

SENSORS and TRANSDUCERS



Klas Hjort, Materialvetenskap

† (Bio)chemical microtransducers

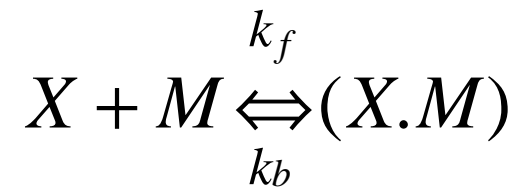
- Basic considerations
- Principles of detection for (bio)chemical sensors:
 - Chemoresistors
 - Chemocapacitors
 - Chemotransistors
 - Thermal chemical sensors
 - Mass-sensitive chemical sensors
- Biochemical principles
- Applications

(Bio)chemical sensors



† Basic definitions

- (Bio)chemical signals \Rightarrow Electrical signals



Change of heat - **Calorimetric**

Change of charge - **Conductometric / Amperometric /
Potentiometric**

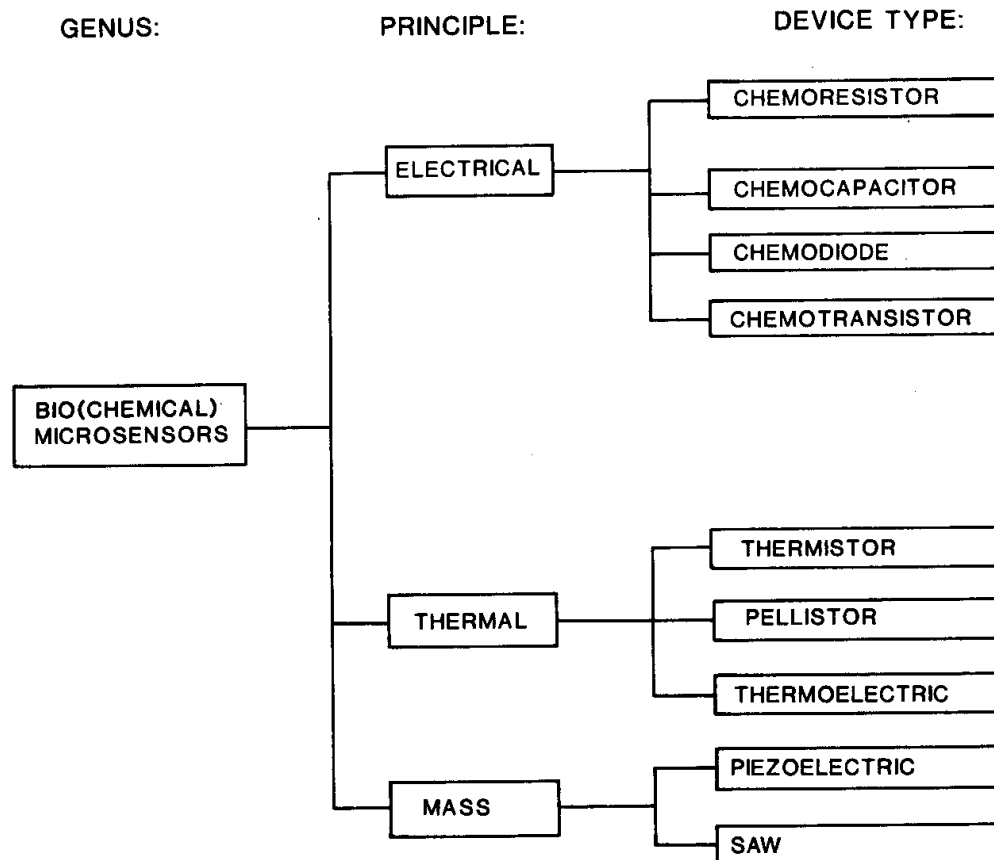
(Bio)chemical sensors



Table 9.1 Principles, measurands and typical examples of (bio)chemical sensors.

