Chemical Sensor Block Course

Schedule

Block course of Chemical Sensors
Institute of Physical Chemistry of the University of Tuebingen
February / March

Timetable:

Lectures: 9:00 – 12:00 h in VG 2.034.

Experimental and data evaluation: The experiments will run in 4 groups of 5 people in the afternoon. Beginning at 13:00 h.

Lecture program week 1

Date	Topic	Content	Lecturer
Mon.	Overview of Block Course	The content of the theoretical and practical parts of the course will be explained in detail together with goals to be achieved by the participants.	Nicolae Barsan
	Overview of gas sensors	The functioning principles of the most employed gas sensors will be explained with more emphasis on the ones that are not subject of dedicated lectures.	
Tues.	Gas sensors performance	Overview over gas sensors performance criteria: Sensitivity, selectivity, stability, etc…Besides explaining the meaning and significance of the performance criteria there will be plenty of examples illustrating the performance of various types of gas sensors. The lecture is also providing the basic knowledge needed for the evaluation of the tests performed by the course participants.	Nicolae Barsan
Wed.	Gas sensors based on Semiconducting Metal Oxides (SMOX)	The complete process of gas sensing will be analyzed starting from the chemical reactions taking place at the surface down to the changes in the resistance of the sensing layer. The influence of SMOX nature, sensing layer morphology and conduction mechanisms will be discussed.	Nicolae Barsan

Date	Topic	Content	Lecturer
Thurs.	Operando SMOX	The Operando research concept will be presented, the most important investigation techniques – work function changes, DRIFT spectroscopy and impedance spectroscopy – explained and a few cases presented in detail such as CO detection in the presence of humidity.	Nicolae Barsan
Fri.	Polymeric gas sensors	General properties of polymers; Gas sensing with polymers and macromolecules; Thermodynamic approach to the gas sensing with polymers; The interactions between the polymer sensing element and analyte will be addressed in connection with selectivity issues; Possible implementations of polymer sensor with gravimetric, capacitive and field effect transducers will be presented. Special focus will be on the humidity sensors because of their practical relevance. Readout modalities will be shortly addressed.	Alexandru Oprea

Lecture program week 2

Date	Topic	Content	Lecturer
Mon.	EC 1	Electrochemistry fundamentals will be presented starting with electrical and chemical basics. The electrochemical systems in equilibrium will be treated on thermodynamic basis. A kinetic approach will be used for the non-equilibrium cases. The connection between reaction rates and flowing currents will be established and the Buttler-Volmer equation inferred.	Alexandru Oprea
Tues.	EC 2	The interaction of the gaseous analytes with the electrochemical systems will be analyzed. Different electrochemical readout types (amperometric, potentiometric and conductometric / impedimetric) will be addressed as possible transducers for electrochemical sensors. Gas sensors with liquid, polymer and solid state electrolytes will be presented.	Alexandru Oprea
Wed.	Operando Polymers	The operando approach for polymer gas sensors will be shortly described. Gravimetric, optical, field effect and impedimetric investigations will be addressed. Humidity, as analyte, will be considered in connection with the large use of capacitive humidity sensors in industrial, commercial and domestic applications.	Alexandru Oprea
Thurs.	Chemometrics	Introduction to chemometrics, especially the qualitative (PCA) and quantitative (PCR, PLS) model based methods.	Udo Weimar

Fri.	Gas sensors applications; Neural network	Some examples of gas sensors in application fields are given: Quality of packaging, Fire detection. Introduction into neural networks.	Udo Weimar

Experimental

The experiments run in 4 groups of 4-5 people. Schedule Experimental

Week 1

Group	Monday	Tuesday	Wednesday	Thursday	Friday
1	GMS SI Lab tour	SprPol	S 3+4+5	S 1+2	KP
2		ScrMOx	SprPol	S 3+4+5	S 1+2
3		KP	ScrMOx	SprPol	S 3+4+5
4		S 1+2	KP	ScrMOx	SprPol

