The influence of the material structure on gas-sensing properties of SnO_x nanoparticle layers

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In order to investigate the dependence of gas-sensitive properties of tin oxide nanoparticle films on particle size, a new thin film synthesis technique has been developed. This process, comprising several independent but controllable steps and allows a control over particle and film properties than single-step synthesis procedures. The steps are thermal evaporation, size-fractionation and in-flight oxidation combined with crystallization and film formation. The set-up allows the deposition of size-selected nanoparticles in the range of 8 to 35 nm, having a geometric standard deviation of 1.1, by electrostatic or inertial deposition to form a thin film [1].

It was emphasized by Göpel [2] that with respect to sensor production, the process should be expected to deliver nanoparticle films with homogeneous particle size in the nanometer range. When polydisperse distributions are used, it can be reasoned that the smaller grains have much more influence on the sensitivity than the larger ones as they constitute the 'bottle necks' of the charge transport.

In this study a systematic study is made in order to investigate the influence of particle size, stoichiometry and operating temperature on the gas-sensing properties of SnO_x layers. The particle size range is 10 – 35nm and the maximum operating temperature is 350°C. The gas sensing in these devices is based on the measurement of the changes in the electrical conductivity of the semiconductor material on exposure to gas molecules.

Changes in electrical conductivity on gas exposure of ethanol is measured using silicon substrates having an interdigitated contact pattern and an integrated heating system (Fig. 1), controlled by a fully automated measurement system. TEM and Synchroton radiation experiments were performed to obtain crystallite size and crystal structure of the particle layers as-deposited as well as post-annealed in a defined atmosphere. It has been shown unambiguously that decreasing the particle size of tin oxide particles leads to an increase of the sensitivity and a more rapid response on changing gas conditions. The effect is especially clear for films with particle size of 20 nm or smaller. Additionally the gas-sensing properties, depending on the in-situ oxidation of the nanoparticles will be presented.

Fig. 2 shows that different sensitivities were achieved for a particle size of D_{ms}: 20 nm at operating temperatures between 100-250°C if the SnO_x particles are oxidized in the gas phase. Sensitivity increases and maximum Sensitivity shifts towards lower operating temperature. This means that it should be possible to build a multisensor consisting of SnO_2 with different particle sizes and different in-situ oxidized nanoparticles.

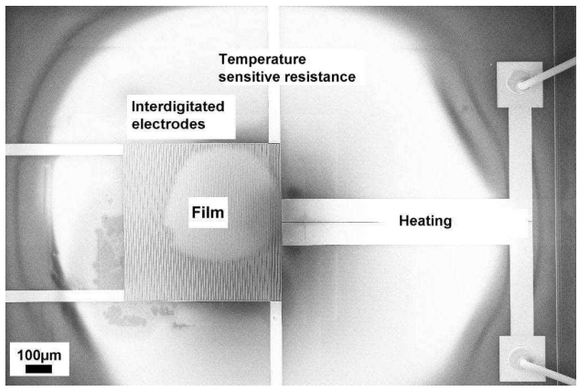

Fig. 1: SEM picture of the substrate device after deposition of monodisperse SnO2 particles

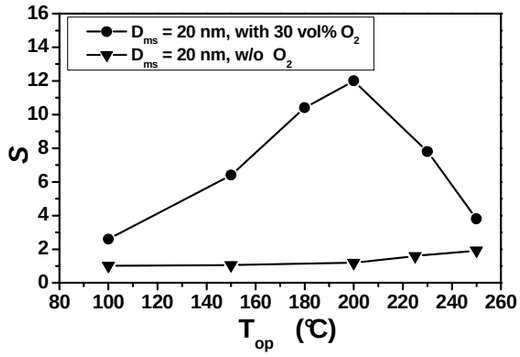

Fig 2: Sensitivity as function of temperature for D_{ms}=20 nm, gas: 1000 ppm ethanol, film thickness: 1500 nm.

[1] M.K. Kennedy, F.E. Kruis, H. Fissan, Gas phase synthesis of size selected SnO_2 nanoparticles for gas sensor applications, Mater. Sci. Forum, 343-346 949 (2000)

[2] W. Göpel, K.D. Schierbaum, SnO_2 sensors: current status and future prospects, Sensors and Actuators B26-27, 1-12 (1995)