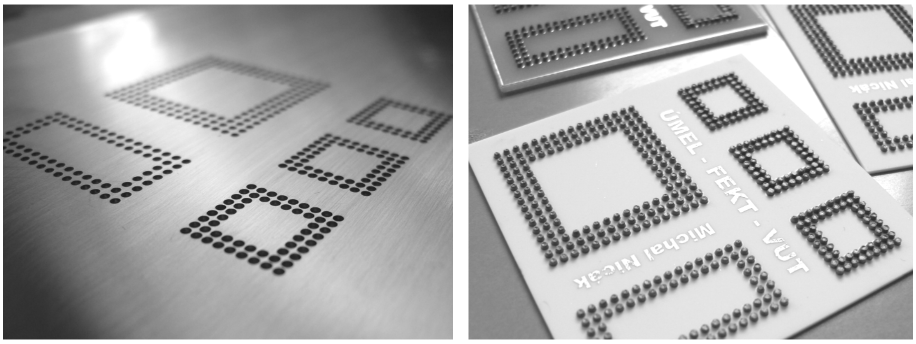

Fig. 3: Detail of stencil (left) and printed substrates (right)

Next challenge was to choose and to obtain suitable soldering material, including plastic-core Sekisui balls [2] and laser-drilled alumina substrates.

3. EXPERIMENTS

Moving to the experimental phase at first we needed to determine which paste to use for further experiments. After series of soldering tests (Fig. 4) we decided to use ESL EnviroFlo K545-39, Sn95 Ag3.8 Cu0.7 paste, because it met our requirements for printing with unusually thick stencil and also behaved well during reflow in vapour-phase oven.

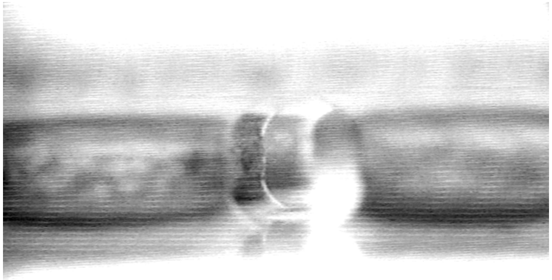

Fig. 4: Photo of soldered joints taken by using ErsaScope

Several structures were made using selected paste and printing methods were evaluated. Thick solder paste layer printed on the upper surface (Fig. 5), or two thin layers printed on both surfaces, proved to be a good solution.

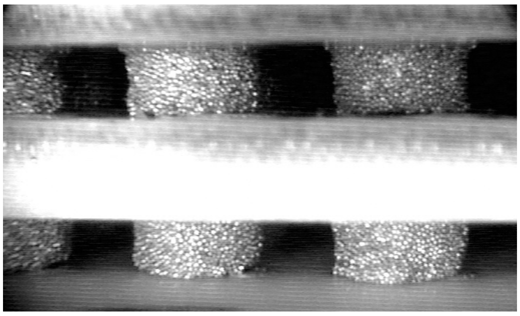

Fig. 5: Detailed photo of stacked substrates with solder paste printed on the upper surface of each.

The second mentioned method also allows the soldering ball to be placed between both paste layers. The solder paste holds balls securely during reflow, which is very difficult to achieve with standard fluxes, because silver-palladium pads are much less wettable and solderable comparing to copper pads.

The last part of this experimental stage was realization of 3D structure made from laser-drilled substrates. At first, hole-metallization issues were solved by usage of solder paste. We have tried to build structure, where solid-core balls held the defined gap between both surfaces. Microsection of the realized structure shows that this method should lead to build successful 3D structures on alumina ceramics (Fig. 6).

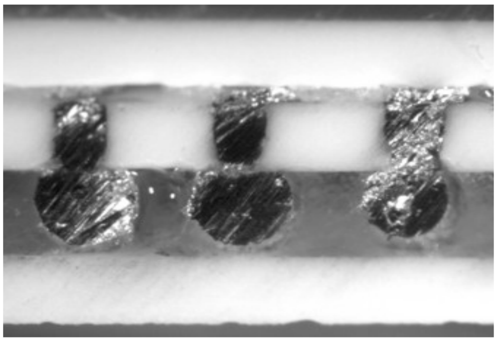

Fig. 6: Microsection of soldered 3D structure with metalized through-holes and plastic-core solder balls holding gap.

