Sensors and Actuators (เซนเซอร์และตัวขับเร้า)

Chapter 2: BIO(CHEMICAL) SENSORS

By

Dr.Santhad Chuwongin
office : 405
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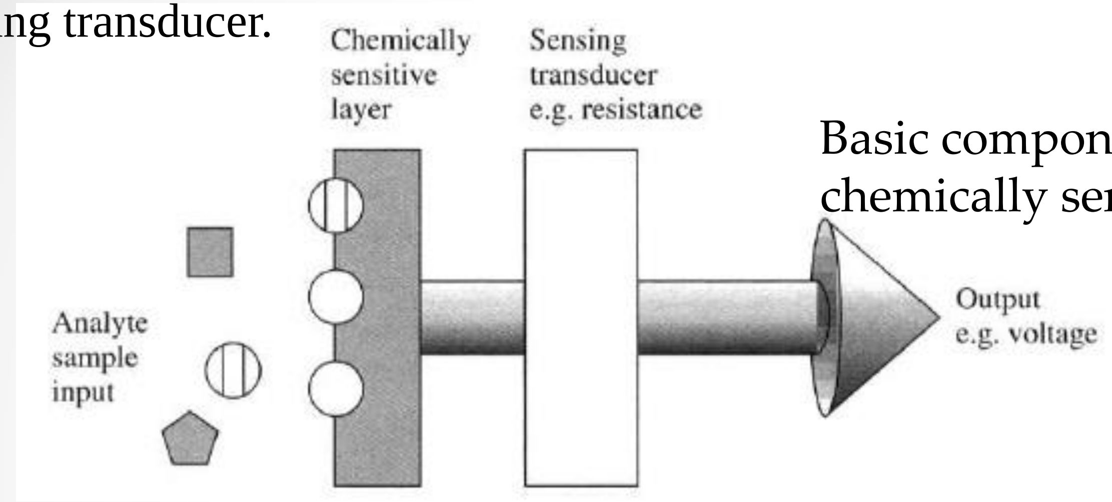
BIO(CHEMICAL) SENSORS

➢The basic components of these sensor comprise a chemically sensitive layer interfaced to a sensing transducer.

