Sustainable Additive Manufacturing of Electronics and 3D Heterogenous Integration for Advanced Packaging

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What if there were an electronics manufacturing technology that could reduce costs by 10-100 times compared to conventional semiconductor manufacturing and the carbon footprint by more than one order of magnitude? Imagine if this technology does not use any corrosive or toxic chemicals. Such a technology exists, and it is the topic of this presentation. It is enabled by the directed assembly of suspended nanoparticles [2] at room temperature and pressure and manufactures devices 1000 faster and 1000 smaller structures than inkjet-based or 3D printing. The process is scalable, environmentally sustainable, and enables precise and repeatable manufacturing of various nanomaterials at a very high rate. This allows the printing of passive and active components monolithically on an interposer platform along with a trace such that the total footprint can be within a few mm of the original IC footprint. The technology has been sown to reduce the carbon footprint by 10-20 times depending on the type of directed assembly method used. The presentation will show the electrical properties of capacitors, resistors, and transistors that are made using a fully additive process down to the submicron scale without using etching, vacuum, or chemical reactions. The presented technology enables the printing of single-crystal conductors and semiconductors [3]. The process demonstrates the manufacturing of transistors with an on/off ratio greater than 10^6.

An immediate application for this technology is 3D heterogeneous integration for advanced packaging applications, where there is a need to shrink the size of traces and interconnects to integrate different passive and active components, including memory, microcontrollers, and power electronics. The new ultrafine resolution requirements for 3D heterogeneous integration have prompted many advanced packaging processes to be transferred to foundries, rather than relying on traditional packaging processes. This led to a much higher cost that made the most advanced packaging applications out of reach for many small companies. This additive high-throughput manufacturing solution can enable low-cost trace, interconnect, passive, and active components manufacturing.

[1] SA Abbasi, A Busnaina, JA Isaacs, "Cumulative energy demand for printing nanoscale electronics," ***Procedia CIRP***, 2019.

[2] Z. Chai, A. Childress, and A. Busnaina, Directed assembly of nanomaterials for making nanoscale devices and structures: Mechanisms and applications," ***ACS Nano***, 2022.

[3] Z. Chai, A. Korkmaz, C. Yilmaz, and A. Busnaina, "High-Rate Printing of Micro/Nanoscale Patterns Using Interfacial Convective Assembly," ***Advanced Materials***, 2020, 2000747.