CHIPS Act : Semiconductor Manufacturing Science and Technologies
Room 207 A W - Session CPS+MS2-MoM
Digital Twins and Advanced Packaging for Semiconductor Manufacturing

Moderators: Tina Kaarsberg, U.S. Department of Energy, Advanced Manufacturing Office, **John Lannon**, Micross

10:30am **CPS+MS2-MoM-10 Overview of research at the Center for Heterogeneous Integration Research in Packaging (CHIRP) Center*, Srikanth Rangarajan,*** Binghamton University **INVITED**

The Center for Heterogeneous Integration Research in Packaging (CHIRP) is a leading research center dedicated to advancing the field of heterogeneous integration (HI) for next-generation electronic systems. This talk provides an overview of CHIRP's research activities, focusing on novel packaging technologies, materials, and designs that enable the integration of diverse components with enhanced performance and functionality. We will highlight key projects and recent advancements in areas such as chiplet-based integration, 2.5D/3D packaging, thermal management, and reliability. Furthermore, the presentation will outline CHIRP's collaborative ecosystem and its role in shaping the future of microelectronics through innovative HI solutions.

11:00am **CPS+MS2-MoM-12 Digital Twins and the SRC MAPT2 Chapter on Digital Twins and Applications*, Robert Baseman,*** IBM Research Division, T.J. Watson Research Center **INVITED**

The semiconductor industry anticipates substantial reductions in manufacturing costs and product times to market as a result of deploying digital twins throughout the design and production ecosystem.Recognizing this, the SMART USA Institute was established as part of the CHIPS Act to accelerate efforts to develop, validate, and use digital twins to improve domestic semiconductor design, manufacturing, advanced packaging, assembly, and test processes.

Here we summarize Chapter 12 of the Semiconductor Research Corporation’s Microelectronics and Advanced Packaging Technologies Roadmap2 (SRC MAPT2), a collaborative effort of experts from academia, industry, and national labs.This new Chapter in MAPT2 is intended to provide a digital twin focus to the industry Roadmap, to inform the SMART USA Institute strategy and to illustrate how digital twins will support the US NSTC Strategic Plan and the National Strategy on Microelectronics Research.

Digital twins of relevance to the semiconductor industry and considered in the Chapter include twins of a vast scope: from twins of atomic scale surface chemistry processes with a characteristic time scale of picoseconds to twins of global supply chains with a characteristic timescale of years.

The Chapter characterizes the state of the art, future industry requirements, challenges to be overcome, and enabling technical directions for twins *per se,* infrastructure enabling development & deployment of twins, and applications of twins.The Chapter includes some perspectives on assessing the impact of twin deployment and concludes with some illustrations of how digital twins will support several domestic strategic initiatives.

11:30am **CPS+MS2-MoM-14 Digital Twins Meet Materials Science: Real-Time AI Analysis for Advanced Manufacturing*, Jeff Terry,*** Illinois Institute of Technology

We have developed an artificial intelligence (AI)-driven methodology for the automated and reliable analysis of advanced materials characterization measurements, including Extended X-ray Absorption Fine Structure (EXAFS), Nanoindentation, X-ray Emission Spectroscopy (XES), and X-ray Photoelectron Spectroscopy (XPS). These techniques are critical for probing the chemical, structural, and mechanical properties of materials at the nanoscale and are commonly deployed across semiconductor fabrication lines for quality assurance, process control, and failure analysis.

At the heart of our approach is a genetic algorithm capable of extracting physically meaningful structural parameters by fitting experimental spectra to a curated set of candidate chemical configurations. Analysts provide a preliminary list of potential compounds and corresponding computational inputs, after which the algorithm iteratively refines the model to best match the observed data. This process is implemented in our open-source Python analysis framework, **Neo**, which is designed to support modular, high-throughput, and reproducible analysis pipelines.

Importantly, Neo interfaces directly with the **XPS Oasis** and **XES Oasis** databases—comprehensive, structured repositories of curated spectral reference data. These databases allow Neo to draw from a rich library of previously characterized materials and electronic structures, significantly enhancing its ability to identify subtle differences in chemical states and bonding environments. This capability is especially valuable in semiconductor production, where minor variations in composition or surface chemistry can have outsized impacts on device performance and reliability.

By embedding this AI-enabled analysis tool within production environments, manufacturers can achieve **real-time, in-line monitoring** of materials during fabrication. Moreover, by streaming these insights into **digital twin platforms**, facilities can build continuously updated virtual models of the physical production line. These models enable predictive analytics, fault detection, process optimization, and adaptive control—ultimately reducing downtime, improving yield, and enhancing materials traceability throughout the supply chain.

Author Index

Bold page numbers indicate presenter