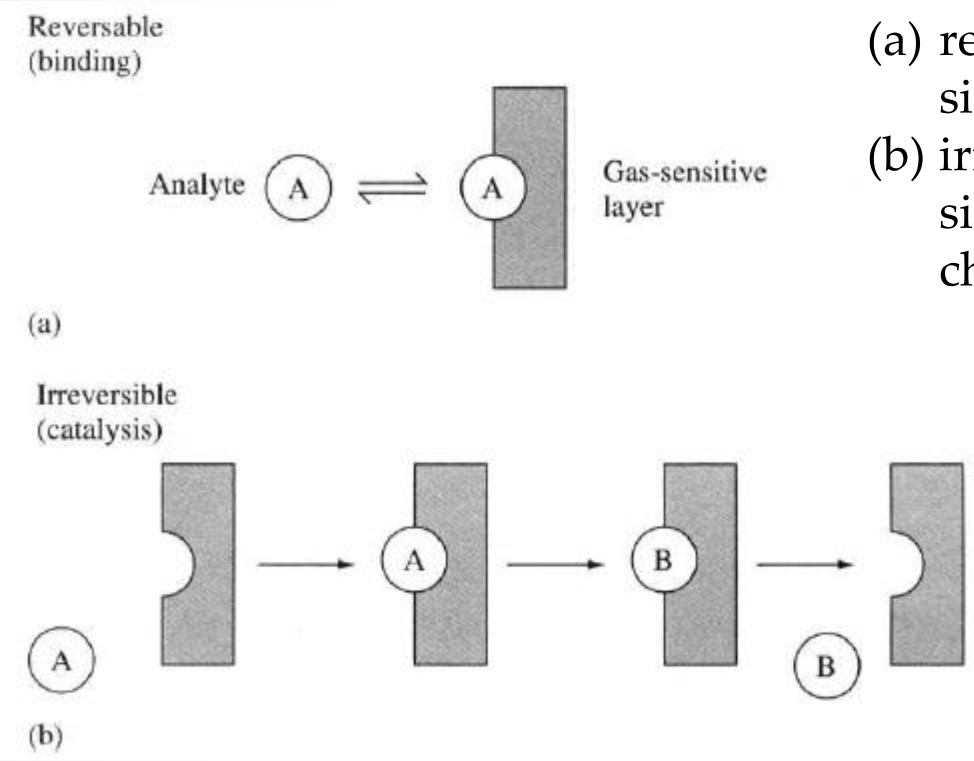


Basic components : analyte molecules, chemically sensitive layer, and transducer

➢The analyte molecules interact with the chemically sensitive layer and produce a physical change that is detected by the transducer and are converted into an electrical output signal.

➢The nature of this interaction is determined by the type of material used and can be either a reversible process or an irreversible reaction

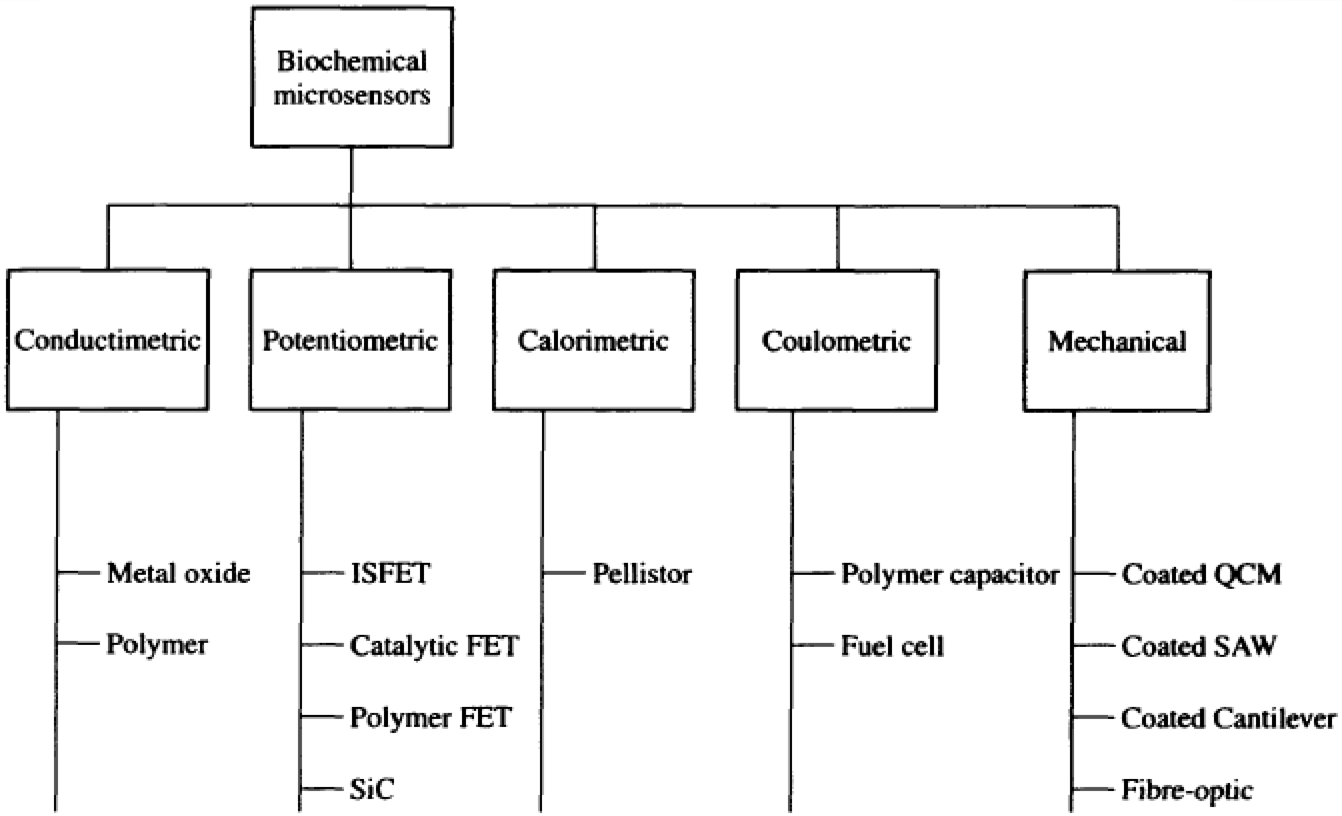
BIO(CHEMICAL) SENSORS



(a) reversible binding of the analyte A to a site at the chemically sensitive layer
(b) irreversible reaction of the analyte A at a site to produce molecule B at the chemically sensitive layer.

