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GREEN THIN FILMS: FROM PROCESSING TO APPLICATIONS

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The rapid expansion of electronic technologies—driven by wearables, IoT systems, and large-area sensing—continues to challenge global sustainability efforts. Electronic waste has reached unprecedented levels, with 62 Mt generated worldwide in 2022 and projections surpassing 82 Mt by 2030. This accelerating waste stream, combined with the depletion of finite raw materials, underscores a critical question: How can we sustain technological growth while reducing environmental impact?

A central part of the solution lies in the development of sustainable electronic materials and low-energy fabrication methods that break away from conventional silicon-based, resource-intensive manufacturing. Two promising and complementary research directions are emerging: transparent amorphous oxide electronics and laser-induced graphene (LIG).

Transparent amorphous oxide semiconductors offer exceptional electronic performance, mechanical flexibility, and, uniquely, optical transparency. Their ability to be processed at low temperatures enables high-mobility thin-film transistors (TFTs), transparent circuits, and unobtrusive optoelectronic systems. These materials also open doors for paper-based and biodegradable electronics, where our laboratory has been internationally recognized as a pioneer, demonstrating fully functional devices on renewable substrates.

In parallel, laser-induced graphene, produced through a single-step, maskless photothermal process, provides an energy-efficient approach to generate highly conductive carbon architectures directly on bio-derived substrates such as cellulose, cork, and other lignocellulosic materials. LIG avoids scarce metals, minimizes process complexity, and enables digital, on-demand manufacturing of conductive patterns for sensors, energy devices, and biomedical platforms. Importantly, because both precursor and substrate can be biodegradable, LIG represents a realistic route to circular electronics.

This plenary talk will highlight how transparent oxide electronics and green LIG materials can converge to reshape the future of sustainable technologies. By integrating advanced functionality—high-mobility semiconductors, transparent conductors, carbon-based electrodes—with renewable, low-impact substrates, we demonstrate electronic devices that meet performance requirements while drastically reducing environmental footprint.

Together, these strategies offer a transformative vision: electronic systems that are not only smarter and more efficient, but also sustainable, recyclable, and aligned with global climate goals.