Principle	Measurand	Typical sensor
Conductometric	Resistance/conductance	Tin oxide gas sensor
Potentiometric	Voltage/e.m.f.	Ion selective FET for pH
Capacitive	Capacitance/charge	Polymeric humidity sensor
Amperometric	Current	Electrochemical cell
Calorimetric	Heat/temperature	Pellistor gas sensor
Gravimetric	Mass	Piezoelectric or SAW sensors
Optical	Path length/absorption	Infra-red detector for methane gas
Resonant	Frequency	Surface plasmon
Fluorescent	Intensity	Fibre-optic

Classification of chemical sensors



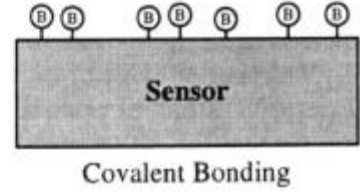
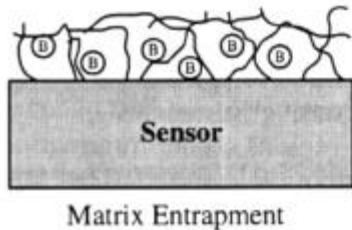
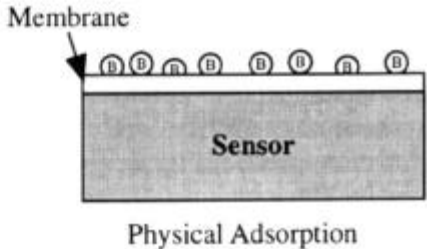
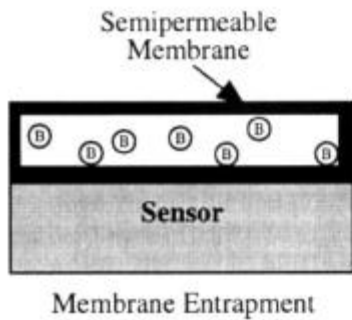
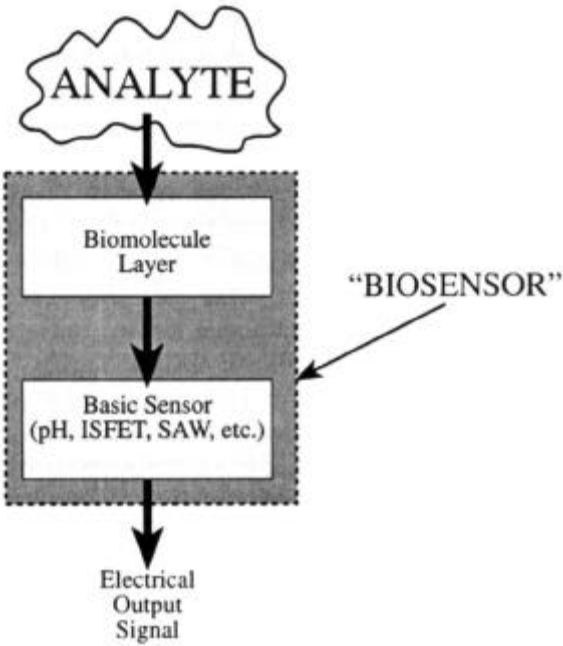
(Bio)chemical sensor materials



