DRY TRANSFER PROCESS OF MO_X NANOWIRES USED FOR GAS SENSING APPLICATIONS

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INTRODUCTION

Monitoring of environmental conditions via gas sensing devices is currently of high interest for air pollution control. One of the most important material systems applied to gas sensors are metal oxides due to their high sensitivity – especially in the form of nanomaterials such as nanowires (NWs) and nanoparticles. Those structures demand proper implementation in gas sensor devices. In this paper we report dry transfer technology of SnO_2 NWs to gas sensor substrates and their gas sensing performance. Silicon-based sensors with gold inter-digital electrode structures (IDES) were produced and high sensitivity to H_2S gas was demonstrated. Simple transfer process with polydimethylsiloxane (PDMS) stamp was employed and potential applications in the future were shown.

EXPERIMENTS

SnO_2 nanowires were synthesized by two-step synthesis[1]. First a SnO_2 thin layer (400 nm) was deposited on a Si-substrate by spray pyrolysis technique. Then the SnO_2-sample was placed in a tube furnace with another Si-substrate coated with a thin catalytic metal layer (i.e. 40 nm copper). The samples were mounted parallel to each other with the SnO_2-coated Si-substrate on the bottom and the Cu-coated Si-sample on top with a spacing of 1 mm in between so that the layers were facing each other (“face to face”), The subsequent annealing process was performed for 3 hours in Ar-atmosphere at a temperature of 900°C and resulted in SnO_2 NW growth on the metal-coated Si-sample. Average diameters and lengths of the SnO_2 NWs were 50-200 nm and 10-100 µm, respectively.

The transfer process of SnO_2 NWs was performed as follows: first a specific PDMS stamp was prepared. Dow Corning Sylgard 184 base and curing agent were mixed in a 10:1 ratio by weight and annealed at 100°C in flat Petri dish (stamp – 5x5 mm piece was used). Next the MOx NWs were picked up manually by the stamp and were transfer printed on Si-based gas sensors with Au-IDES as electric contacts (Fig. 1). The print transferred SnO_2 NWs electrically connect the electrodes and serve as gas sensing elements. As a result resistance measurements can be performed along the NWs in the presence of various target gases. The gas sensor with MOx NWs on top was glued on micro heaters (10×2 Pt 6.8 Delta-R GmbH) and thermocouple (4×1 Pt100, Delta-R GmbH) and bonded on chip carrier (mb-Technologies GmbH).

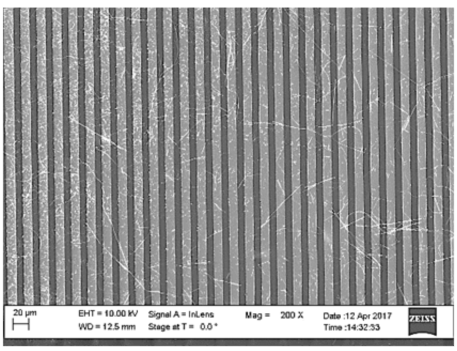

Figure 1: SnO2 NWs on Au-IDES gas sensor substrate.

RESULTS AND DISCUSSION

Gas measurements were performed in an automated gas measurement setup. The flow rate was kept constant at 1000 sccm and synthetic air (80% N_2, 20% O_2) was used as background gas. The resistance of the NW sensor devices was measured in constant current mode (10nA) and in different hydrogen sulfide concentrations ranging from 10 to 1000 ppb. The gas response was investigated at constant temperature – 400°C and three different relative humidity (rH) levels: 25%, 50%, and 75%. The sensitivity for each gas concentration and humidity level was calculated as follows:

$$S = \frac{R_{air} - R_{gas}}{R_{air}}$$

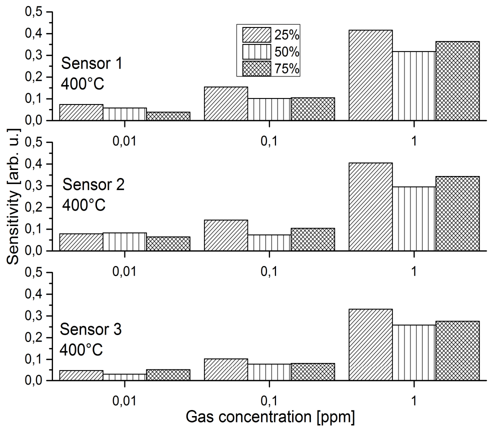

Figure 2: SnO_2 NWs gas sensor sensitivities for three different sensors produced by the same transfer method.

The measured sensitivity performance of three different sensors (produced the same way) are shown in Fig.2: the results are comparable which demonstrates a good reproducibility of sensor fabrication although the transfer process is performed manually. Highest sensitivity for each of the sensors was achieved at lowest humidity level, which shows that the sensors have also cross-sensitivity to humidity.

The integration of MOx NWs on gas sensor substrates with dry transfer print process demonstrates that this comparatively simple and low cost technology can be employed to fabricate nanomaterial-based devices. Previously we have integrated MOx NWs on CMOS-based micro-hotplate arrays using drop coating and ink-jetting techniques[2]. For these technologies solvents have to be employed that might have detrimental properties on the gas sensing properties because of organic residuals. The advantage of the print transfer method is that it is a dry non-solvent based technique. However, both technologies are presently used for the development of nanomaterial-based gas sensors. A combination of the dry print transfer process for integration of NWs and a solvent-based technology for functionalizing NWs with NPs might be the method of choice for optimizing gas sensor devices.

CONCLUSION

In summary we evidenced that SnO_2 nanowires-based gas sensors produced by dry transfer process are sensitive to hydrogen sulfide. This print transfer method demonstrates high reproducibility and could be easily implemented as industrial fabrication approach. Thus the next step is to transfer metal oxide nanomaterials on CMOS-based devices involving dry transfer stamping method described in this paper. This is currently under progress.

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