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# Two-dimensional sensor array for discrimination of amines

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ABSTRACT

A two-dimensional sensor array was prepared for the discrimination of various amines. A simple combination of four molecularly imprinted polymers and three dyes was used to produce a 12-channel sensor array capable of discriminating between structurally similar amines.



Chemical sensing using sensor arrays is based on the utilization of arrays of differential receptors. Since all sensors or receptors in an array might not be selective to a specific analyte, data analysis of the responses of various analytes by pattern recognition is performed to facilitate discrimination between structurally similar analyte molecules.[1] Sensor arrays are promising tools because they enable accurate analysis, owing to their responsiveness to a broad range of analytes, and because the synthesis of these sensors requires minimal effort. Previously, classical electronic noses have been developed, which utilize metal oxide sensors, surface acoustic wave sensors, metal oxide field effect transistors, or conducting polymers.[2] More recent studies have demonstrated the use of colorimetric sensor arrays that utilize metalloporphyrins, calix[4]pyrroles, and Zn(salicylaldimine).[3]

Several groups have reported on the discrimination of amines by pattern recognition using molecularly imprinted polymers (MIPs), dyes, or kinetic spectral data.[4] Herein, we present a two-dimensional (2D) sensor array that can be used for the discrimination of various structurally similar amines. This sensor array has 12 channels and is composed of sensor elements that can be easily obtained through a simple combination of MIPs and metalloporphyrin dyes. A simple combination of two orthogonal arrays yields an array with diverse components; furthermore, this combination amplifies the discriminating power of the resulting sensor array.

Two arrays were selected in this study: an array of molecularly imprinted polymers and an array of metalloporphyrin dyes. Figure 1 shows the amines selected as target analytes. The analytes include primary amines (**A1**, **A2**, and **A5**), secondary amines (**A3** and **A4**), amines having other functional groups (**A2**, **A3**, and **A4**), and pharmaceutical (**A3**). It would not be an easy task to discriminate between the various sets of different amines by employing conventional methods.

Although, in general, analytes can be efficiently discriminated by using an MIP array, the introduction of a signaling unit into the polymer matrix is rather difficult. Therefore, in most studies on MIPs, spectroscopically active analytes were used or the binding of analytes to the MIPs was examined using an indicator displacement assay (IDA).[5] A metalloporphyrin array can be used to identify analytes; further, metalloporphyrins also provide useful information such as distinct absorbance and fluorescence patterns upon binding to analytes.[6] However, elaborate design and synthesis of porphyrin derivatives are required for the analysis of structurally similar compounds. In order to enhance the discriminating power of the sensor array, we utilized the positive aspects of both MIPs and metalloporphyrins. For constructing the MIP array, four polymers were prepared by thermal polymerization using methacrylic acid (MAA) and ethylene glycol dimethacrylate (EDMA) in acetonitrile. **P0** is a non-imprinted polymer, while **P1**–**P3** are imprinted polymers prepared using **A1**–**A3**, respectively, as templates (Table S1). The dye array comprises three metalloporphyrins that are prepared using 5,10,15,20-tetrakis-(3,5-di-*tert*-butylphenyl)-21*H*, 23*H*-porphine.[7] A sensor array with twelve channels could be easily prepared by the combination of four MIPs (**P0**–**P3**) and three metalloporphyrin dyes (Zn(II)-por, Co(II)-por, and Co(III)-por).

For example, **P0**·Zn(II)-por indicates that polymer **P0** and dye Zn(II)-por were employed for sensing an analyte (Table S2).

The general process adopted for sensing an analyte is shown in Scheme 1. First, a mixture of analytes and MIPs is equilibrated. Then, the MIPs are removed by syringe filters, and the remaining

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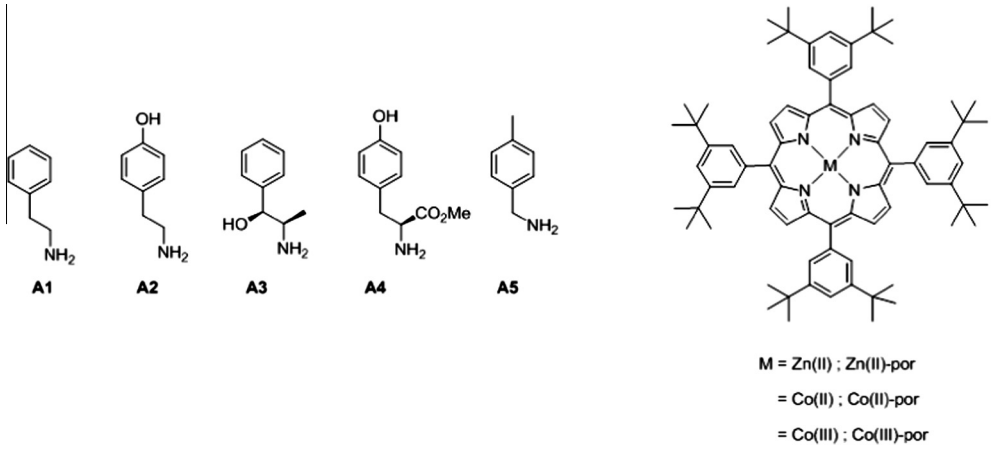
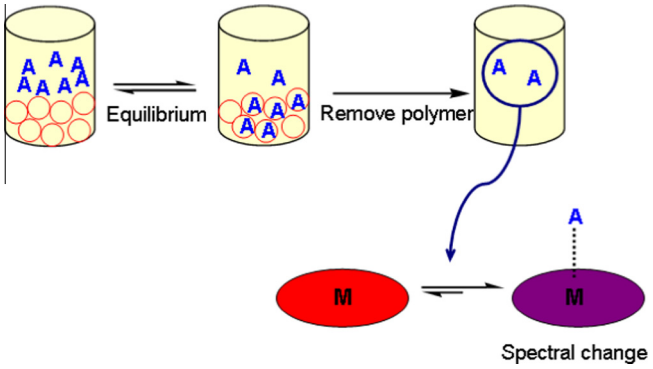