Week 2

Group	Monday	Tuesday	Wednesday	Thursday	Friday
1	ScrMOx	KP Evaluation	S 1+2+3+4+5 evaluation		Chemo-metrics
2	KP				
3	S 1+2				
4	S 3+4+5				

Legend:			**Meeting point**
SI		Safety Instructions	VG 2.034
GMS		Gas Mixing System	
Lab tour		Tour through the laboratory	
MOX	ScrMOx	Screen Printing of MOx	VG 1st floor
	KP	Kelvin Probe	VG 1st floor
Polymer	SprCPol	Spray Coating Polymer	VG 2nd floor
S 1+2+3+4+5	S 1	Metal oxides	VG 1st floor
	S 2	Humidity sensors/Polymers	
	S 3	Pellistors	VG 1st floor
	S 4	Electrochemical cells	
	S 5	Photoionization detector	
Evaluation of S 1+2+3+4+5 Chemometrics		Gas sensor evaluation	C – Building, ZDV-room, F07

General introduction into gas sensor evaluation

Operating a gas mixing system	Within this session the technical basis for measuring and composing multiple gases are learned and will be performed on a state of the art gas mixing system. In the first part of the session the technical concepts behind the gas mixing system will be introduced. The physical principles behind mass flow controllers, magnetic valves and vaporizer will be explained in detail. In a second part of the session the learned theory will be transferred to a real world gas mixing system used to compose multiply gases to a desired and accurate composition. To ensure the performance of such a system a classical calibration of the gas mixing system will be performed and evaluated.

Metal oxide gas sensors

Sensor preparation	This session demonstrates all steps necessary to create a gas sensor from metal oxide powders; the preparation of gas sensors starts with preparing a printable paste of SnO_2 powder and paste deposition by screen printing on Alumina substrates equipped with electrodes and heaters. The so prepared sensors are dried and thermally treated to stabilize the sensing layer. As a last step the heaters of the sensor are calibrated.
MOX gas sensing performance in S1+2	Sensors are repeatedly measured in different atmospheres (humid air) exposing the sensors to carbon monoxide or ethanol. The changes in DC resistance are measured. Additionally, humidity is measured during S 1+2 in the experimental part.
Kelvin probe	Simultaneous DC electrical resistance and work function changes measurements are performed on undoped SnO_2 based gas sensors. The target gas CO will be dosed in dry and humid air. Evaluation of the results: Extraction of the relationship between resistance and band bending.

Polymeric gas sensors

Fabrication of polymeric gas sensors	Preparation of polymeric gas sensors starting from available commercial polymers. Out of these polymers a solution suitable for spray coating is prepared and spray coated.
Polymeric gas sensor performance in S 1+2	Performance of homemade humidity sensors based on polymers and commercial SMOX gas sensors are demonstrated (S 1+2)..

Electrochemical gas sensors, Pellistors, Photoionization detectors

Operation of E-cells, PIDs and Pellistors S 3+4+5	The performance of commercially available electrochemical gas sensors, pellistors and PIDs is shown in comparison to each other during S 3+4+5. The test gases CO and Ethanol are dosed in different humidity backgrounds.

Data evaluation

Evaluation of S 1+2+3+4+5	The raw data of all different types of sensors obtained by exposure of different concentrations of CO and EtOH in 10%, 30% and 60% r.h. are plotted and discussed. For each sensor type a typical calibration curve will be plotted and fitted with a suitable function. After calculating the analytical sensitivity, the different types of sensors are compared.

Chemometrics

Introduction to VOC discrimination by using an array of gas sensors	Within the practical session of the chemometric will aim to use multivariate techniques to analyze the quality of a test gas atmosphere in order to determine which sensor contributions are relevant to “perceived quality”. The analysis will cover areas of the PCA for classification and the PLS for regression purposes.