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Tin dioxide-graphene based chemiresistive device for NO_2 detection in the sub-ppm range

In this work chemical devices based on films of nanofibers of tin dioxide (SnO_2) - pure and doped with pristine graphene (Gr) - are developed and characterized for the detection of nitrogen dioxide (NO_2) at sub-ppm level, and their performance compared to state-of-the art sensors of complementary metal oxide semiconductors (CMOS) available in the market.

The devices are fabricated by depositing nanofibers on the surface of micromachined silicon substrates with interdigitated electrodes and heating resistance (microhotplates). Nanofibers of SnO_2 and SnO_2-Gr are prepared by electrospinnig of an aqueous solution of polyvinyl alcohol (PVA), tin(IV) chloride pentahydrate ($SnCl_4{\cdot}5H_2O$) and eventually Gr, and collected onto microhotplates [1]. An optimal trade-off between electrospinn-ability and significance in regard to gas sensing is attained for a content of 1000 ppm of Gr to Sn in the solution. The as-prepared films are subjected to thermal annealing at 500 ºC in air for four hours and then analyzed by SEM (Figure 1). SEM images show highly porous layers of randomly oriented nanofibers of different morphology. Whereas nanofibers of SnO_2 are continuous, show a uniform diameter (30-50 nm) throughout their length, and have a granular surface with grains smaller than 10 nm [2,3]; discontinuous beaded nanofibers and nanoribbons are obtained when Gr is added to the solution.

The performance of the nanostructured sensors to detect NO_2 on the sub-ppm level was assessed in the laboratory with controlled air-NO_2 mixtures as a function of temperature, from room temperature up to 300 ºC, and compared to the performance of sensors CCS 801 and CCS 803 (ams AG, Austria) [4,5] operating at higher temperature (300-400 ºC). An improvement in sensing performance in terms of sensitivity and response time, together with higher response at room temperature, is obtained when composite nanofibers of SnO_2-Gr are used. The response of nanofibers-based sensors and CMOS sensors to NO_2 is displayed in Figure 2. As it can be seen, the performance of the nanostructured sensors largely exceeds the performance of the commercial sensors.

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Figures

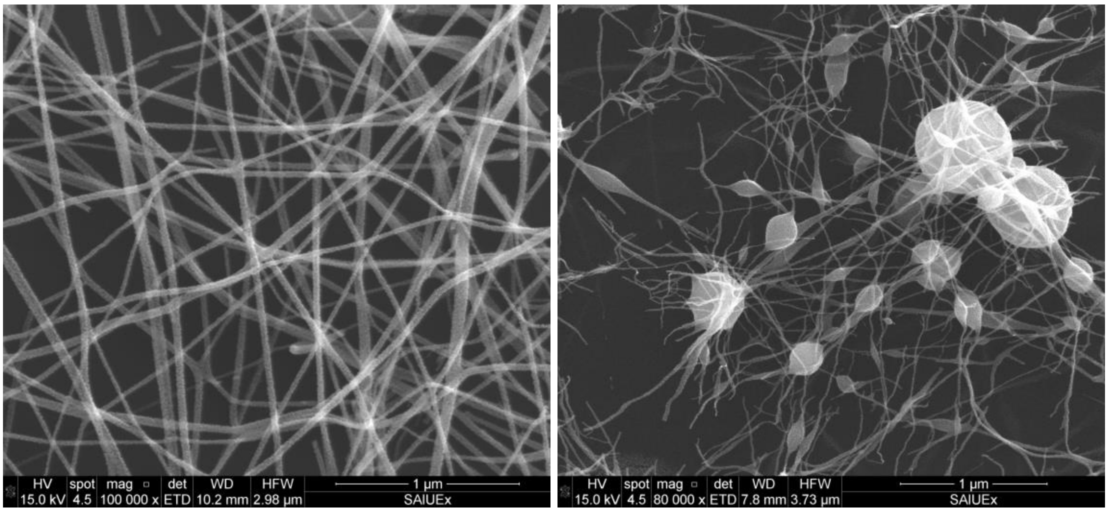

Figure 1: SEM images of nanofibers of pure tin dioxide (left) and tin dioxide doped with pristine graphene (right).