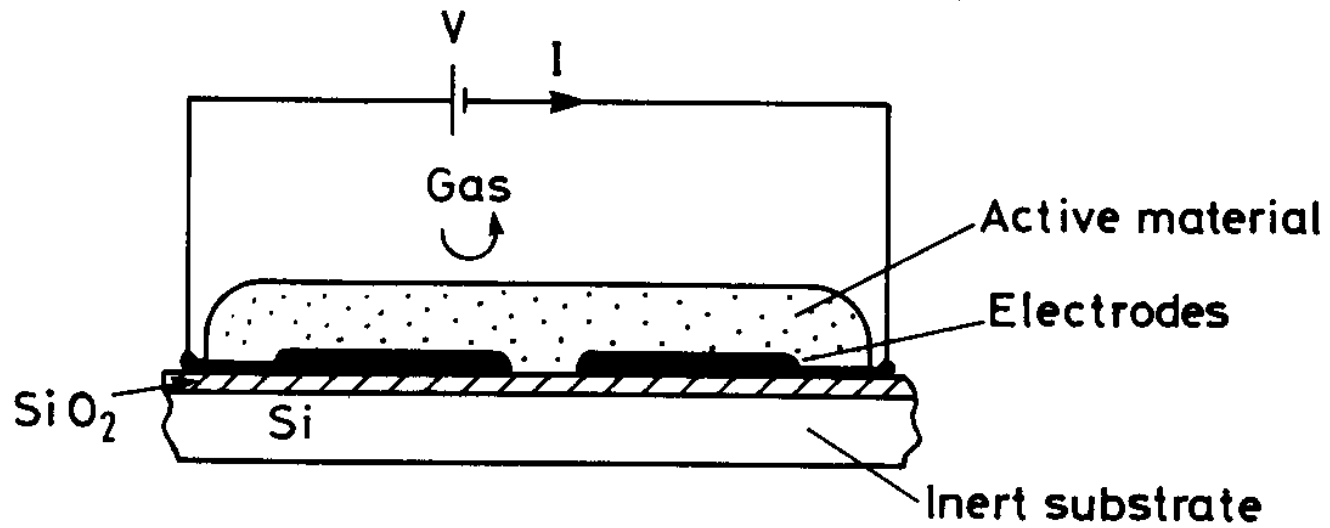
Table 9.2 Some common materials used in (bio)chemical microsensors.

Active material	Examples	Sensing principles	Measurands
Thin oxide layer	SnO ₂ , ZnO	Surface conductance	Combustible gases
Thick porous oxide layers	SnO ₂ , ZnO, TiO ₂	Bulk conductance	Combustible gases
Catalytic metals	Pd-TiO ₂ , Pd-MOS, Pd-MOSFET	Surface potential Threshold voltage	H ₂ , CO H ₂ , NH ₃ , CO
Ion-selective devices	AgCl, AgBr	Electrochemical potential	Cl ⁻ , Br ⁻
