Dual-channel odour separation columns with large chemosensor arrays for advanced odour discrimination

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Abstract

Here we report on an improved concept for electronic noses (e-noses) that combines three large chemosensor arrays (300 resistive elements) with two micro-packages containing a column inspired by our study of the human olfactory mucosa and nasal cavity. In this novel system, a test odour passes over the first chemoresistive array giving "spatial" response data, equivalent to a traditional sensor-based e-nose. Then the odour is divided evenly and passes through the two micro-packages (and thus columns) simultaneously. As the odour pulse travels along these columns, chemical components within it are selectively delayed, thus the second and third array, placed after the micro-packages, provide temporal retentive information as well as spatial information. This combination of a front-end sensor array with back-end second and third arrays, coupled with appropriate pattern analysis algorithms, is shown to enhance significantly the system's ability to discriminate between simple odours.

I. Introduction

Although e-noses are often compared to their biological counterparts, they neither mimic fully its mechanical structure nor its huge sensor diversity, e.g. about 300 identified human olfactory binding proteins. Here we report on a new e-nose system that combines large sensor arrays with a partially retentive column that is inspired by the biological mucosa and the "nasal chromatograph" effect [1]. Fig. 1 shows the concept of our system combining three sensor arrays with a two GC like columns. Thus, the system provides both spatial data from the first array and spatio-temporal data from the second and third arrays. The spatio-temporal data are believed to be used by the biological system to achieve improved discrimination. We have recently demonstrated this concept and shown that the temporal information from a single column can be combined with two large sensor arrays [2]. Here we report on a further improvement of our concept by adding a second retentive column and a second end array. The second column can either be uncoated or coated with a different retentive polymer to provide additional information with which to separate out the input odours.

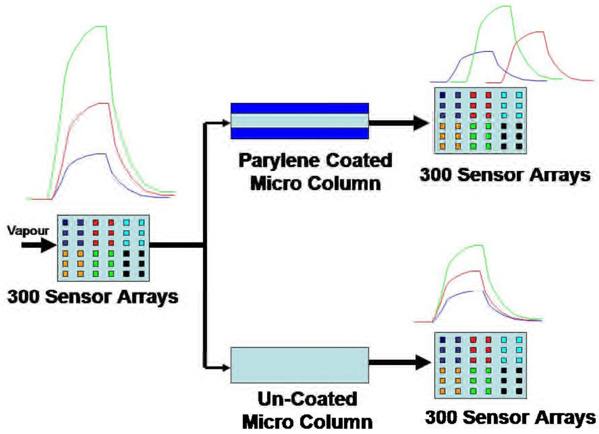

Figure 1. Dual- column concept with large sensor arrays

II. Experimental

This set-up has been realized by combining three 300 chemoresistive sensor arrays, employing composite polymer materials as the sensing layer (carbon black, Cabot corp. USA, mixed with 24 combinations of different sensing polymers), and two plastic polymer columns. The sensor array was fabricated using standard silicon processing, containing two Au/Cr layers, to form the pads and electrodes, and an SU-8 passivation layer. The array is laid out in a matrix configuration (12 columns and 25 rows) to reduce the pad count. The sensor array was coated in blocks of 12 sensors, where each block uses the same sensing coating, thus improving the redundancy of our system. The sensor based resistance was controlled while depositing to be around 1 kΩ to 5 kΩ.

Here two columns of similar size (0.25 mm x 0.25 mm x 512 mm) but with different coatings were used as shown in Fig. 1. In preliminary experiments the first column is coated with a 5 μm thick layer of Parylene-C as the stationary phase. The second column is uncoated to function as a reference. Previously we have successfully reported a working column with a square block design. Although the original column produced reasonable results, the square column reduced laminar flow within the column. Here we report on a second, spiral design, removing any sharp corners, thus aiding flow separation. The new design, as shown in Fig. 2, comprises of 2 separate components that can be stacked together to increase the total length.