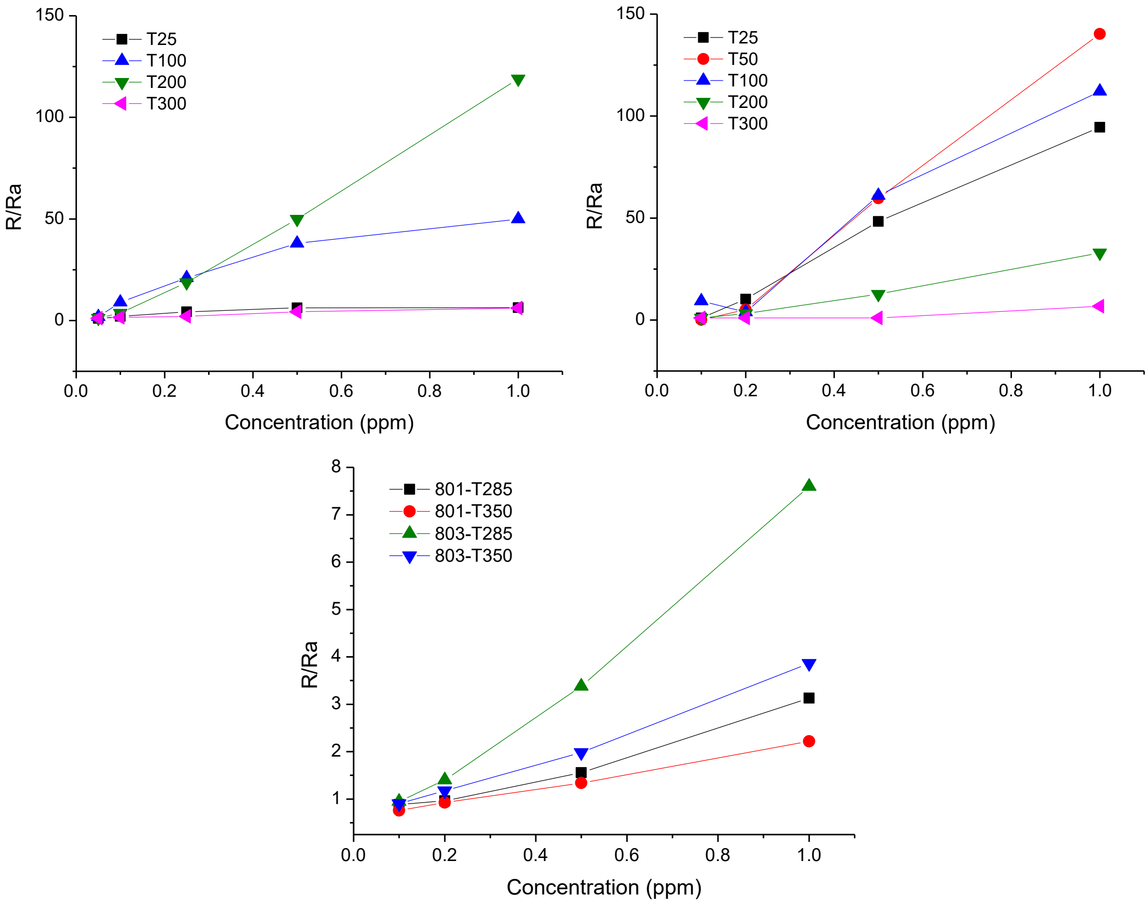

Figure 2: Response to NO_2 of resistive sensors based on SnO_2 nanofibers (top-left), SnO_2-Gr composite nanofibers (top-right) and commercial CMOS sensors (bottom) at various temperatures.

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