BIO(CHEMICAL) SENSORS

➢The signals that are measured can be the change in electrical resistance (i.e. conductimetric), change in work function (i.e. potentiometric), change in the heat of reaction (i.e. calorimetric), and so on.



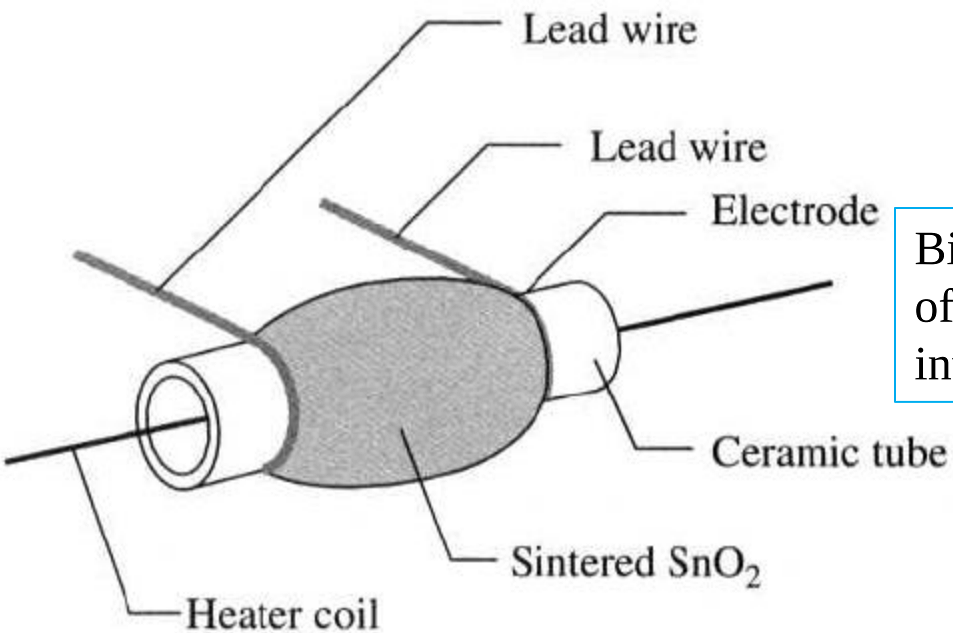
Classification of the main types of bio(chemical) sensors.
Devices listed are those that can be regarded as microsensors

CONDUCTIMETRIC SENSORS

➢Conductimetric gas sensors are based on the principle of measuring a change in the electrical resistance of a material upon the introduction of the target gas.

➢The most common type of gas sensor employs a solid-state material as the gas-sensitive element. The principal class of material used today is emiconducting metal oxides, with tin oxide (SnO_2) being the most popular.