4. ACTUAL DEVELOPMENT - LTCC

Current research continues with LTCC substrates, which replaced previously used alumina. We decided to use Heraeus HeraLock HL2000 tapes [4]. This material is characterized by almost zero shrinkage in x and y axis during firing. Only z axis shrinks by about 30%. The main advantage of LTCC is the possibility of machining raw material into desired shape before firing, which is much easier than machining alumina substrate.

So far we have conducted initial experiments aimed at creating the “dimpled structure” (Fig. 7) which consists of two LTCC layers as a base, Ag paste printed on these two layers as a conductive pattern and finally one LTCC layer containing holes with 0.5mm in diameter.

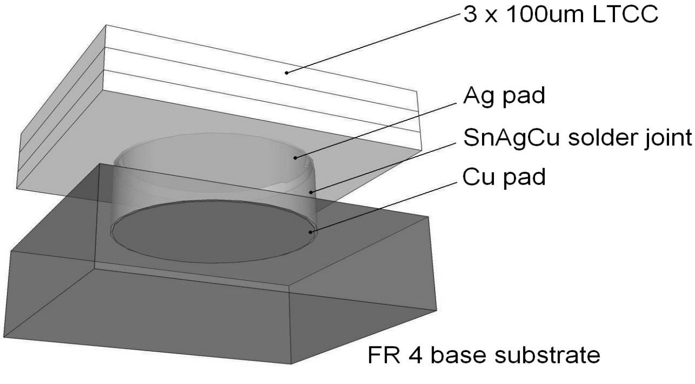

Fig. 7: Detail showing dimpled LTCC structure soldered to FR 4 substrate

This structure is supposed to hold solder balls securely on place during reflow and it also prevents short-circuits.

Pattern selected for initial tests corresponds to standardized BGA patterns and connected by daisy-chain it allows us to examine samples for the occurrence of a fault during thermal cycling. During next phase, we will use new dedicated layout usable for testing and comparing both LTCC and Al_2O_3 substrates. Also dedicated cofireable solderable silver based conductor paste TC0306 [4] produced by Heraeus will be used for HL2000 LTCC structures.

5. CONCLUSION

This research shows that it is possible to build 3D stacked and interconnected structures based on ceramic substrates and solder paste bumps or solid-core solder balls. These structures can combine the ceramic’s advantages of thermal and mechanical properties with organic substrates and other technologies resulting in compact system. Possibility of one step reflow also features way how to reduce number of reflow cycles and save energy. Our research continues and is now focused mainly on LTCC substrates stacked and interconnected together, which brings new challenges for materials and technology.

ACKNOWLEDGMENT

Funding for this research was obtained through grant project from the Czech Ministry of Education (MSM 0021630503 MIKROSYN „New Trends in Microelectronic Systems and Nanotechnologies”) and the Grant project GACR 102/09/1701 “Research and Development of New Principles in Soldering to Increase Solder Joints Reliability”. Research has also been supported by the Czech Ministry of Industry and Trade in the frame MPO TIP FR-TI1/072

REFERENCES

[1] Tummala, R. : Introduction to System-On-Package, The McGraw-Hill, 2007

[2] Sekisui SOL - Plastic Core Solder Balls assembly applications, available from WWW: http://www.sekisui.com.hk/eng/product/fcd_a05.htm (March 2010)

[3] Nicák, M.; Szendiuch, I.: Moderní pouzdření a 3D systémy - diploma thesis, Brno, 2009, available from WWW: https://www.vutbr.cz/?gm=gm_prohlizeni_zp&zp_id=23601 (March 2010)

[4] Heraeus HL2000 Design Guidelines, available from WWW: http://www.heraeus-thickfilm.com/media/webmedia_local/media/datasheets/ltccmaterials/HL2000DesignGuidelines.pdf (March 2010)