Development of Microsensors for Air Quality Monitoring

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Primary CNF Tools Used: Metal film deposition, photolithography, mask making equipment, optical pattern generator, ABM contact aligner, wafer processors

Abstract:

Air pollution is a major problem that is dangerous not only to the environment but to the health and safety of humans. Due to the increase in air pollution in recent years there has in turn been a decline in health. Particularly conditions such as respiratory and cardiovascular diseases have seen a rise in prevalence. People who had preexisting conditions have seen their conditions worsen due to this rise and there has been a rise in prevalence of health defects such as headaches, dizziness, trouble breathing, damage to the liver and in some cases cancer. As such there is a need for a device to monitor air pollution levels for personalized use. Existing technology lacks sensitivity and selectivity as well as cost efficiency and are not equip for personalized use. Gold nanoparticles fabricated into microelectrode array devices allow for the selectivity and sensitivity need to make theses sensors. Working with company FlexSurfaces and the Cornell NanoScale Science and Technology Facility, we have used the clean room facilities to begin developing the technology for low-cost sensors with high sensitivity for use in portable and wearable air quality monitoring systems.

Summary of Research:

The design of the sensors is very important. The parameters and shape of the microelectrode used in the array impacts its performance when measuring air quality. The composition of the nanostructure thin film also has a large impact on the performance of the sensor to detect VOCs. Current array measurements are made of combinations of the following, finger width (FW, 5 µm, 10 µm), finger space (FS, 5 µm, 10 µm), and finger length (FL, 100 µm, 200 µm). Previously gathered sensor array response data shows that smaller parameter values for width, length and space typically result in a higher response sensitivity when tested and exposed to various VOCs. (See Figure 1.)

Flexible devices use a similar mask design and parameters as the glass substrates. (See Figure 2.) The material used in the flexible design is Kapton also known as polyimide. This material is both flexible and inexpensive making it perfect for this application. This design while testing and optimized for glass array devices still needs alterations to maximize ability on flexible substrates. This is currently being tested and studied.

The photos in Figure 3 demonstrate the diminished finger space as seen in the first photo the finger space is so small you cannot see it and in the second is disappearing. The final photo shows what a well-made finger space should look like. This problem with the disappearing and diminishing of the devices parameters was predicted to be one of two problems — over exposure or loose contact. Several experiments were carried out to find a solution to these problems.

The possible problem of a loose contact was addressed by cleaning the mask more thoroughly before contact with the substrate. While the problem of overexposure was delft with in a more expansive method.

Design #	FS (µm)	FW (µm)	FL (µm)
1	10 (1)	10 (1)	100 (-1)
2	10 (1)	5 (-1)	200 (1)
3	5 (-1)	10 (1)	200 (1)
4	5 (-1)	5 (-1)	100 (-1)

Design	W/µm	S/µm	L/µm
1	5	5	100
2	5	10	100
3	10	5	100
4	10	5	300
5	10	10	100
6	10	10	400

Figure 1: Device parameters for glass samples (right) and polyimide samples (left).

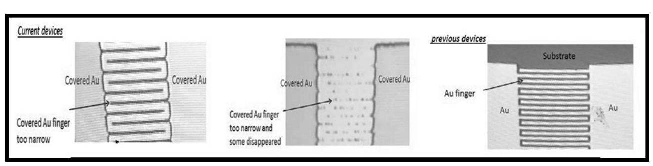

Figure 3: The finger spaces between first devices and older devices. As can be seen in the photos on the left, the finger space has been diminished.

Materials

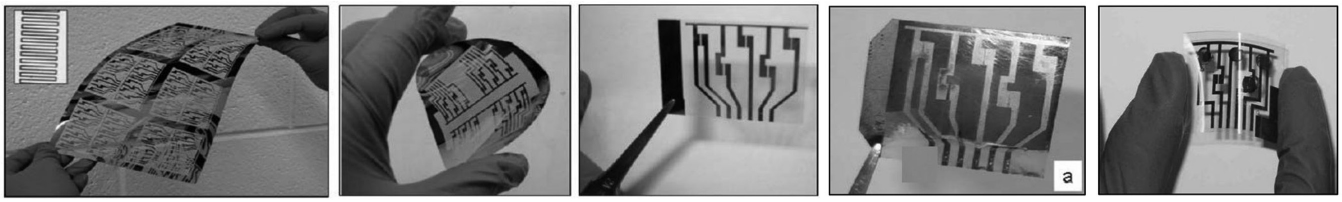

Figure 2: Examples of flexible devices. Devices are very versatile as demonstrated in the photographs.

In order to address overexposure a single substrate was taken and exposed at six different exposure times. Exposure times from 4-11 seconds were tested. The image below shows an example of what one of these test samples would look like. One can see in the images the finger of a sample produced at six seconds, nine seconds and eleven seconds. From these images one can already see how the finger parameters are affected by the exposure time. The sample at eleven seconds has a much smaller finger space than the sample at six seconds. After etching and careful observations under the microscope it could be seen that six seconds was the exposure time that developed the optimal device parameters for flexible substrates. All future tests were carried out with flexible substrates at six seconds exposure times.

Testing of the array devices is done at Binghamton University. Where further processing of the wafers is first conducted. The interdigitated microelectrode devices are first coated with a sensing tin film which is prepared by molecularly-mediated assembly of nanoparticles. Samples were then housed in Teflon® chambers and hooked to computer-interfaced multimeters, resistance was measured. Vapor sources and N_2 were connected via tubing. Vapor concentration in ppm moles per liter was calculated from partial vapor pressure. N_2 is used as the reference gas, and all experiments were performed at room temperature, 22 ± 1°C.

The graphs in Figure 4 are examples of glass and polyimide device response profiles to benzene and or hexane. The images show that both the glass and flexible devices show somewhat similar response profiles. This means that only slight adjustments will need to be made to the device parameters in order to maximize their ability on the polyimide substrate.

Conclusions:

Through this project we have developed a process for fabricating interdigitated microelectrodes on flexible polyimide substrates. This development process differed from the one used on glass substrates in order to ensure the optimal parameters. Particularly within the process the exposure time needed adjustments for flexible substrates. Tests conducted so far have shown that the microfabricated IMEs on both glass and polyimide substrates worked well, showing similar response profiles to certain VOC's.

Further testing is still being carried out to evaluate the performance of these sensors. Experiments into other possible substrates such as paper are being considered. A systematic study is underway to evaluate the device parameters. As we gather more information, we are beginning to develop a prototype sensor device to be used in air quality monitoring.

References:

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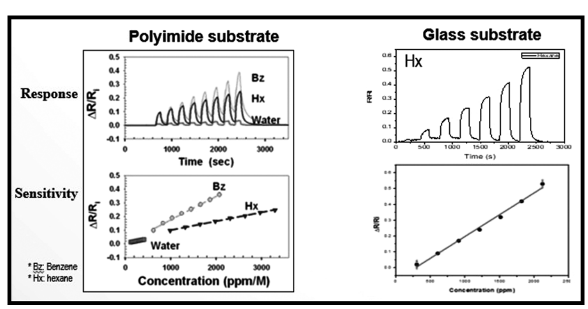

Figure 4: Response profiles for polyimide (left) and glass (right) substrates to hexane and for poluimide benzene vapors.