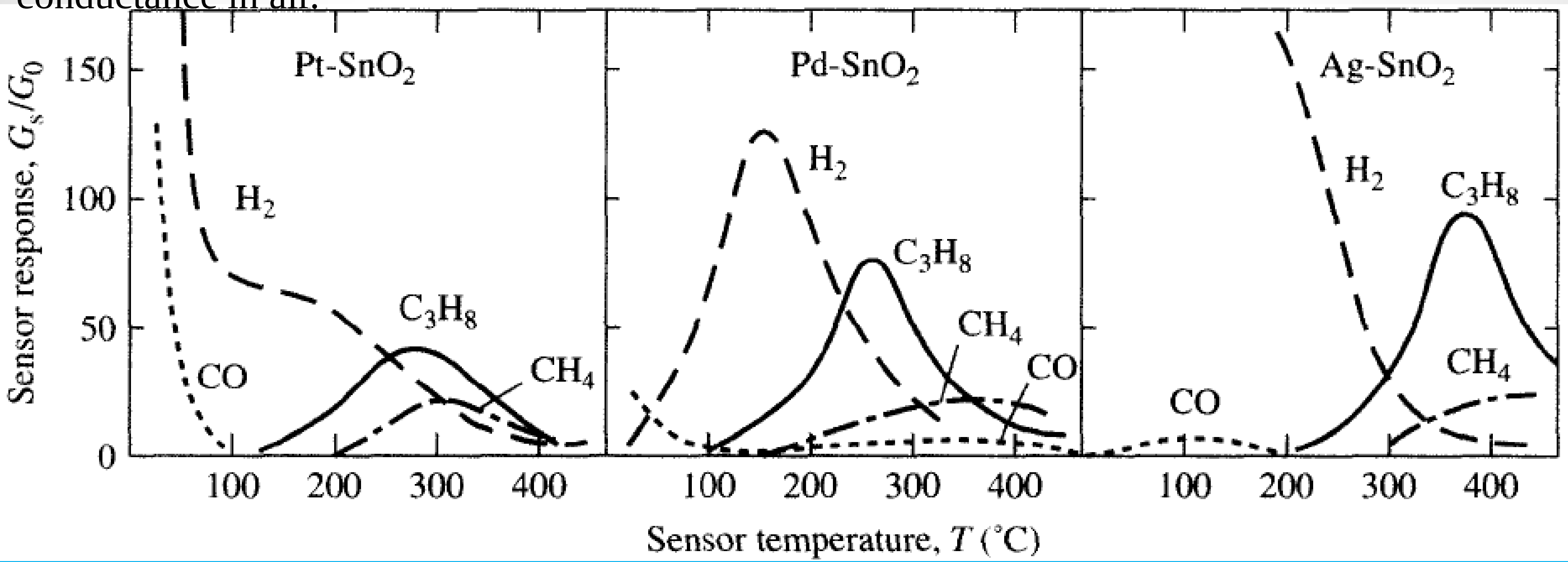
➢The device consists of a wire-wound platinum heater coil inside a ceramic former onto which a thick layer of porous tin oxide is painted manually.



Bio(chemical) sensor is a device which is capable of converting a chemical (or biological) quantity into an electrical signal

CONDUCTIMETRIC SENSORS (Selectivity Enhancement by Doping)

➢Tin oxide devices are operated at various high temperatures and doped with different materials to enhance their specificity. The response of a tin oxide sensor, in terms of its relative conductance G_s/G_0, where G_s is the conductance of a gas of fixed concentration and G_0 is the conductance in air.



Variation of the response of three doped tin oxide gas sensors with temperature for four different gases.

$$\frac{1}{2}mO_2 + \{\text{vacancy}\} + e^- \xrightarrow{k_1} \{O_m^-\}$$

➢vacant sites within the tin oxide lattice react with atmospheric oxygen to abstract electrons out of the conduction band of the tin oxide creating chemisorbed oxygen sites such as O^-, O_2.

CONDUCTIMETRIC SENSORS

- reversible reaction is disturbed when the analyte molecule X reacts with the chemisorbed oxygen species