Catalytic coating	ThO ₂ /Al ₂ O ₃	Heat of combustion	H ₂ , CH ₄
Organic films	Substituted phthalocyanines	Bulk conductance	NO _x
Langmuir-Blodgett films	Steric acid	Piezoelectric/SAW	Various polar molecules
Conducting polymers	Poly(pyrrole)	Bulk conductance /mass	Polar compounds, NH ₃

Principles of biochemical sensors



Chemoresistors



Tin oxide gas sensors

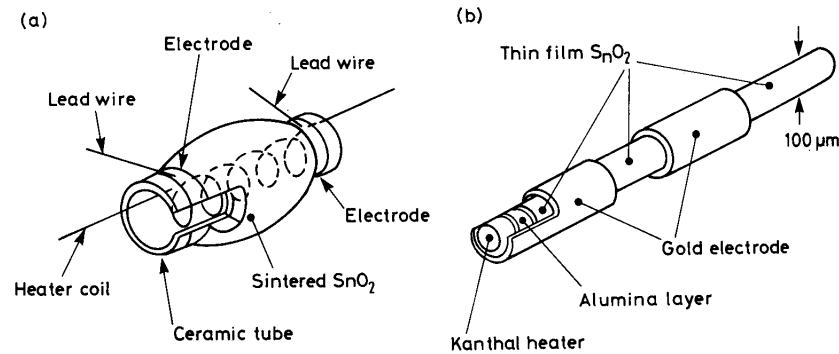
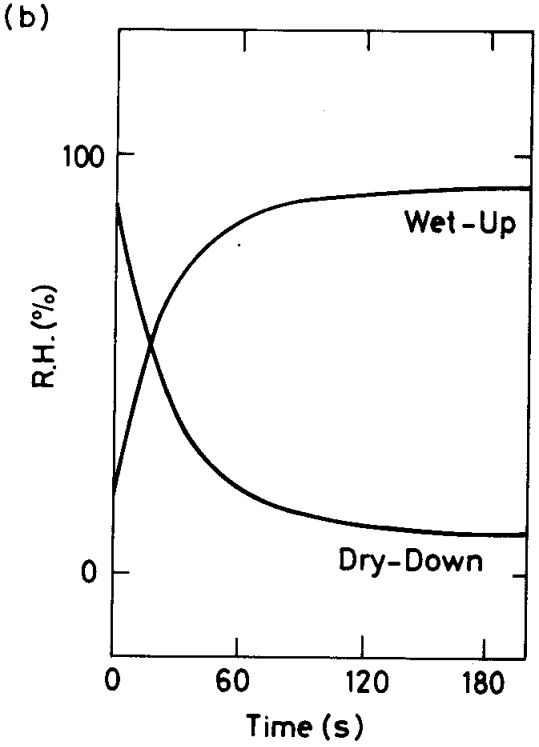
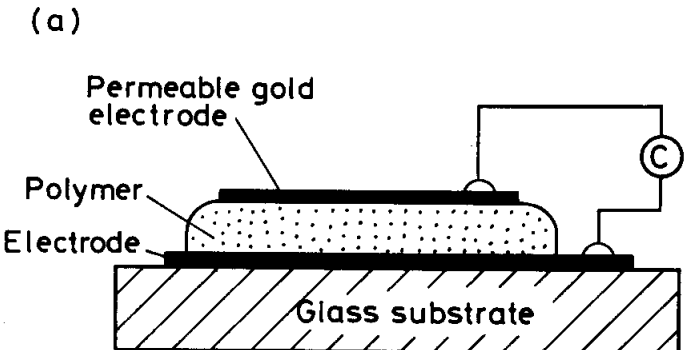


