Session SS

SMART SENSOR MATERIALS AND TECHNOLOGIES

SS-01 (Invited Talk)

About Processes and Performance of Integrated Gas Sensor Components

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The integration of gas sensor components into smart phones, tablets, and wrist watches will revolutionize the environmental health and safety industry by providing individuals the ability to detect harmful chemicals and pollutants in the environment using always-on hand-held devices. However, in order for this goal to be achieved the fabrication of gas sensors and, more precisely, the deposition of gas sensing metal-oxide materials, must be performed using a cost-effective technique which is integrable in the full CMOS sequence [1]. A sensor array requires a combination of MEMS and CMOS analog and digital circuitry in order to generate a useful product, as shown in Fig. 1.

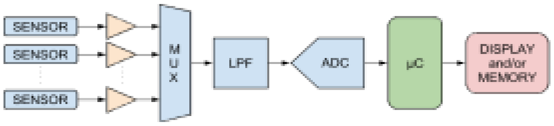
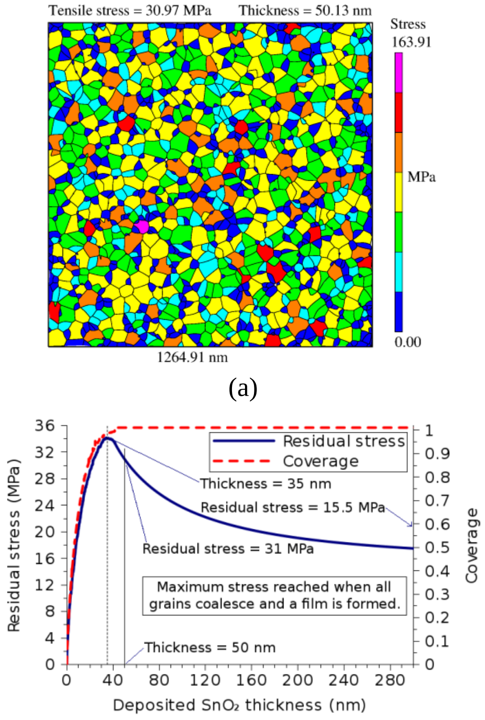


Fig. 1: Sensor array with interface electronics blocks

Spray pyrolysis has proven to be an inexpensive technique which can be used to deposit the metal oxide sensing material at the backend of a CMOS process. A model for the spray pyrolysis deposition of tin oxide (SnO_2) has been developed and is described by the Arrhenius expression $d(t,T)=A\cdot t\cdot e^{-E/k_bT}$, where A=3.1µm/s, E=0.427eV, k_b is the Boltzmann constant, and T is the temperature in Kelvin. The growth of the metal oxide grains is characterized by the Volmer-Weber growth model [2], which can lead to residual stress development due to the interaction between the expanding grains. The grain growth after thin film deposition at 400ºC has been simulated, resulting in a residual stress of approximately 30MPa at a 50nm thickness. The stress distribution along the grains is shown in Fig. 2(a) while Fig. 2(b) shows the stress development during film growth. After coalescence, the minimum residual stress reached is about 15.5MPa.



(a)

(b)

Fig. 2: (a) Stress distribution along the grains of a deposited tin oxide layer with a 50nm thickness. 1000 grains were used for the simulation.
(b) Average residual stress development during the growth of the tin oxide thin film.

After cooling the device to room temperature following deposition, the SnO_2 experiences further stress due to a difference in the coefficients of thermal expansion between SnO_2 ($4\cdot10^{-6}K^{-1}$) and the oxide ($0.5\cdot10^{-6}K^{-1}$). The final stress at room temperature for a 50nm thick SnO_2 film with 100µm×5µm dimensions is 500MPa.

The sensor operates at temperatures between 150°C and 400°C by oxygen being adsorbed at the SnO_2 surface. After exposure to a target gas, the resistivity of the metal oxide is reduced by an amount which depends on the temperature and concentration of the target gas in the atmosphere. A relationship which relates the H_2 concentration (C_{H2} in ppm), a gas used for fire and smoke detection, to the SnO_2 resistance is described by the expression $R_{norm}=R_0-m\cdot ln(C_{H2})$, where R_0 and m are geometry-dependent variables in Ω.

1. M. Ortel et al., *Solid-State Electronics* **86**, 22 (2013).
2. J. Boltz, *Sputtered tin oxide and titanium oxide thin films as alternative transparent conductive oxides*. PhD diss. (2011).

SS-02 (Invited Talk)
Effect of Magnetic Field in Organic Semiconductor Devices

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Organic semiconductors have been used as active layer in devices such as organic light-emitting diodes (OLEDs), photovoltaic cells, field-effect transistors. Recently there has been a growing interest in spin and the effect of magnetic field in OSEC devices. These include OLEDs, where substantive magneto-electroluminescence and magneto-resistance (OMAR) were obtained;[1] organic spin valves (OSV) where spin injection, transport and detection of holes were demonstrated; this leads to the so-called giant magneto-resistance (GMR) in OSVs;[2] and bipolar OSVs or spin-OLEDs,[3] where spin aligned holes and electrons are simultaneously injected into organic spacer causing electroluminescence, whose intensity depends on the relative spin polarization direction of the carriers. The interest in spin transport in organic semiconductors has been motivated by the weak spin-orbit interaction (SOC) that is caused by the light-weight building block elements such as carbon and hydrogen, and the relatively small hyperfine interaction (HFI) of the π-electrons with the adjacent nucleus. In this talk the status of the young field of 'Organic Spintronics' will be reviewed. The necessary ingredients needed for the success of this field will be summarized and evaluated by recent experiments. In particular the role of the HFI in magneto-transport will be elucidated via the isotope effect.[3,4]

1 Mermer, Ö. *et al.* Large magnetoresistance in nonmagnetic π-conjugated semiconductor thin film devices. *Physical Review B* **72**, 205202-205213 (2005).
2 Xiong, Z. H., Wu, D., Vardeny, Z. V. & Shi, J. Giant magnetoresistance in organic spin-valves. *Nature* **427**, 821-824 (2004).
3 Nguyen, T. D., Ehrenfreund, E. & Vardeny, Z. V. Spin-Polarized Light-Emitting Diode Based on an Organic Bipolar Spin Valve. *Science* **337**, 204-209 (2012).
4 Nguyen, T. D. *et al.* Isotope effect in spin response of [pi]-conjugated polymer films and devices. *Nat Mater* **9**, 345-352 (2010).

SS-03 (Invited Talk)
Design and Fabrication of Magnetic Tips for High Resolution Magnetic Force Microscopy

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Magnetic force microscopy (MFM) has been used in the investigations of magnetization structure of various magnetic devices such as magnetic recording media, magnetic heads, permanent magnets, etc. Magnetic sensor tip, which detects the magnetic interaction between the tip and a magnetic sample, is the key component. There are several requirements for the sensor tip; high spatial resolution, high sensitivity, high magnetic switching field, mechanical durability, corrosion resistance, etc. Figure 1 shows the trend of MFM spatial resolution through improvements of sensor tips [1]. It is currently becoming possible to observe