ULTRA SMALL SYSTEM-IN-PACKAGE FOR MEDICAL APPLICATIONS

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ABSTRACT

The 3-D Interconnection technology has been industrially developed for 11 years, and as of 2001, an extremely ambitious European programme “Walpack” (45 millions USD) has allowed to develop a new interconnection technology about 20 times denser.
This technology is full wafer level, but does not use the Wafer-to-Wafer techniques since they do not generally allow Systems-in-Package.
It has been named Wirefree Die-on-Die (“WDoD”) and utilises the Rebuilt Wafer notion.
Whatever the type of dice, a wafer is rebuilt from dice, not necessarily KGD.
This technology allows to build Systems-in-Package from totally heterogeneous dice (memories, processors, analogue devices, passive components, MEMS, antenna, etc).
The sizes of the module obtained are extremely small: in X, Y only 100 µm are necessary around the largest die. In Z, the thickness of one level is 100 µm, hence the stacking of 10 levels per mm.
This WDoD technology allows to test and/or burn-in the levels prior to stacking, which leads to extremely good yields.
Some applications have been performed such as micro cameras for endoscopy and ultrasonic echography.
An European project using the WDoD will allow to build a complex medical system which comprises storage and calculation dice (memories, processors), communication dice with associated antenna, energy storage, cryptography, MEMS in the 3 directions, the whole in a volume well under one cm3.
These extremely ambitious approaches become possible thanks to these Wafer Level Package interconnection techniques.

Key words : System In Package, Stacking, Full Wafer Level, 3-D

INTRODUCTION

The fantastic development of the components interconnection allows to imagine « Systems in Package » of around a few mm3, which opens new perspectives for medical applications.
Since the use of hybrid modules, then Multichip Modules « MCM » which were identical to the previous ones but named differently, the coming of the interconnection in 3-D allowed to divide both the volume and weight of a module by a factor comprised between 25 and more than 100.
We can distinguish several technologies among the technologies used for the 3-D interconnection, (table figure 1)

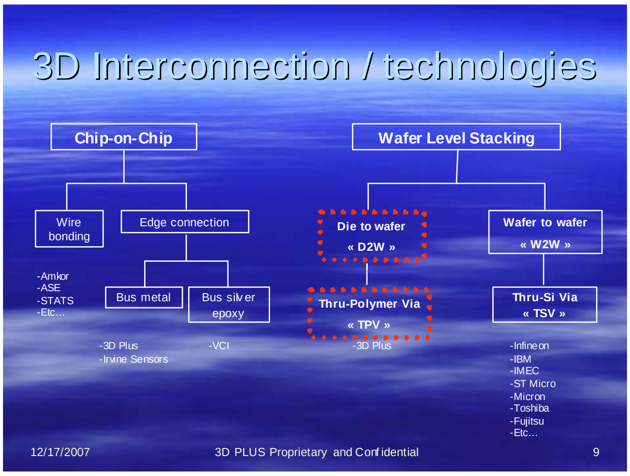

Figure 1

. The so-called Chip on Chip technology, with the chips interconnection carried out by wire bonding
. The Wafer Level Packaging technology with an interconnection carried out without wire bonding ; These lead to modules even denser than the above ones.

Among this last category, two families can be distinguished :

- The technology called Wafer to Wafer studied and developed by almost all the semiconductors manufacturers and the large laboratories worldwide, and which is based on the use of Thru Silicon Via « TSV » ; This technology presents the following disadvantages :
. Use of non standard wafer with the need for smallest possible Thru Silicon Vias. For instance, vias of 2µm diameter lead to a thickness of 20µm or less for the 8 or 10inches wafer
. Cost for a set of new masks at least K$ 500
. Copper’s TSV inside the silicon leads to a composite material which modifies its mechanical properties
. Almost impossible to make “System in Package” since die of different size
. Impossible to have 100% good wafer (very low global yield)

- The technology named Stacking of Known Good Rebuilt Wafer which is based on the Edge Connection and the Thru Polymer Via « TPV ». This technology avoids these

disadvantages and adapts perfectly to the Systems In Package as well as to small and large volumes.
We have registered a trade mark : Wirefree Die on Die « WDoD » :
. Use of standard wafers without TSV
. Each layer testing prior to stacking, only "Known Good Rebuilt Wafer" are stacked
. Parallel processing from A to Z with the standard semi-conductor equipment
- Very small form factor:
- Thickness of each layer: 100µm (10 levels perm)
- Size: 100 µm around the larger die

This approach can very well be adapted to medical applications, which by essence necessitate heterogeneous components and small and medium volumes.
For large volumes, we will be fabless and are signing agreements with semiconductors manufacturers. A non-exclusive agreement has been signed with NXP Semiconductors.

