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Gas Reception and Transduction in Oxide Semiconductor Gas Sensor

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For better understandings of oxide semiconductor gas sensor, we are investigating the gas reception and signal transduction involved from a basic standpoint. The premises are; (1) Oxide semiconductors used are very small. (2) Resistance (R) is inversely proportional to the surface density of conduction electrons ($[e]_S$) in usual cases (assumption). (3) Gas adsorption and surface reactions follow conventional schemes.

Gas reception Semiconductor crystals feel gases only through supplying electrons for the ionosorption of the gases. As shown by the Poison's equation, with increasing gas adsorption, electron depletion of the conventional type (regional depletion) goes to completion easily for small crystals, to be followed by new type one (volume depletion) in which the Fermi level shifts down instead. The correlations of R with P_{O2}, P_{NO2} in air and P_{H2} or P_{CO} in air, derived on the assumption that oxygen is adsorbed as O^-, have agreed satisfactorily with experiments, where P stands for partial pressure of each gas. Influences of size and shape of crystals on gas responses and rates of response and recovery transients are accounted for satisfactorily as well. Recent studies have revealed that oxygen adsorption is influenced strongly by moisture, adsorption as O^{2-} being suppressed almost completely in the presence of small moisture. The gas reception theory can be extended to include such a case and is likely to provide a useful tool to analyze the moisture effects.

Transduction If the constituent crystals are identical in size, shape, donor density and the kind of semiconductor, all of them have the Fermi level in common under any conditions of ambient. There is nothing particular happening at the contact between them (homo-contact). Conduction electrons present at the surface and interface go forth and back through the contact as exchange current under non-bias condition, while they are forced to flow through it as drift current under bias condition. Conductance of each contact is thus given by a product of elementary charge of electron, $[e]_S$, contact area and drift mobility of electrons (□), and this results in the transducer function (2) as originally assumed above. If not, on the other hand, characteristic phenomena happen at the contact between non-identical crystals (hetero-contact). Free crystals, if different in either of the above properties, have the Fermi level at different positions under exposure to gas, while they are obliged to have it in common when contacted. Important in this regard is the pinning of the Fermi level, known well for metal – semiconductor contact. The pinning theory shows that the hetero-contact is featured by the occurrence of contact potential (CP) and a gap between conduction band edges (Gap). CP reduces μ for electrons flowing against it under bias condition, while Gap plays a role to establish exchange current under non-bias condition. Owing to these effects, conductance of hetero-contact under exposure to gas is subject to change dually not only through a change in $[e]_S$ but also through μ, being made more sensitive to the gas than homo-contact. Although the μ - term vanishes in usual devices, it is expected to exert profound effects when hetero-contacts are arranged in order, as already evidenced by some experimental observations.

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