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Review Article

A REVIEW ON ORGANIC THIN FILM TRANSISTOR MODELS FOR THERMAL SENSING

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A B S T R A C T

This paper reports a review on temperature sensors based on organic thin film transistors. This is generally applicable to the organic thin film transistors using polymer semiconductors and small molecules. This kind of sensors has the advantage that they are flexible, low cost and can be integrated within a fabric. Another advantage of this type of sensors is that, since the organic material is based on carbon they are degradable. Thus e-wastes can be reduced using this technology.

INTRODUCTION

During these last decades organic semiconductor based electronics have attracted a huge attention. These materials are suitable for the fabrication of electronic circuits with multiple functionalities, low cost and on flexible substrates. Applications range from sensors, RFID tags, e-skin and so on. Also several sensors can be made using OS, like temperature sensor, humidity sensor, light sensor etc. The properties like structural flexibility, low processing temperature and especially low costs make the OS based devices suitable for these applications. The surface strain induced on semiconducting layer leads to the mechanical deformation and it results in variation of structural or morphological properties. This character of OS is exploited for parameter sensing application and when it is undeserved there are techniques for reducing the mechanical deformation.

Organic Thin Film Transistors

An organic thin film transistor is similar to a field effect transistor. A conventional inorganic FET, consist of lightly-doped Si as active layer, where the applied voltage causes accumulation of minority charge carrier at the dielectric interface, e.g. holes in n type material, which is termed an 'inversion layer'. Carrier injection in this channel from source to drain electrodes occur by the application of bias voltages, resulting in a current flow. This is not the case for an organic transistor, in which the active layer is a thin film conjugated small molecule Pentacene. Unlike the inorganic materials, organic materials pass current by majority carriers, and inversion regime does not exist and the conduction is by accumulation. This difference makes the OTFT to has lower mobility value compared with that of inorganic semiconductor FETs. So OTFTs are not suitable for applications, which demand high speed operation. But their processing characteristics, OTFTs are competitive for large area, physical flexibility, low speed and low cost applications, such as large area, bendable displays. Performance of OTFTs are usually evaluated in terms of mobility values and on/off current ratio, which determine the speed and leakage current of devices. OTFTs have typical surface mobility values range from 0.1-2 $cm^2/V\text{-}s$, which are comparable with those of amorphous-Si (a-Si) devices and the on/off current ratio ranges from 10^3-10^8.

Otft Structure

In different device architectures OTFTs can be made. One of these structures are depicted in Fig. 1 [6]

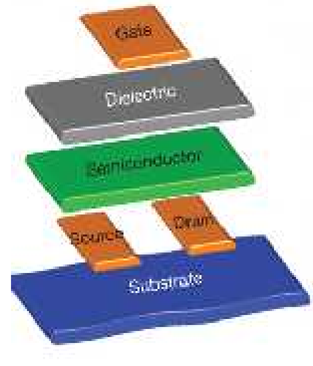


Figure 1 Bottom gate top contact structure

By shadow mask contacts are deposited in top contact, where as in bottom contact microlithography technique is used [15]. In comparison with bottom gate bottom contact structure bottom gate top contact structure shows better field effect mobility. This difference is often explained by the large metal-semiconductor contact resistance due to interface contact barrier and irregular deposition or poor morphology of the semiconductor film around the already patterned source and drain contacts [16].

Temperature Sensing

Temperature measurement is for the comfort of human beings as well as essential for other living organisms, agriculture, industrial processes, storage transportation, etc. Temperature sensors are classified into contact and non-contact sensors. The former type includes resistance temperature detectors (RTDs) and thermocouples. The RTDs may also be classified into thermal sensitive resistors (thermistors) and resistance wire RTDs. For the fabrication of temperature sensors, the most commonly used sensing materials are platinum and gold, which are very expensive. Cheap, low-density, flexible, and easy-to-fabricate materials have been used to replace expensive sensing materials. For this purpose, organic materials are considered to be very promising. [17–20] Resistance-temperature devices were found to be highly sensitive and accurate. For some cryogenic applications, carbon-based resistance-temperature sensors are currently being used.

In[1] charge modulated OTFT is used for sensing temperature. The device architecture is such that devices have been fabricated on a flexible plastic poly(ethyletherephtalate) (PET) film with a nominal thickness of 175 µm. This is the standard plastic substrate employed for the fabrication of flexible electronics, with a good thermal stability up to 80° C, which is compatible with many of the fabrication process employed for the realization of OTFTs. Then a 80 nm thin aluminum film was deposited on the top of it by thermal evaporation and patterned by photolithography This metal layer acts as the floating gate for the sensor. Such a film is then annealed in oven at 50°C for at least 12 hours in order to create a thin aluminum oxide layer, after patterning. Afterwards, Leaving a small area of the floating gate uncovered, a 60 nm film of Parylene C was deposited over the entire device structure. This will be used for the sensing process. The combination of these thin layers will allow the final transistor to be operated at very low voltage. Afterwards, gold source and drain electrodes and a control gate electrode were fabricated and Pentacene was used as p-type organic semiconductor. Finally a 5x5 mm2 (nominal thickness 100 µm PVDF film, purchased by Measurement Specialties Inc.) was patterned in order to have a capacitor, and it is transferred and glued over the uncoated area of the floating gate using a conductive paste. This configuration of transistor is the Organic Charge Modulated Field Effect Transistor (OCMFET). The working is such that, for setting the working point of the sensor control gate is used. If additional charges are induced on the floating gate, a modulation of the charge carriers density in the transistor channel is induced i.e a threshold voltage variation will be induced, thus leading to a variation of the device output current. The pyroelectric properties of PVDF were exploited for monitoring temperature variations. To do that, onto the sensing area of the floating gate a PVDF-based capacitor was transferred. Any temperature variation in the sensing area will induce e charge separation in the PVDF film. This effect will induce a charge perturbation in the device floating gate, and will be employed for the fabrication of temperature transducers.

