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Additive Manufacturing of Micro and Nanoscale Electronics for Heterogenous Integration and Advanced Packaging

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In advanced packaging, there is a need to shrink the size of interposers and be able to integrate different passive and active components in addition to memory, microcontroller, power electronics, etc. The new ultrafine resolution requirements for 3D heterogeneous integration have moved many advanced packaging processes to foundries instead of 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. It allows the required passives and active components to be manufactured along with the trace such that the only added discrete packaged components, such as microcontrollers. This technology will reduce cost by 10-100 times compared to conventional semiconductor manufacturing. It is enabled by directed assembly-based 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 presentation will show the electrical and materials chrematistics 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 [1]. The process demonstrates the manufacturing of transistors with an on/off ratio greater than 10^6.

[1] Z. Chai, A. Korkmaz, C. Yilmaz, and A. Busnaina, Advanced Materials, 2020, 2000747.

[2] Z. Chai, A. Childress, and A. Busnaina, ACS Nano, 2022.