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Tuning hydrothermal deposition of ZnO on flexible substrates by seed layer procedures

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Wearable electronics drives to great extent the current developments on electronic device fabrication, where using flexible substrates is one of the key issues [1]. Actually, the integration of alternative materials, such as ZnO, into (conventional) electronic device configurations allows the design of novel systems, based on innovative transduction mechanisms and principles of operation for sensing devices. ZnO can be obtained by several processing techniques and has many interesting characteristics, such as piezoelectricity, which can be used in sensors [2]. We use hydrothermal synthesis as an affordable, scalable and simple process to produce ZnO films for sensing applications.

Our standard procedure for ZnO seed layer deposition consists in the immersion of a thermalized substrate into a ZnO-Ammonium Hydroxyde solution and hot plate-annealing of the sample. The hydrothermal growth of ZnO films is based on a mixture of ZnO, aqueous ammonia, sodium chloride and trisodium citrate solution at 80°C. Then, the sample is annealed at 200°C for 10 min, after H_2O rinsing. In this paper, we analyze the impact of ultrasonication-assisted pure H_2O rinsing at intermediate stages of the seed layer deposition. We show the results on smooth rigid substrates, thermal SiO_2 on Si wafers, as a way to optimize the process; yet same processing conditions had been successfully applied onto polyimide substrates.

Firstly, we observe that just by introducing ultrasonication (US) the number of unwanted micro-crystals is dramatically reduced (Fig. 1). Secondly, we observe that, although ultrasonication in water may affect even dispersion **or** particle size of seed layer characteristics (Fig. 2), its impact on ZnO growth is lower than the combined effect of particle density **and** size. Thus, the main challenge for preparing ZnO films for operational sensors relies on a uniform smooth seed layer with specific particle density and size over a large area, as it is critical to control the deposition a low roughness ZnO film with regular nanorod-like crystals of c-axis preferential alignment (Fig. 3)

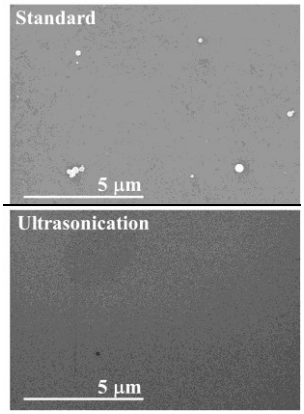

Fig. 1 Micro-crystal cleaning by US

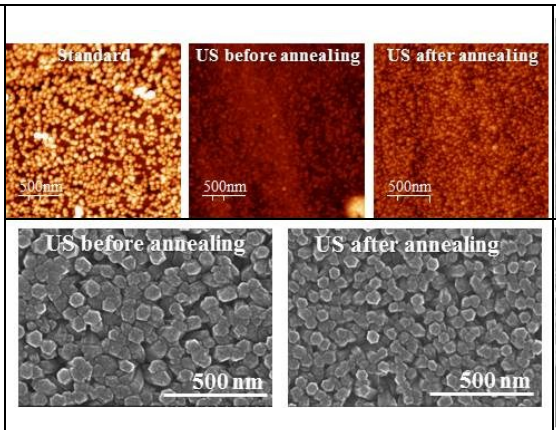

Fig. 2 (Top) Seed layer. (Bottom) ZnO growth

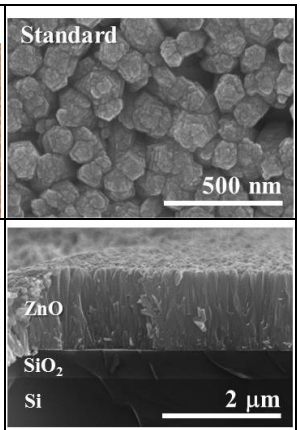

Fig. 3 ZnO & film cross section

[1] Dagdeviren *et al.* Nature Materials (2015) DOI: 10.1038/NMAT4289. [2] Gutruf *et al.* Small (2015) DOI: 10.1002/smll.201500729.