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Presentation title:

2.5D, 3D Assembly Technologies for RF, mmW and Sub-THz Heterogeneous Systems

ABSTRACT

Heterogeneous integration is a must for future mmWave, sub-THz communication systems: there is fierce competition to develop components and systems with high data communication bandwidth. Combining III-V high speed/low-noise technologies with ultra-dense smart CMOS/BiCMOS technologies is a promising and exciting approach to investigate. Many technical challenges need to be addressed in different areas of physics: mechanical, electromagnetic, thermal. The solutions to these multi-physics problems must be cost-effective with a reasonable environmental impact in order to have a chance to be in pockets, cars, communication infrastructures, and others in a few years. CEA-Leti is investigating different 3D integration solutions that have been mastered in-house for tens of years, from the most mature one to the most advanced: chiplet copper pillar assembly and die to wafer direct hybrid bonding. This presentation focuses on different issues raised by mmW/sub-THz heterogeneous integrated systems and is illustrated by concrete examples.

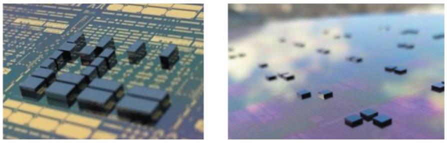

Fig. 1. 3D assembled demonstrators: (a) copper pillar assemblies; (b) direct hybrid bonding assemblies.

A passive silicon radio frequency (RF) interposer was designed and manufactured. It is the basis of many different passive and active RF-3D objects and demonstrators as shown in Figure 1. Top dies of different technologies can be reported on different bottom footprints, dedicated to RF measurements and characterizations, using different CEA-Leti 3D assembly techniques. Some passive structures, such as transmission lines in 2D and 3D contexts and their RF performances,

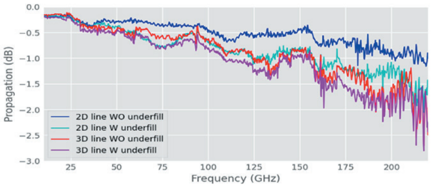

Fig. 2. Transmission line propagation in 2D and 3D contexts.

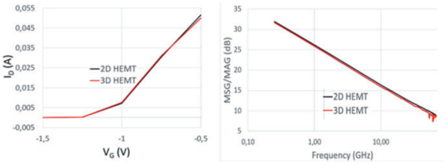

Fig. 3. DC and RF measurements of 2D vs. 3D GaN-High Electron Mobility Transistor (HEMT).

have been investigated (Figure 2). Several III-V devices were also assembled on the passive RF interposer: a GaN-RF HEMT, on which some electrical measurements are shown in Figure 3, and other indium phosphide (InP) Double Hetero-junction Bipolar Transistor (DHBT) using a similar 3D copper pillar assembly strategy will be presented. These different demonstrators allow evaluation of issues and optimizations to address to reach the electrical performances needed for future heterogeneous RF systems. The environmental impacts of the evaluated 3D assembly technologies are also studied and compared (Figure 4).

If the chiplet copper pillar assembly shows interesting results for short- and medium-term 3D RF applications, optimizations and enhancements will allow the direct hybrid bonding process to open up new fields of possibilities for 3D RF systems in the medium and long terms.

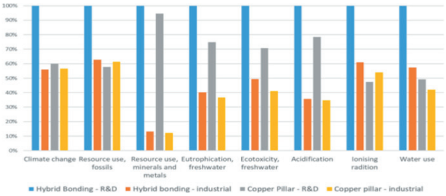

Fig. 4. Impact assessment comparison of hybrid bonding and CuPi.

KEYWORDS

Copper pillar, direct hybrid bonding, heterogeneous RF systems, impact assessment, passive RF interposer.

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BIOGRAPHIES

Dr. Olivier Valorge joined CEA-Leti in September 2020. He received the Ph.D. degree in 2006 from INSA, Lyon, France, on substrate and power supply coupling in mixed-signal integrated circuits. This work was carried out in an industrial design environment: a mixed-signal design team at STMicroelectronics in Grenoble (France). Since 2006, his research has been focusing on possible applications of high technology devices in the semiconductor industry, in particular heterogeneous 3D integration for communication and lighting systems. He has worked as a researcher or research engineer in several academic, industrial, or start-up R&D units in France and Canada. His current research focuses on 3D heterogeneous integration for sub-THz applications and he coordinates CEA-Leti advanced internal projects

Dr. Christophe Dubarry received the M.Sc. degree in process engineering in 1996 from the University of Grenoble, France. He received the Ph.D. degree from University Joseph Fourier of Grenoble in 2001, with a thesis on the soft magnetic material CoFeCu for passive components. He joined CEA-Leti in 2001 in the framework of photonic devices development for laserdiscs. From 2008 to 2017, he worked in the new energy department for solar cells and microbatteries as a Process Integration Engineer and was involved in several European projects. Since 2017, he has been working at the Component on Silicon Department in CEA-LETI as a Device Integration Engineer and Project Leader. He is currently developing interconnection, in particular, bump and hybrid bonding for photonic and RF applications.

Dr. Hervé Boutry received the M.Sc. degree in materials sciences and microelectronics engineering in 1997 from the University of Lille, France. He received the Ph.D. degree from the Institute of Microelectronics and Nanoelectronics of Lille in 2002, with a thesis on the technological development of high electron mobility transistors based on Antimonide III-V based semiconductors for high-frequency low-noise amplifiers. After a few years at UCL-Louvain, Belgium, in the materials and physics laboratory, he joined CEA-Leti in 2004 in the framework of TFT transistors development for microdisplay cells. From 2008 to 2012, he worked in the Packaging and Interconnection Laboratory as a Process Integration Engineer and involved in several European projects. Since 2012, he has been working at the Component on Silicon Department in CEA-LETI as a Device Integration Engineer and Project Leader. He is currently developing an InP-based HBT technology integrated in Si-Fab platform.