Future Microsystems for Extreme Environments

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At the 2023 DARPA Electronics Resurgence Initiative (ERI) 2.0 Summit, it was emphasized that the next major wave of microelectronics innovation is expected to come from the ability to integrate heterogeneous materials, devices, and circuits through advanced packaging, producing a tightly-coupled system that extends into the third dimension, with performance that exceeds what is available from today's monolithic approach. These 3DHI (3-dimensional heterogeneously integrated) microsystems are anticipated to provide significant performance advantages in sensor and information processing efficiency at the edge, artificial intelligence and machine learning, secure communications, and electronics that not only tolerate, but thrive in extreme environments across the globe and beyond.

In this context, 3DHI refers to separately-manufactured components composed of distinct heterogeneous materials that are stacked in the third dimension (through chip-to-wafer, chip-to-chip, or wafer-to-wafer assembly) within a single integrated package. This tight physical density offers revolutionary improvements in functionality and performance. To broadly impact defense systems, the types of microelectronics that can be integrated and assembled must be expanded to include materials and functions such as compound semiconductors for radio frequency (RF) and photonic interconnects, novel memory devices for computing, magnetics for filtering, and wide-bandgap and ultra-wide-bandgap semiconductors for power electronics. In order to address such a diversity of materials and functions, integration technologies will be challenged to improve thermal management, improve power conditioning, improve testing and electrical characterization for known good die, and improve the design tools for modeling and simulation of these new microsystems. This presentation will focus on some of these challenges related to manufacturing complex 3DHI microsystems, including the need to evaluate the reliability of these microelectronic systems and discuss particular considerations for extreme environment microsystems.

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