Conductive Polymer Sensor Arrays

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In the food and beverage industry, one of the major analytical tools used to assess product quality is the human nose.[1] A need exists for an artificial nose that could replace or enhance this relatively subjective and costly quality control method.

In 1982 Persaud and Dodd demonstrated that an array of tin oxide sensors could act as an artificial nose.[2] Since then the artificial nose research field has expanded as chemists have been exploring materials that function as useful chemical sensors which exhibit broad selectivity. For example, materials such as metal oxide devices, conductive polymers and metalloporphyrins have been incorporated into artificial nose technology.[2,3]

Typical conductive polymers used in sensor arrays are polypyrrole and polythiophene (Figure 1). These polymers have an extended conjugated p electron system along the polymer backbone and a band structure resembling that of a semiconductor.[4] In the neutral state, the polymers exhibit a low conductivity which increases with increasing temperature. However, once these polymers are either oxidized (p-doped) or reduced (n-doped), the conductivity increases by many orders of magnitude (up to $\sim 10^4$ S/m), depending on the amount of doping.[5] Upon initial doping, electron paramagnetic resonance data suggests that polarons (radical ions with localized polymer bond deformation) are first formed, creating midgap states.[6] As the doping level increases, bipolarons (di-ions with localized polymer bond deformation) form to create midgap bands. When a voltage is applied, these polarons and bipolarons act as charge carriers that conduct through the polymer in a percolative fashion.[7]

Conductive polymer sensors are normally prepared via electrochemical deposition onto two microelectrodes placed on an insulator. The conductive polymer bridges the gap between the microelectrodes, thus allowing the resistance of the conductive polymer to be measured.[8] To create diverse sensor responses, the final conductivity of the deposited polymer can be engineered by varying the type of counterions incorporated, the doping level and the type of monomer used.

When a conductive polymer sensor is exposed to a given vapor, a rapid conductivity change occurs within seconds. This reversible change is the basis for obtaining a signal that corresponds to the adsorption of a gas. The adsorbed gas is thought to affect the polymer's conductivity through the mechanisms of polymer swelling, solvated counterions and/or applicable hydrogen bonding interactions.[9,10] These factors affect the amount of charge carrier hopping which will change the polymer's conductivity.

Most conductive polymer sensor arrays contain 12-32 sensors made of polypyrrole, polythiophene and/or polyanaline. Upon exposure to an odor, each sensor responds differently and the resulting pattern can be viewed in a histogram format. The process of distinguishing histograms can be done through data analysis techniques such as principal components analysis and cluster analysis.[11]

Over the past few years, many exciting applications of conductive polymer sensor arrays have appeared in the literature. A few examples follow that illustrate the broad range of fields to which conductive polymer sensor arrays have been applied. In the forensic science field, Barshick used an array to distinguish vapors from fire debris that were started with different liquid accelerants.[12] Arnold *et al.* applied the technology to the identification of volatiles emitted from cultured bacteria that were obtained from processed poultry.[13] On the MIR space station, Persuad *et al.* determined that their array could continuously monitor the quality of the station's environment and provide real-time feedback for the crew.[14] In terms of sensitivity and selectivity, Neaves *et al.* found that they could detect methanol at the 10^3 ppm level and distinguish a homologous series of n-alcohols.[15]

Conductive polymer sensor arrays have been shown to work well when distinguishing different odors. Future research will most likely focus on increasing the number of sensors in each array and integrating conductive polymer sensor arrays into multi-arrays so that the resulting artificial noses will come closer to mimicking the human nose.

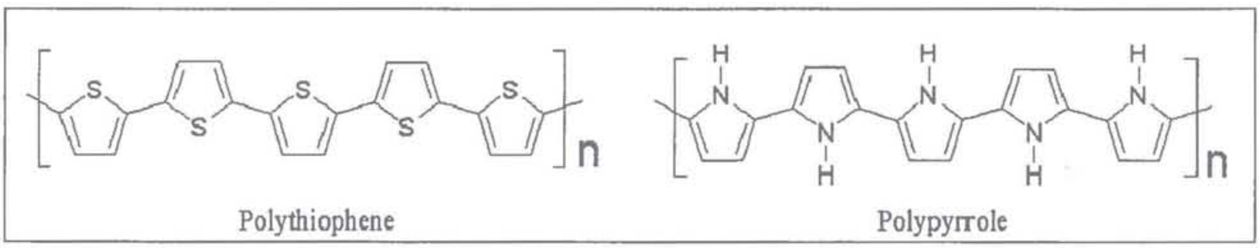

Figure 1

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