Hybrid Solid State Chemoresistive and Fluctuation-Enhanced Gas Sensors by Advanced Gas Deposition Methods: Exhaled Breath and Indoor Air Analysis

L. Österlund[1], T. Welearegay[1], J. Smulko[2], R. Ionescu[1]

[1]*Dep. Solid State Physics, The Ångström Laboratory, Uppsala University, P. O. Box 534, SE-75121 Uppsala, Sweden*
[2]*Faculty of Electronics, Telecommunications and Informatics, Gdańsk University of Technology, Gdańsk, Poland*
e-mail: lars.osterlund@angstrom.uu.se

Gas sensing by means of solid state sensors rely on the interaction of gas molecules with an active sensor surface that changes the response of one of several measurable physical quantities. Obviously, it is desirable that such sensors expose large surface areas that interact with the gas molecules to achieve large signal-to-noise ratios. Nanoparticles have by definition a large surface-to- volume ratio and are extensively used as sensor materials in electronic solid state sensors. It is however difficult to prepare well-defined nanoparticles with desired physico-chemical properties with well-behave and reproducible properties. This is partly due to the fabrication methods, but also due to kinetically controlled structural and chemical changes of the sensors during operation in a reactive environment.

In this talk, I will review our work on chemoresistive and fluctuation-enhanced solid state sensors based on so called advanced gas deposition (AGD). AGD is a physical vapor deposition technique that utilizes inert or reactive gas cooling of evaporated atoms and ions from a target source held at a constant, high temperature, close to the melting point of the source material. The technique stands out as a particularly suitable method to achieve reproducible properties in samples with high porosity and surface area, since nanoparticle growth is separated from thin-film formation. Two families of sensors made by AGD will be presented: 1) Chemoresisitive hybrid noble metal – organic ligand nanoassemblies, where changes in electron conduction through a metal-ligand network is measured as the functional groups of the ligands interact with targeted gas molecules.

Almost 97 % accurate diagnosis of gastric cancer in exhaled breath was demonstrated for such sensors based on gold nanoparticle – ligand nanoassemblies, while 100% accuracy was demonstrated for Dengue diagnosis based on copper nanoparticle – ligand assemblies. Similarly, robust and 100 % accurate diagnosis of human Echinococcosis was achieved for an array consisting of eight noble metal – ligand based chemoresistive sensors. 2) Secondly, we show results for a novel p-type NiO nanoparticle chemoresisitve-type sensor and show how fluctuation-enhanced sensing can be utilized to obtain surpassed selectivity and sensitivity for gas detection employing films of nickel oxide nanoparticles made by AGD methodology.