Autonomous flexible electronics with zinc-tin oxide thin films and nanostructures

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While indium-gallium-zinc oxide (IGZO) thin-film transistors (TFTs) are nowadays assumed as a crucial technology to fabricate active matrix backplanes for high-resolution, low power consumption and even flexible displays, it is imperative to seek for sustainable routes to push the boundaries of oxide electronics. One of the dreams is to conceive a technologic platform enabling seamless integration of autonomous electronic functionalities into everyday objects.

At CENIMAT we are exploring in detail the zinc-tin oxide (ZTO) multicomponent system towards that end. In 2018 we reported for the first time flexible amorphous ZTO TFTs processed at only 180 °C [1]. Controlled hydrogen incorporation during ZTO sputtering and integration with an engineered high-κ multicomponent dielectric were critical to achieve performance metrics similar to IGZO TFTs. Such low-temperature TFTs enable multiple digital and analog circuit blocks operating at 10s of kHz, such as logic gates with rail-to-rail operation or differential amplifiers with gain of 17 dB, even with non-optimized transistor designs (i.e., long channel length, 20 µm, and electrode overlap, 5 µm). Another approach has been exploring ZTO at nanoscale level. In this case we are using hydrothermal synthesis to grow different nanostructures within the ZTO system, such as ZnSnO3 nanowires (NW) or Zn2SnO4 NW, nanoparticles (NP), nanocubes (NC) and octahedrons. While in thin film form we are interested in obtaining amorphous structures for large area processing, investigating multiple crystalline phases of the ZTO nanostructures opens up an enormous potential for different applications. Indeed, while the most stable Zn2SnO4 phase has been considered as a high-mobility semiconductor material, the metastable ZnSnO3 phase has the potential to greatly improve piezoelectric response over ZnO. To synthesize the desired ZTO nanostructures it was imperative to understand the role of the multiple chemical and physical parameters governing the hydrothermal process. Aspects such as multiple Zn precursors, ratio between Zn-Sn precursors, concentration of the surfactant agent and of the mineralizer, or volume, synthesis duration and process temperature needed to be addressed for this end [2, 3]. Multiple applications are being explored, such as pH sensors, photocatalysis, memristors and energy harvesters. For the later, composite nanogenerators combining piezo and triboelectric effects show output voltage, current, and instantaneous power density of 120 V, 13 µA, and 230 µW·cm⁻², respectively [4].

References