ULTRA LOW PROFILE 3-D TECHNOLOGY

This technology resulted in the registration of more than 23 patents worldwide. The flowchart is represented on figure 2

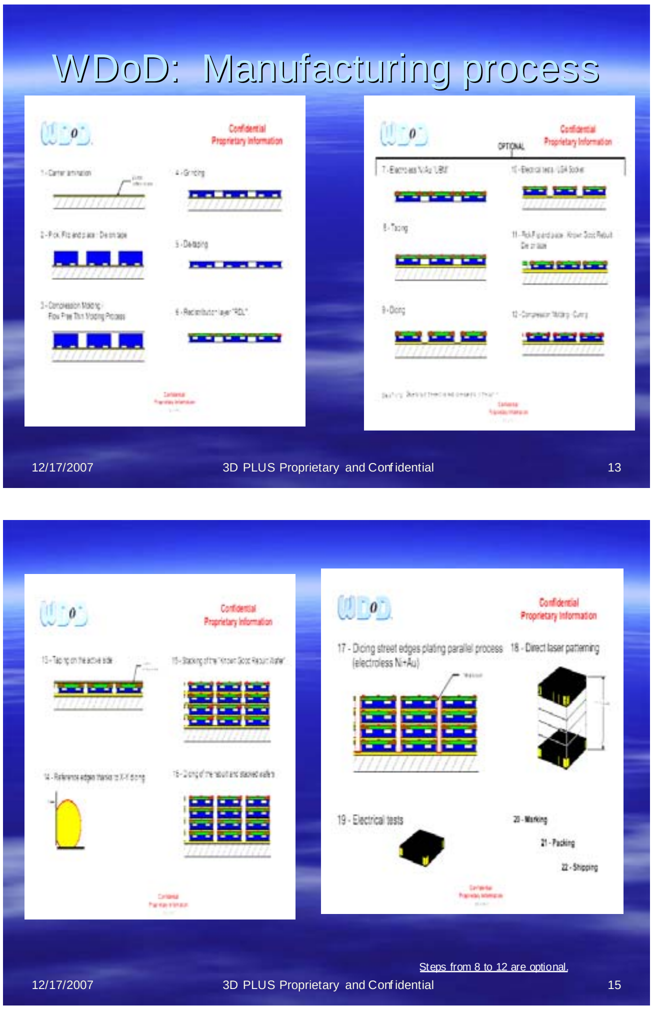

Figure 2

It can be observed that steps from 7 to 12 are optional, they are used only when the Burn-In is necessary, this is the case with some memories such as DDR or some analogic components or ASIC.
Figure 3 shows a « Known Good Rebuilt Wafer » of 6" diameter

Figure 3

The status of this « WDoD » technology is the following :
- Proof of concept completed (2001 to 2004) with an European funding of 45M US$ with several companies: CEA/LETI, Thales, ST Microelectronics, Gemalto and 3D Plus
- Process development and optimization with NXP/Philips (4Q 2007)
- Functional prototypes/Qualifications (2Q 2008)
- Ramp up for the manufacturing (3Q 2008).

APPLICATIONS

Applications for endoscopy

Since year 2000, microcameras heads are being developed and manufactured for endoscopy medical applications. The size of these heads has followed the evolution of these CCD sensors.

The 1/6" camera head, initially manufactured by stacking of the sensor which packaged in TAB.
The price of the TAB CCD has drastically increased, while the cost of the same CCD sensors mounted in ceramic chip carrier is much more lower.

It has been decided to stack this type of ceramic package with the other components, which led us to modify the chip carrier in order to keep within the sizes of the camera, i.e. 3.2 mm X 3.2 mm. The ceramic chip carrier as well as the levels bearing the components are sawn by means of blade diamond, the process of plating and direct laser patterning being carried out as before. Several sizes of CCD can be used to manufacture these cameras :
1/6" camera – diameter : 4.8 mm (Figure 4)
1/10" camera – diameter : 2.8 mm
1/15" camera – diameter : 1.8 mm

Figure 4

Applications for Hard X-Ray camera [1]
Although this camera has not been designed for the medical field, it perfectly represents the current trend which consists in using a pixels array, which catches a radiation and transforms it into an electrical signal which must be then amplified and multiplexed.
In order to perform all this, it is absolutely necessary to use stacking techniques, as one electronic level must be placed under each column of the array.

One first camera was equipped with a 64-pixel array sensor.
Another one is being designed with 256 pixels of 625-micron pitch, instead of 1-mm pitch with 64 pixels.
Figure 5 represents one hard X-ray camera of a 64-pixel dummy.

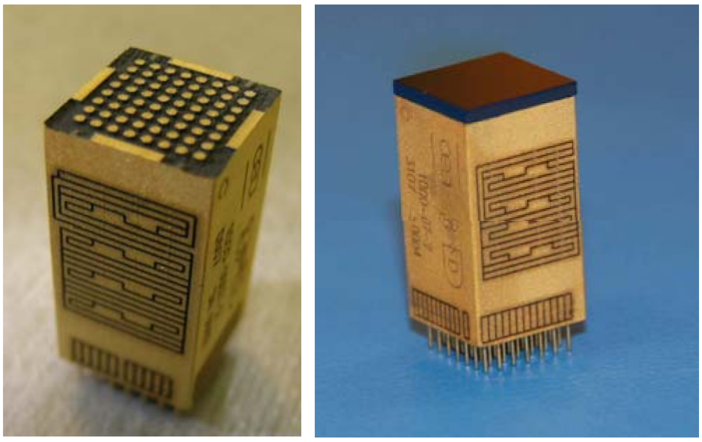

Figure 5

Applications for ultrasonic echography
The same stacking principle of level perpendicular to the pixel array as the one utilized for the X-ray camera, will be used.
A development is in progress with the French company Vermon which specializes in ultrasonic materials.