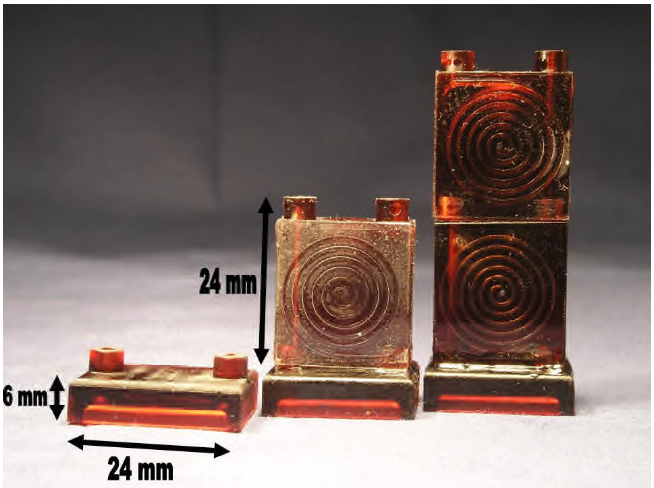

Figure 2. Plastic spiral-based micro retentive columns

The sensor chamber is located at the bottom of the spiral to complete the set-up. This combination reduces dead volume within the overall system thus making the design more efficient. The length of one spiral block is 512 mm with an initial channel cross-section of 0.25 mm x 0.25 mm. The micro-package was fabricated using a modified Envisiontec Perfactory Mini system and the column and chamber was fabricated out of methyl acrylate. These components were built unsealed to aid cleaning and then coated with a 5 µm thick Parylene C using an SCS/PDS 2010 Specialty Coating System. After coating, the column is then sealed using glass slides that was spin coated with a thin layer of UV adhesive.

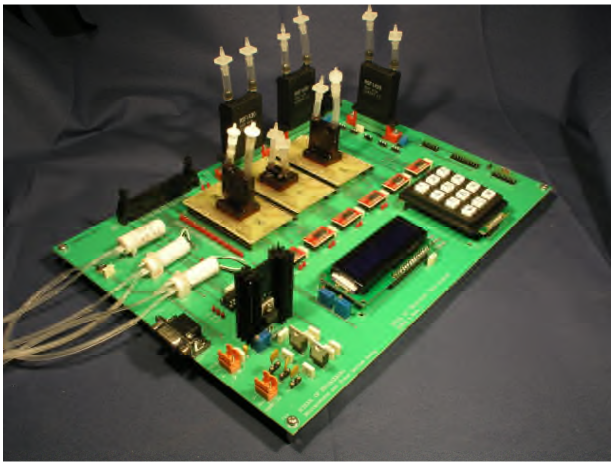
Figure 3. Electronic circuitry and three sensor arrays

The large sensor arrays has been specially designed and developed for extracting the high number of signals from individual sensing units. The electronic circuitry has been design to support up to 4 × 300 sensors, operated with a constant current, so that tests can be performed with different system settings. Fig. 3 shows the circuitry with three sensor arrays and two retentive columns.

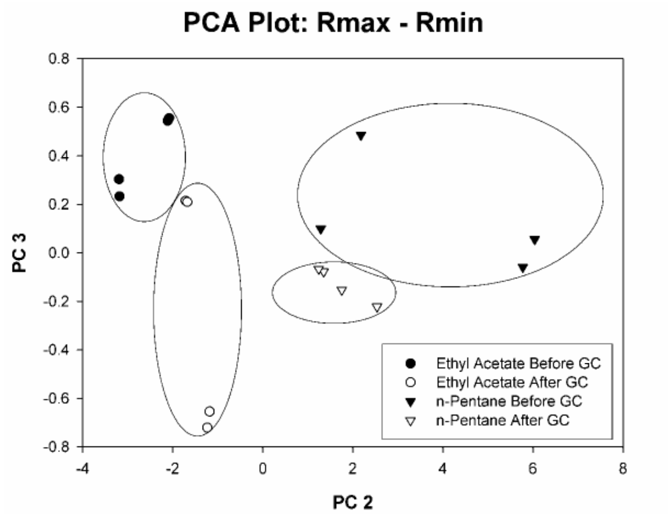

Figure 4. PCA plot for response before and after column

The system was tested with 170 s pulses of ethanol and toluene vapour in laboratory air (flow rate 20 sccm, temperature 20 C ±1°C, 10 s pre-test and 100 s flush). Preliminary results of the system are shown in Fig. 4. Here a principal components analysis (PCA) plot of the response before and after the coated column is shown.

III. Conclusion

Here we have demonstrated the successful integration of three large chemosensor arrays and two micro-columns to mimic the behaviour of the human olfactory system - viz a viz its division into distinct sensing zones. In addition to the diversity of the 300 sensors coated with 24 different polymer composite films, this system provides temporal information that can be used to enhance odour discrimination. It should be noted that we are not seeking to make a perfect gas chromatograph but combine time series algorithms with partial separation of odour types. We believe that this model represents more closely the nature of the biological system.

References

[1] J.A. Covington, J.W. Gardner, et al., "Towards A Truly Biomimetic Olfactory Microsystem: An Artificial Olfactory Mucosa," IET Nanobiotechnology, 2007,1, pp.15-21.

[2] F.K. Che Harun, P.H. King, J.A. Covington, J.W. Gardner, "Novel gas chromatographic microsystem with very large sensor arrays for advanced odour discrimination", Proc. of IEEE Sensors 2007 Conference, pp. 1361-1363, 2007.