Table 9.3 Commercial tin oxide gas sensors [9.3].

Model	Category	Measurand	Range (ppm)
TGS 815	Combustible gases	Methane	500 to 10,000
TGS 821	Combustible gases	Hydrogen	50 to 1,000
TGS 824	Toxic gases	Ammonia	30 to 300
TGS 825	Toxic gases	Hydrogen sulphide	5 to 100
TGS 822	Organic solvents	Alcohol, toluene	50 to 500
TGS 830	CFCs	R-113, R-22	100 to 3,000
TGS 800	Air quality	Cigarette smoke	< 10
TGS 550	Odour	Sulphur compounds	0.1 to 10

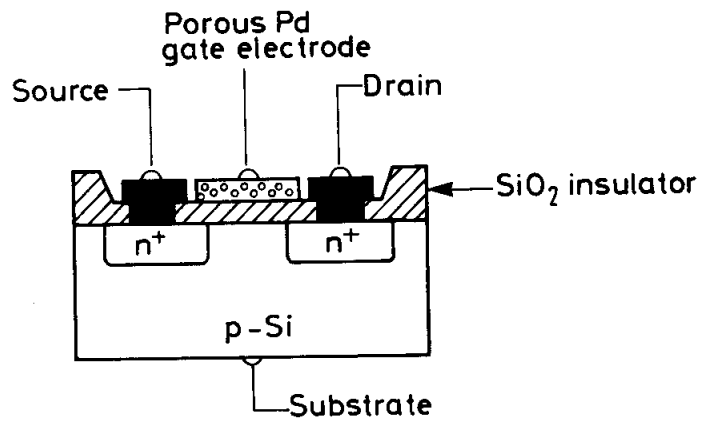
Chemocapacitors



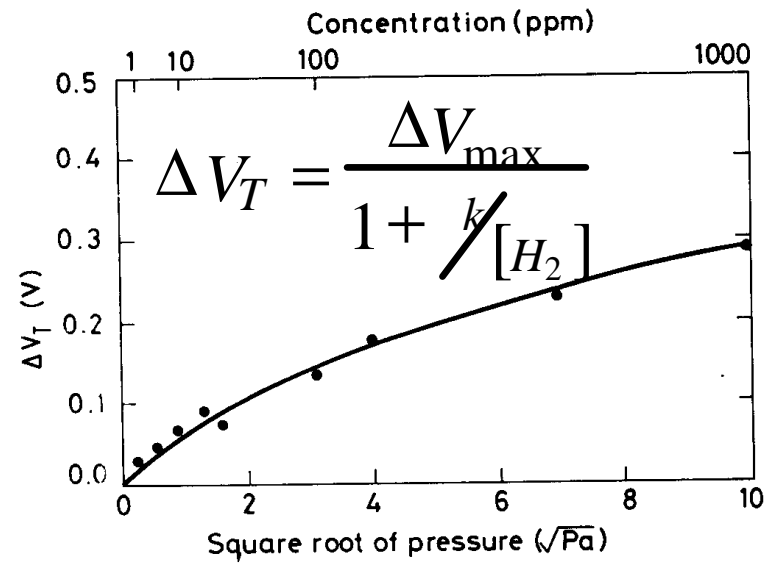
Chemotransistors



MOSFET -PFET:



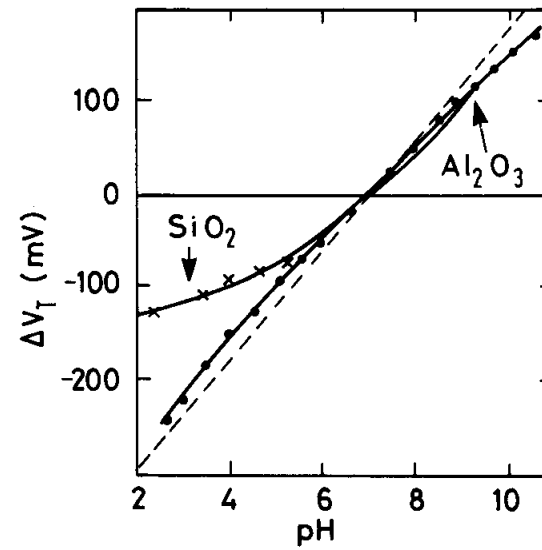
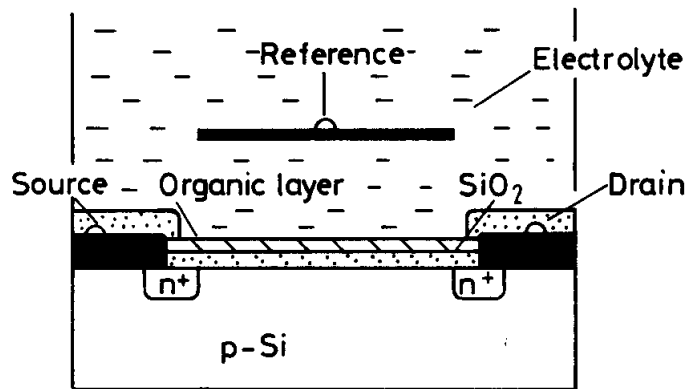
(Lundström 1975)



Chemotransistors



ISFETs



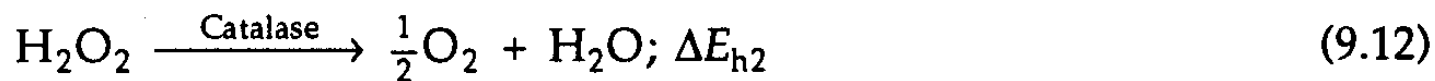
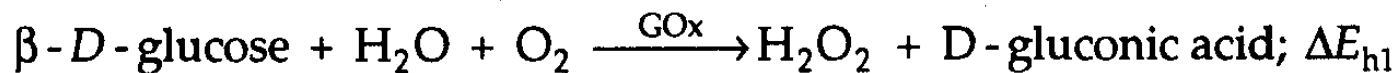
Thermal chemical sensors



Thermistors

Table 9.5 Molar enthalpies of some common biosensing reactions.