Para-Medical Applications
A device for localisation of avalanches victims is currently being developed with CEA/LETI. The 3-D module comprises accelerometer sensors and magneto-resistive sensors which allow to spot precisely the victim by triangulation.

Micro stimulators
3D Plus has prototyped an extremely dense SiP built with the WDoD technique for micro stimulators applications. The electronic (5 ASIC) had a size of 1.4 mm X 7 mm X 0.7 mm and was placed inside a tube of 3-mm external diameter.

PERSPECTIVES

The extreme miniaturisation brought by the WDoD technology allows to contemplate the possibility of multi-functions System-in-Package (SiP) :
- Multi-sensors function
- Multi-functions amplifier
- Storage function
- Signal treatment function
- Cryptology function
- Energy management function
- Energy storage function
- Communication function with associated antenna

Several significant European projects are currently in progress, among which the “White Bird” project for medical applications.
These projects derive from a very important European project, e.Cube, started in 2006, one application of which consists in building abandoned sensors for aeronautic applications. This type of System-in-Package takes up a part of the functions mentioned above and will comprise around 30 bare dice and associated passive components for a volume of 6 X 6 X 6 mm.
It will be placed within planes structure in order to measure their ageing.
Several hundreds of these modules will be used per plane ; they should be as small as possible with the smallest weight in order not to interfere on the structure and most importantly be completely independent with regard energy and communication.
Figure 6 presents a prospective view of what could be the future SiP for medical applications ; a part of its bricks being used for the White Bird project.

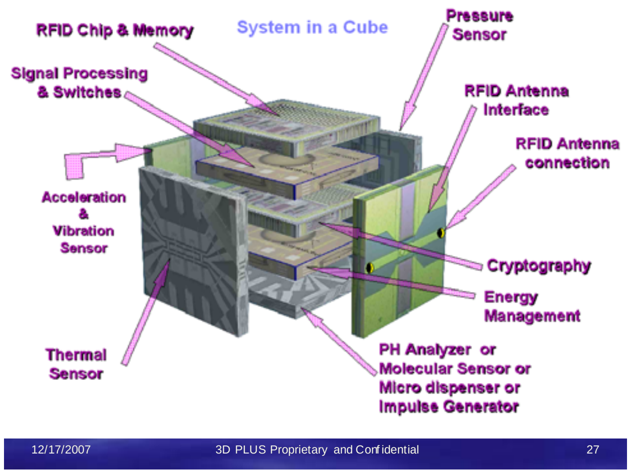

Figure 6

CONCLUSION

The stacking of components has reached an extremely high degree of miniaturization, since we manage to stack 10 levels per mm, even 15 in a near future, and since additionally we know how to stack MEMS and sensors.
However, as MEMS should in no way be in contact with humid resin or even be stressed, we have developed a technique called “opposite dual cavity”, which permits to stack and mould the MEMS. (Figure 7).

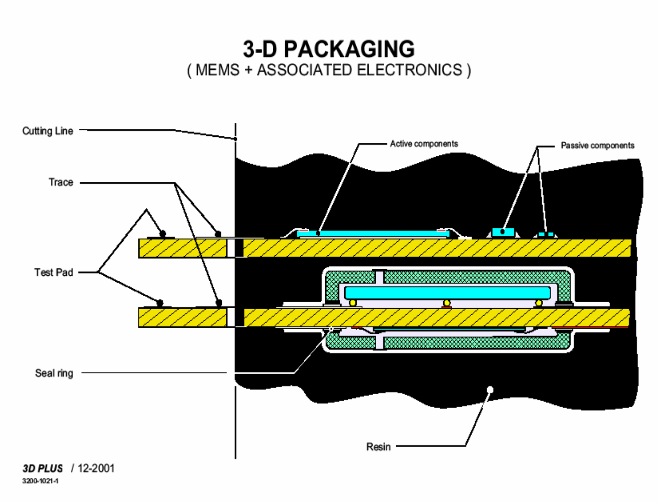

Figure 7

The needs of the medical market represent a major application for this type of technology.

In the space field, for instance, a transposition of this type of of SiP could give appearance of the paradigm of Satellite-in-a-Cube, which means a SiP gathering all the functions, including navigation and propulsion in a cube of approximately 1 cm3.

[1] A. Meuris, O. Limousin, F. Lugiez, O. Gevin, F. Pinsard, I. Le Mer, E. Delagnes, M.C. Vassal, F. Soufflet, R. Bocage
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