Chapter 7

Olfactory Sensing Using Quartz Crystal Microbalances with Radio–Frequency Sputtered Organic Films Based on Phenomenological Gas–Sorption Dynamics

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ABSTRACT

Olfactory information is made up of a wide range of volatile chemical compounds that can be detected by gas sensors with sensing layers, which play a crucial role in gas detection. The sorption-desorption dynamics in the vicinity of the top surface of the sensing layer are largely responsible for the sensor response. Carbonaceous films produced by the radio frequency sputtering of organic materials have granular structures with unsaturated chemical bonds that make them promising olfactory sensing layers. The pre-adsorbates of carbonaceous films, such as water in realistic circumstances, are regarded as dynamic active sites that affect the gas sorption characteristics. The authors have focused on surface water as the most common pre-adsorbate and ionic liquid as an artificial ionic pre-adsorbate. These pre-adsorbates modulate the structures of the sensing layers and act as an absorbent that generates dynamic changes in the sensory responses.

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INTRODUCTION TO GAS-SORPTION SUBJECTS AT A SENSING LAYER

Human olfactory interfaces for virtual reality devices can be developed by organizing a coder and decoder of olfactory information via information networks. The coder is generally referred to as an odor sensing system, and the decoder is termed an olfactory display, and is designed to be wearable and suitable for use as a human interface. Recent studies have revealed that the perception of olfactory information is profoundly affected when combined with visual information (Matsukura, 2009; Nishiguchi, 2010; Narumi, 2011).

An odor sensing system is symbolically called an electronic nose or an artificial olfaction (a machine olfaction) (Pearce, 2003). The representative odor sensing system is basically composed of a multiple gas sensor array that is generally made up of a sensing layer, a transducer/amplifier, and a signal processor. The sensor array consisting of various different types of sensors is considered to expand the chemospectrum of detectable species, and discrimination capability is also enhanced by a combination of specific sensor responses.

Environmental odor sensors must provide precise olfaction information reproducibly despite the continuous fluctuation of environmental conditions as characterized by temperature, humidity, and flow rate (Peter, 2009; Mumyakmaz, 2010). Gas sensors are required to extract electrical signals from physicochemical phenomena occurring at the atmospheric interface of adsorption/absorption (sorption) layers on the transducer. Irrespective of application, the gas-sorption dynamics of the sensing layer will determine the functionality of the gas sensor.

The molecular structure and surface morphology of the sensing layers are basic determinants of the gas sorption characteristics. The material design and structure of the sensing layer provide unique opportunities for tailoring functionality by means of intermolecular interactions between sorbate gases and sorbent (solvent) films, as depicted in Figure 1. In an ideal situation, the gas-sorption dynamics at sensing layers without pre-adsorbates can be characterized by physicochemical molecular descriptors, such as polarity, polarizability, chirality, volume, flexibility, and proton acidity (basicity) (Abraham, 2004; Abraham, 1994; Grate, 1991). The adsorbed gas molecules at the top surface of the sensing layer are likely to diffuse successively into the film in the vicinity of the top surface. The predominant process will differ with different combinations of film and gas.

In the realistic circumstances in which an electronic nose will be used, the pre-adsorbates in the vicinity of the top surface of the sensing layer will play crucial roles as regards sensor response. The pre-adsorbates at the sensing layer are regarded as dynamic active sites that profoundly affect the gas sorption characteristics.

Figure 1. Sorption behaviors of sorbate vapors at the sensing layers of a sorbent with pre-adsorbates
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