**Figure 1.** Analytes and metalloporphyrin dyes. **A1**: Phenethylamine, **A2**: tyramine, **A3**: (+)-norephedrine, **A4**: L-tyrosine methyl ester, **A5**: 4-methylbenzyl amine.




**Scheme 1.**

unbound analytes (supernatant) are treated with a solution of each metalloporphyrin, which results in a spectral change in each dye. It is noteworthy that this method can be used for easily detecting analytes using spectroscopy, and is useful for sensing spectroscopically inactive analytes. Next, we attempted to determine the relationship between the spectral change and the binding of the analytes to the MIPs. For this purpose, we measured the absorbance of the supernatant using the batch rebinding test and determined the spectral change induced by the supernatant observed for the dye solution. For the rebinding study (Fig. 2), different amounts of polymer **P3** were added to 4 mL of a 6 mM solution of an analyte (**A3**) in chloroform, and the resulting solution was shaken for 30 min. Subsequently, the UV spectrum of the supernatant was obtained. Further, 1.5 mL of the same supernatant solution was mixed with 1.5 mL of 5 μM Zn(II)-por in chloroform, and the absorbance of the resulting solution was measured. The graph shown in Figure 2a reveals that the absorbance of the supernatant decreased with increasing amounts of **P3**; this indicates that a greater amount of **A3** was bound to **P3**. A similar relationship was observed between **P3** and the absorbance of Zn(II)-por, as shown in Figure 2b; as the amount of **P3** increased, the absorbance of Zn(II)-por decreased at 430 nm and simultaneously increased at 421 nm. Thus, it was confirmed that the binding of an analyte is indicated by a spectral change, which can, therefore, be considered to be a response of the polymer toward the analytes.

The sensor array **P0**·Zn(II)-por–**P3**·Zn(II)-por, which had four channels and contained only one dye Zn(II)-por, was initially tested to discriminate between the analytes **A1**–**A5**. For evaluating the responses of the sensor elements, 4 mL of a 3 mM solution of an analyte in chloroform was shaken for 30 min in the presence of 20 mg

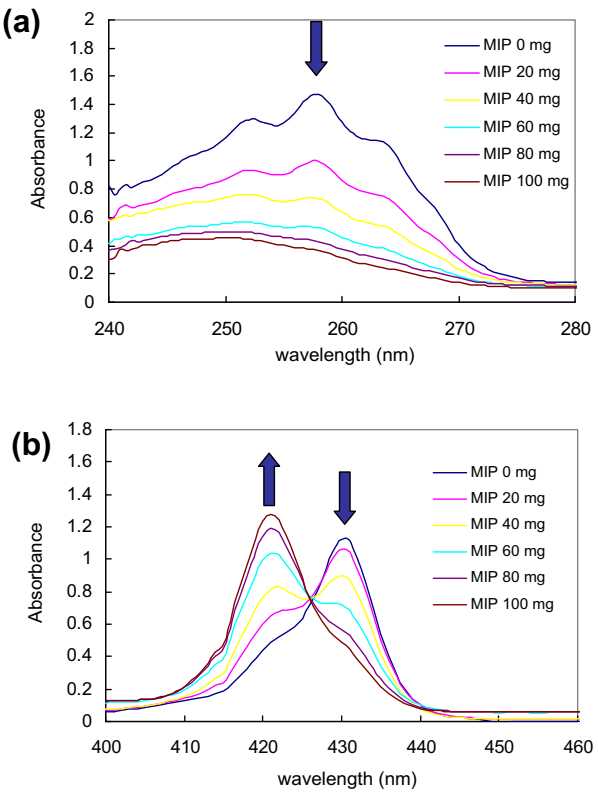



**Figure 2.** Absorbance change in (a) supernatant and (b) Zn(II)-por observed for binding of **A3** with **P3**.

of polymer. Next, 0.75 mL of the supernatant solution was mixed with 0.75 mL of a solution of 5 μM Zn(II)-por in chloroform; the absorbance of the resulting solution was measured. The response was recorded as the ratio of the observed absorbance (A, 421 nm) to the initial absorbance (Ai, 421 nm), that is, A/Ai, where Ai was measured from 1.5 mL of a 2.5 μM dye solution. Six replicates were conducted, and the entire data were consolidated in a 4 × 30 matrix data sheet (4 sensors × 5 analytes × 6 replicates). The analytes were discriminated by means of statistical analysis. The numerical responses obtained using the **P0**·Zn(II)-por–**P3**·Zn(II)-por array were consolidated in a 4 × 30 matrix, after which, a linear discriminant analysis (LDA) was performed to reduce the dimensionality of the data. Two different LDA plots are shown in Figure 3. Figure 3a represents the case in which all the analytes were successfully dis-