Student Paper

Printable Ammonia Sensor Based on Organic Field Effect Transistor

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Recently, ammonia sensing has received a great attention from the scientific community worldwide due to the potential role of ammonia as a trigger for severe respiratory diseases such as asthma. As the common sources of ammonia are farm residues, paints & varnishes and industrial waste, it is commonly present in our environment in varying concentration. Thus there is a pressing need for a detailed study for the role of ammonia vapors as the trigger for Asthma and other related respiratory diseases to design a suitable personalized intervention strategy and also to make a broader case for environmental remediation.

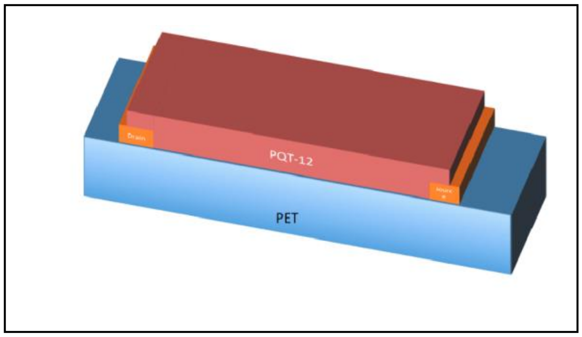

Figure 1: Schematic of the device developed

Organic field effect transistor (OFET) based ammonia sensors have many advantages over other sensing techniques, such as high sensitivity, low cost, low weight and potential to make flexible sensors [1]. There has been a lot of advances in OFET based ammonia sensors but to develop a sub ppm v/v level sensitive organic field effect transistors had been a great challenge for a very long time until recently when our group reported OFET-based ammonia sensors which could detect concentrations of 450 ppb v/v, with a limit of detection of 350 ppb, the highest sensitivity reported till date for semiconductor films [2]. These OFETs were vapor deposited leading to high time and cost of production and hence making the sensor unfeasible for mass-production.

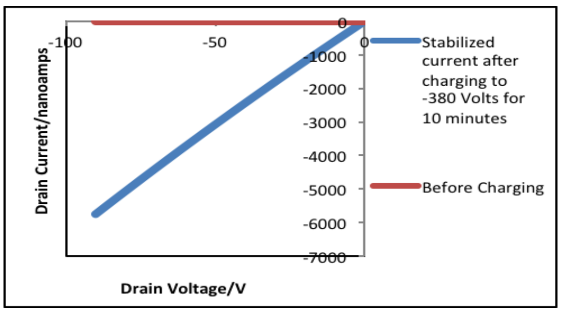

Figure2: Drain current measurement for drain voltage sweeping from 0 to-90 Volts, Red curve is showing the current for device without any charging while the blue curve is for device with -380V

Herein we report a fully printable OFET sensor with the sensitivity of 450 ppb v/v for ammonia making it much more time and cost efficient then vapor deposited structure. The device developed is a polyethylene terephthalate (PET) substrate based bottom contact device with poly (3,3'''-didodecylquaterthiophene) (PQT-12) cast from 4mg/ml cholorobenzene solution as active semiconductor and PEDOT: PSS source and drain electrodes. Inherent static charges present on PET surfaces could be easily tailored using techniques like corona charging and can be used for threshold voltage tuning. We used these static charges as a static gate thus, sidestepped the major challenge of developing a reliable printable dielectric. Hence the whole structure is simplified as a chemiresistor This device structure only needs two terminals, source and drain, as the permanent gate voltage present on the PET surface has replaced the gate terminal (fig.1). The effect of corona charging has been demonstrated in fig.2. For this plot, two devices are made on the same PET sheet, the device made without any charge is in off state while the device which has -380 volts of corona charging give stabilized current up to 5.7 micro ampere under ambient condition with drain sweeping between 0 to -90 V.

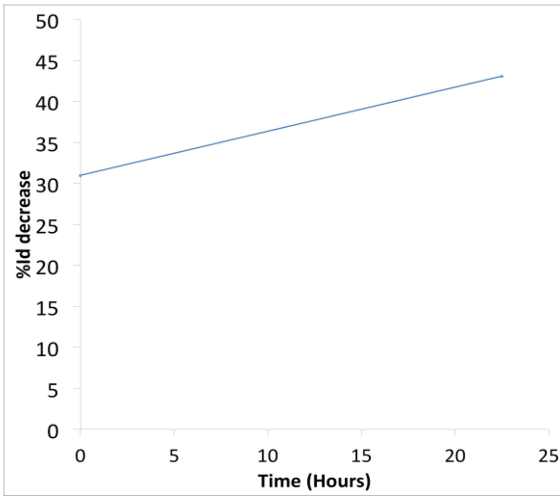

Figure.4: response retention of a device refrigerated in a sealed container for 2 days

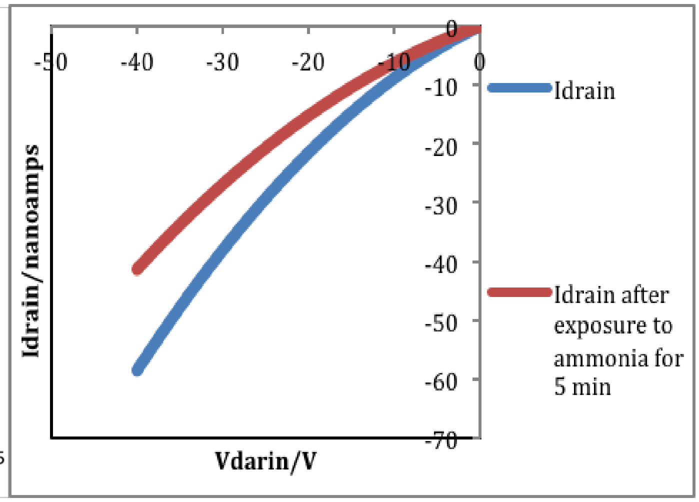

Figure.3: Response of OFET sensor to 5 minutes exposure of 0.45 ppm ammonia

For the sensor test, drain Current is monitored in output curve measurements at -40 Volts drain voltage under ambient condition for 2-3 times at an interval of 10 minutes to ensure the stability of the device performance in air. On exposure to 0.45 ppm of ammonia for 5 minutes the drain current decreases by 30% (fig.3). Selectivity studies have been conducted for acetone, which shows the acetone vapors have no effect on the device performance. Devices demonstrate good memory behavior when refrigerated in a sealed container. These devices have been developed such that all the steps are compatible with large scale printing techniques and be can be fabricated using a variety of techniques including gravure and inkjet printing (for soluble semiconductor and receptor systems) and hybrid photolithographic. Corona charging has been used for a long time to print on plastic sheets. Thus we have developed a prototype to fabricated highly flexible very low cost printable ammonia sensors, which could act as a platform to develop printable sensors for many other reagent of interest.

References

[1] Huang, J et.al." Monolayer-Dimensional 5,5′-Bis(4-hexylphenyl)-2,2′-bithiophene Transistors and Chemically Responsive Heterostructures ",Volume 20, Issue 13, pages 2567–2572, July 2, 2008 Adv. Mater.

[2]Huang, W et.al, "Highly Sensitive NH3 Detection Based on Organic Field-Effect Transistors with Tris(pentafluorophenyl) borane as Receptor", *134* (36), pp 14650–14653 , September 12,2012 J. Am. Chem. Soc.