Analyte	Enzymes	$-\Delta E_h$ (kJ/mol)
Cholesterol	Cholesterol oxidase	52.9
Glucose	Glucose oxidase (GOx)	80.0
H ₂ O ₂	Catalase	100.4
Lactate	Lactate oxidase	-
Urea	Urease	6.6
Lipids	Lipase	-
Peptides	Trypsin	-
ATP	ATPase	-



Resonant mass-sensitive sensors



QCMs - quartz crystal microbalances

AT-cut thickness-shear resonators, typical at 10 MHz, m_{\min} 1 ng

SAW - surface acoustic wave devices

Y-cut SAW resonators, typical at 1 GHz, m_{\min} 1 pg

Table 9.7 Adsorption masses and partition coefficients of 19.3 ppm strychnine or β -ionone for various active coatings on a QCM held at 45°C [9.22].

Coatings	Strychnine		β -ionone	
	Δm (ng)	P	Δm (ng)	P
Uncoated	2 ± 10	10	2 ± 10	10
$2C_{18}N^+2C_1/PSS^-$	533 ± 10	2,700	610 ± 10	3,050
DMPE ²	560 ± 10	2,800	540 ± 10	2,700
Poly(vinyl alcohol)	4 ± 10	18	4 ± 10	19
Poly(methyl glutamate)	5 ± 10	25	6 ± 10	30
Poly(styrene)	7 ± 10	35	7 ± 10	35
Bovine plasma albumin ³	5 ± 10	25	6 ± 10	30
Keratin	7 ± 10	35	6 ± 10	30

Applications of chemical sensors



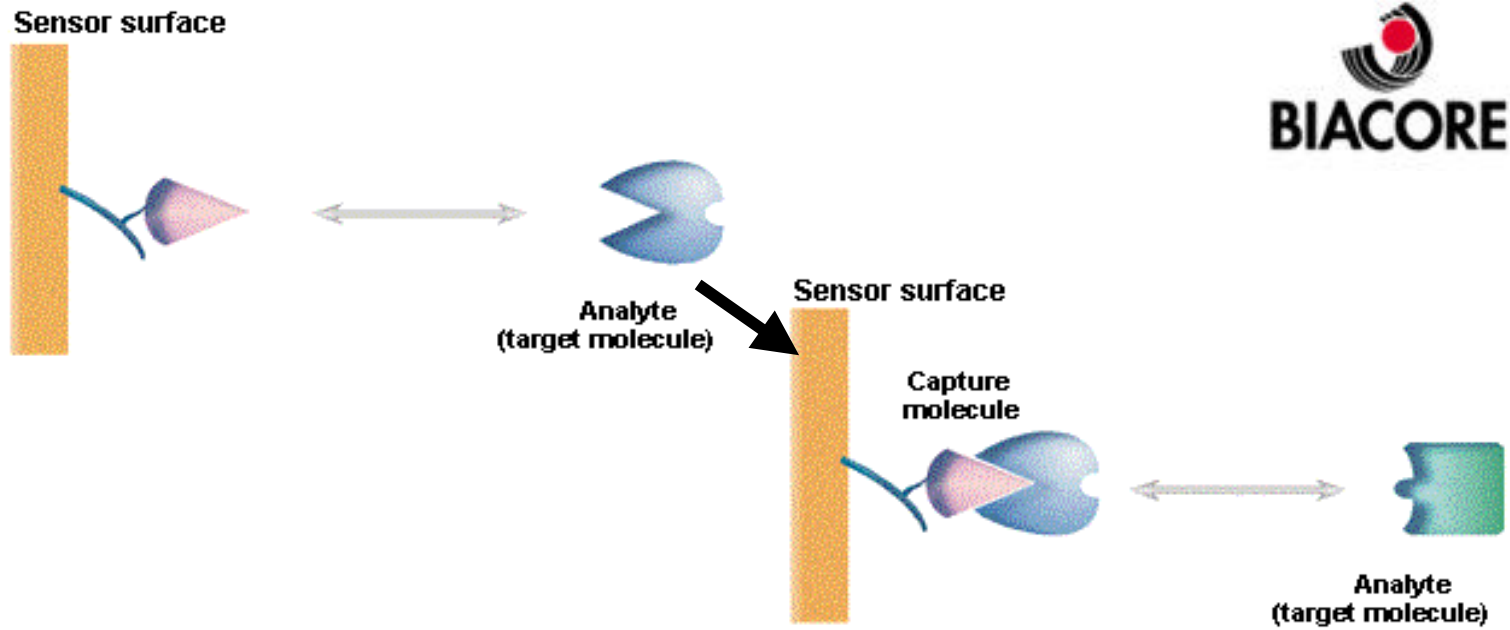
Table 9.8 Typical applications of chemical sensors.