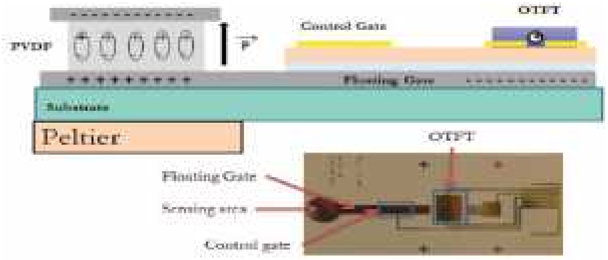


Figure 2 schematic representation of the OCMFET integrated with a pyroelectric capacitor (up); picture of the fabricated device (down Kapton foils (polyimide sheets, 50 μm-thick, provided by DuPont) were used as substrate for the fabrication of sensors[1]

According to [1] a clear response of the sensor to each variation in temperature is obtained, real temperature variation (induced by the Peltier cell) on the sensing area was well reproduced by the devices, meaning that the response time of the pyro- OCMFET is comparable to the one of the commercial infrared thermometer used for these experiments. Average current variation for each temperature step are reported in the figure [4] given below.

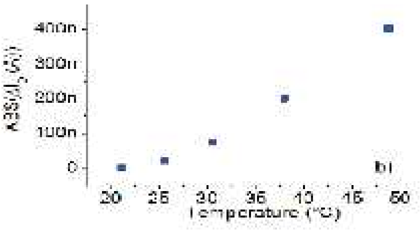
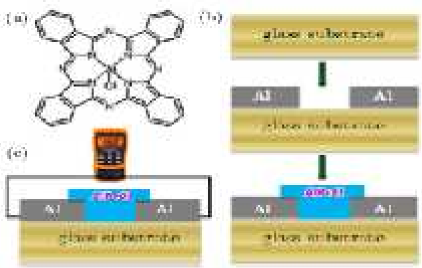


Figure 3

In [2] temperature sensor based on AlPcCl is used and the sensor was evaluated on two different thickness. The scheme of fabrication process and the schematic diagram of the sensor are shown in Figure1. The plot of resistance Vs temperature in [2] shows that resitance decrease with increase in thickness, the plots are shown in figure 4 [2] .



Figures 4 (a) Molecular structure of AlPcCl (b) Scheme of the fabrication process (c) Schematic diagram of Al-AlPcCl-Al sensor[2]

CONCLUSION

The [1] paper describes a review of temperature sensors based on organic thin film transistors. In [1] temperature sensor on a flexible substrate is made and it was found that [1] produces more linear and accurate results than [2]. So it can be easily integrated on textiles thus can be utilized for monitoring a person. In this paper a temperature range of 20 °C to 50 °C was obtained , this temperature range can be further increased by selecting suitable layout of the structure. In [2] apart from the previous reference sensing layer used is Aluminium Phthalocyanine Chloride is used. According to [2] the proposed model can sense temperature from 25 °C to 80 °C. But the flexibility is less since glass substrate is used.

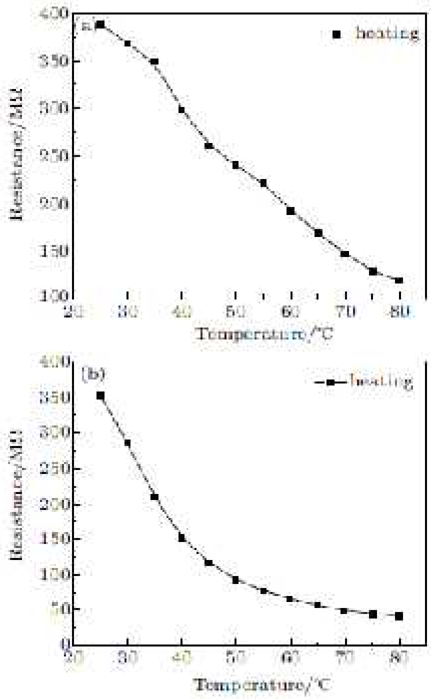


Figure 5 (a) sensor with 50 nm thickness (b) sensor with 100 nm thickness[2].

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