

## COLORIMETRIC SENSOR ARRAY: DO I SEE WHAT YOU SMELL?

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Array based vapor sensing has emerged as a potentially powerful approach toward the detection of chemically diverse analytes. Based on cross-responsive sensor elements, rather than specific receptors for specific analytes, these systems produce composite responses unique to an odorant in a fashion similar to the mammalian olfactory system.<sup>1-2</sup> In this design architecture, one receptor responds to many analytes and many receptors respond to any given analyte. A distinct pattern of responses produced by the array provides a characteristic fingerprint for each analyte. Advantages of array-based chemical sensing include its response to analytes for which it was not originally designed to detect, and its ability to generate unique responses to complex mixtures (i.e. coffees, perfumes, and beers) without the need for component by component analysis

Previous array technologies for such electronic noses, generally rely on multiple, cross-reactive sensors based primarily on changes in properties (e.g., mass, volume, conductivity) of some set of polymers or on electrochemical oxidation reactions occurring on heated metal oxides. Specific examples include conductive polymers and polymer composites sensors,<sup>3-4</sup> polymers impregnated with a solvatochromic dye or fluorophore optical sensors,<sup>5-6</sup> mixed metal oxide sensors,<sup>7-9</sup> and polymer coated surface acoustic wave (SAW) devices.<sup>10-11</sup> While preliminary results from such technologies were promising, the limited range of sensor-analyte interactions limits both their sensitivity for detection of compounds at low concentrations and their selectivity for discrimination between similar compounds; the latter proves especially problematic when large environmental changes in humidity induce changes in these technologies analyte responses.

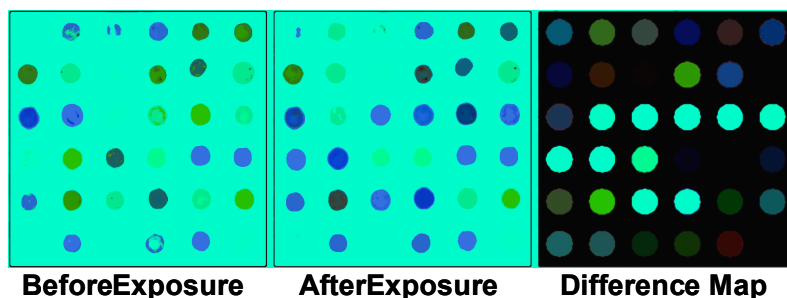


Figure 1. Image of the 36-dye colorimetric sensor array before exposure (left) and after exposure to decylamine (middle) after equilibration at full vapor pressure at 295 K. A subtraction of the two images yields a difference map (right).

We have developed and patented a unique chemical detection technology in which colorimetric changes in an array of dyes yields a unique pattern (difference map) for each analyte studied. The design of the colorimetric sensor array is based on two fundamental requirements: (1) the chemo-responsive dye, a dye that changes color upon a change in its

chemical environment, must contain a center to interact strongly with analytes, and (2) this interaction center must be strongly coupled to an intense chromophore. The first requirement implies that the interaction must not be simple physical adsorption, but must involve stronger chemical interactions, i.e. bond formation, acid-base interactions, or strong dipolar interactions. The consequent dye classes from these requirements are (1) Lewis acid/base dyes (i.e. metal ion containing dyes), (2) Brønsted acid or base dyes (i.e. pH indicators), and (3) dyes with large permanent dipoles (i.e. solvatochromic dyes). These dyes are printed onto a thin PVDF (polyvinylidene fluoride) membrane, producing inexpensive and disposable arrays. Data acquisition is obtained using a simple flat bed scanner which allows RGB (red, green, and blue) values to be obtained for each of the 36 dyes (i.e. 108 data points). A difference map is created from the before and after exposure (to an analyte) scans. Each difference map is unique to a specific analyte. Figure 1 shows the color change in the array after exposure to decylamine.

The array is particularly well-suited for the detection of biogenically important compounds such as amines, thiols, and acids.<sup>12</sup> It has previously been shown that the array can detect VOCs (volatile organic compounds) at the part per billion levels with extremely low error rates. Unlike most other electronic nose technologies, the colorimetric sensor array shows a high degree of dispersion and requires 22 independent dimensions (principal components) for 95% of the discriminatory ability of the array.<sup>13</sup> Additionally, the arrays are essentially non-responsive to changes in humidity, thus permitting real-world analyses. With this in mind, the array has also been used to detect and identify a wide variety of complex mixtures: coffees, beers, perfumes, and personal care products.

More recently, the array has been used for the detection and identification of pathogenic bacterium. The field of gas chromatography has extensively studied the volatile chemicals emitted from microorganisms during growth, and it is clear that different species, even strains with small genetic differences, emit a distinct profile of enzymatic products in the form of volatile organic compounds such as amines and sulfides. The VOCs emitted from various microorganisms have been studied in some detail. For example, *E. coli* emits acetic acid when grown in a glucose rich media and ammonia and amines in a protein rich media, while *Pseudomonads* are known to produce alcohols, ketones, and amines. These volatile products can accumulate to substantial levels, allowing for detection with an electronic nose.<sup>14</sup>

The colorimetric sensor array can readily detect and identify between *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Moraxella catarrhalis*, and *Streptococcus pyogenes* grown on a protein rich solid media (tryptic soy agar with 5% sheep blood) with high reproducibility. It has a limit of detection of 10 microorganisms in as little as 3 hours, a great improvement over today's standard methods which can take 24 to 72 hours. The colorimetric sensor array has a 97% success rate in determining type of bacteria present.<sup>15</sup> This technology can also be used to determining growth curves of bacteria grown on solid media, eliminating conventional multi-step, expensive processes currently used today.

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