Field of application	Typical example
Automotive	Engine control, air quality in car, emission
Aerospace	Engine control, air quality in cabin, emission
Agriculture	Fertiliser and pesticide control
Chemical analysis	Laboratory testing of materials
Safety (fire)	Fire warnings in mines, buildings, houses etc.
Process control	Production of chemicals, foodstuffs, etc.
Environmental monitoring	Detection of pollutants in air, water and soil
Medicine	Anaesthetic gases, diagnostics, biochemistry
Customs	Illegal and dangerous substances (explosives)
Quality control	Smell/flavour of drinks, foodstuffs, tobacco

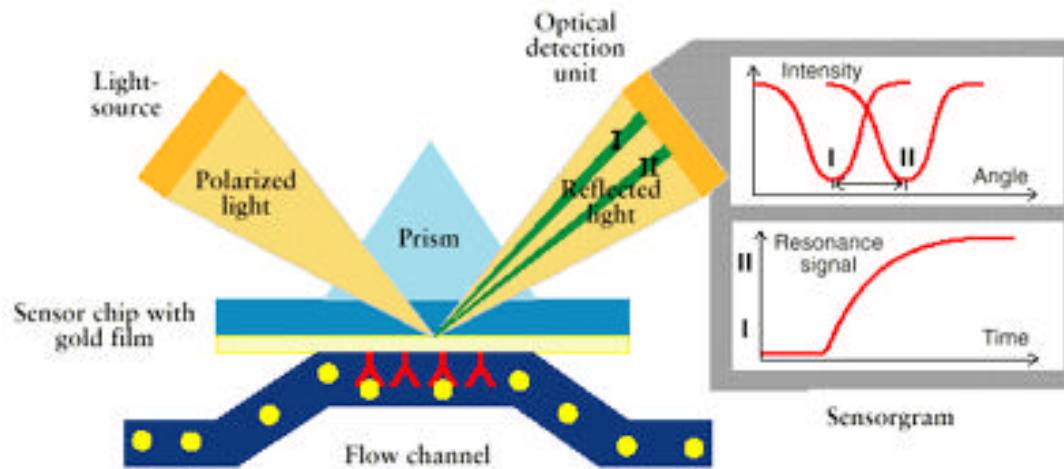
BIACORE



Enzyme sensor



BIACORE - Surface plasmon detection



S-SENCE (Bio)chemical sensor center



Industrial Competence Center at Linköping University:

- High-T sensors on SiC
- New control methods for production quality
- Surveillance of chemical processes

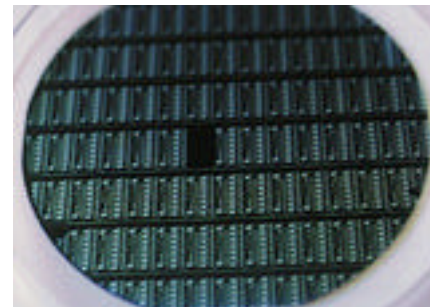
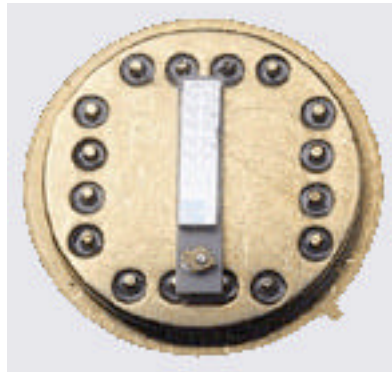
Surface plasmon resonance



Nordic Sensor Technologies



**Electronic Noses: Arrays of
with different materials on the gate**



Telair Europe



Model M-SENSE II:
Integrated CO / CO₂ / Moisture /
Temperature sensor &
ventilation controller

