Low-Temperature 3D Integration Processes for Advanced Sensor Systems

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Abstract: Key application demonstrators of heterogeneous 3D integrated systems were evaluated already in 2009 by Infineon, SINTEF and Fraunhofer for automotive sensors [1] and later in the European Integrating Project e-BRAINS by a consortium of Infineon, Siemens, IMEC, CEA, SINTEF, Tyndall, Fraunhofer, EPFL and others for bio-sensors (Magna, Infineon, EPFL), infrared imagers (SensoNor, SINTEF), active medical implants (Sorin, 3D Plus) and smart gas sensors (Siemens, EPFL, Fraunhofer). A particular focus of the e-BRAINS project was the development of novel low-temperature processes for highly reliable advanced sensor systems [2]. As another key application, we demonstrated high-performance communication devices with Infineon Technologies Austria, IMEC, Fraunhofer and EPFL. For high frequency components, Fraunhofer EMFT developed a specific fine-pitch 3D-TSV technology for RF-MEMS and RF-IC applications. High-performance RF test structures, antennas and 3D embedded high-Q RF inductors were designed and evaluated by EPFL and IMEC [3-4].

One of the main drivers of 3D heterogeneous integration is certainly sensor integration. The system integration of sensors with ICs, passive components and even energy harvesting systems is becoming more and more important especially for the high growth market area of distributed wireless sensor systems – which will constitute the key connected hardware infrastructure of the Internet-of-Things (IoT). The application IoT is predicted as a third wave of MEMS proliferations, after Automotive and Mobile Phones. A subset of IoT are “smart objects” showing local intelligence and awareness. We are in the phase of rapidly growing markets and increasing competition and we must reach for cost reduction, standardization and increasing functionality and performance. A corresponding key is simplification of processes and explicitly regarding the fabrication of device stacks by wafer bonding. The challenge to realize such complex 3D systems mainly consists on the heterogeneity of the components – typically at least one sensor, one IC for data processing and one IC for data transmission. In this field the new low temperature processes are the key to realize robust heterogeneous sensor system with high performance and reliability. Relevant bonding schemes, including oxide-oxide bond and variants of metal bond technologies - as thermocompression bonding, solid-liquid-interdiffusion (EMFT) and DBI® (XPERI) - will be compared. The dicussion is focused on bond quality for MEMS processing and 3D Integration of sensor/IC products and critical process temperatures for the integration of sophisticated devices as charge sensitive fluid sensors [5], vertically stacked SiNWs, fin or ISFET bio-sensors [6-7] and capacitive gas sensors (based on CNT [8] and other technologies). In addition, the integration and post-process limitations of other *beyond CMOS* devices will be discussed as the tunnel FETs, negative capacitance and metal insulator transition (MIT) phase change materials (as VO_2 [9]) which present interesting subthermionic switching principles (steep slope switches), very promising for ultra-low power applications.

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