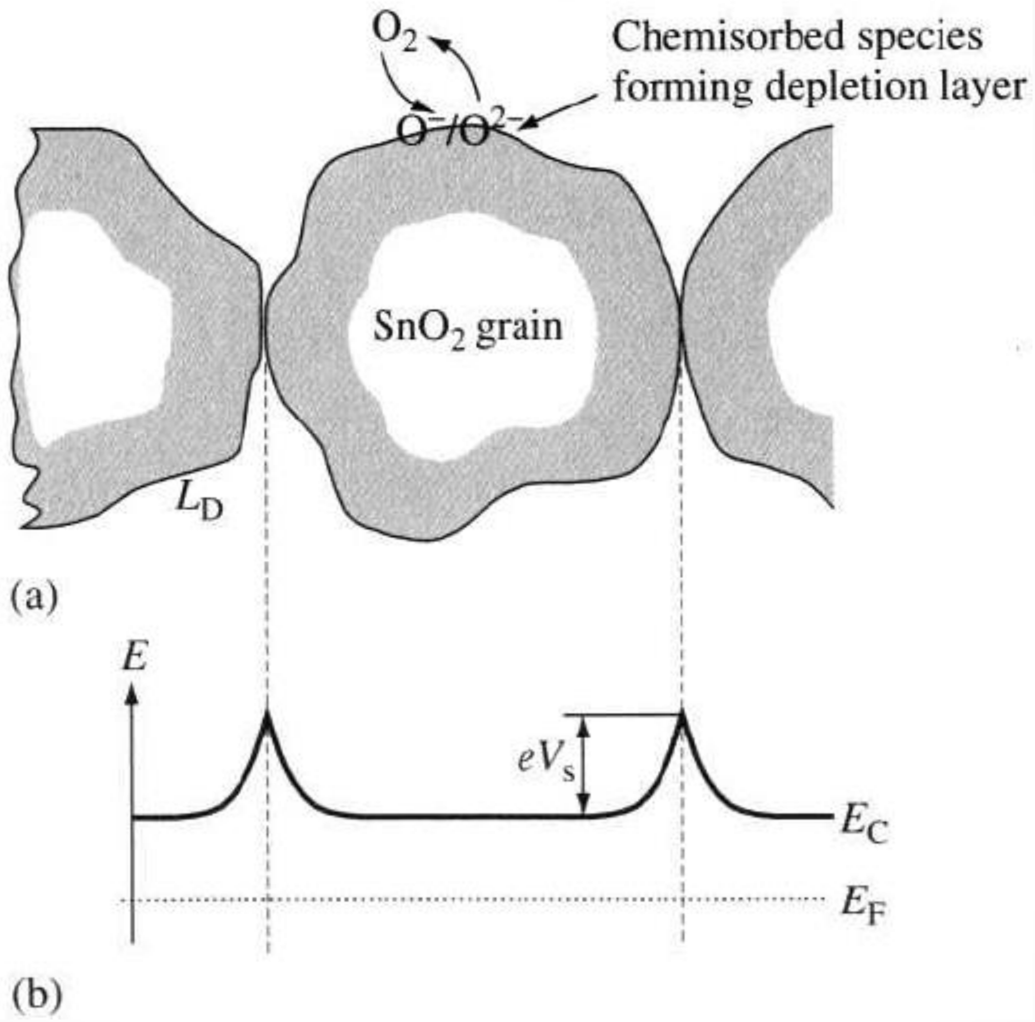
$$X + \{O_m^-\} \xrightarrow{k_2} \{XO_m\} + e^-$$

$$\Delta\sigma = \mu_n e \Delta n$$

$$\Delta G \propto \frac{k_1}{k_2} C^r$$

- This change in device conductance can be approximately related to the gas concentration C from the chemical rate constants k_1 and k_2 defined in Equations ,where the exponent r has a value that lies between 0.5 and 0.9 and depends on the kinetics of the reaction

CONDUCTIMETRIC SENSORS



(a) Schematic diagram showing a series of nanometre-sized grains in a sintered tin oxide film and (b) band diagram showing the effect of the oxygen-induced depletion regions.

CONDUCTIMETRIC SENSORS

- lists some tin oxide gas sensors that are commercially available together with their properties.

Some commercial gas sensors based on semiconducting metal oxide

Manufacturer	Model	Material	Measurand	Range (PPM)	(Power mW)	Cost[a] (euro)
Figaro Inc. (Japan)	TGS842	Doped SnO_2	Methane	500–10 000	835	13
Figaro Inc. (Japan)	TGS825	Doped SnO_2	Hydrogen sulfide	5–100	660	50
Figaro Inc. (Japan)	TGS800	Doped SnO_2	Air quality (smoke)	<10	660	13
FiS (Japan)	SB5000	Doped SnO_2	Toxic gas - CO	10–1000	120	13
FiS (Japan)	SP1100	Doped SnO_2	Hydrocarbons	10–1000	400	15
Capteur[b] (UK)	LGS09	Undoped oxide	Chlorine	0–5	650	25
Capteur (UK)	LGS21	Undoped oxide	Ozone	0–0.3	800	25

- The requirement to run this type of gas sensor at a high temperature causes the power consumption of about 0.8 W of a Taguchi-type device to be a problem for handheld units.

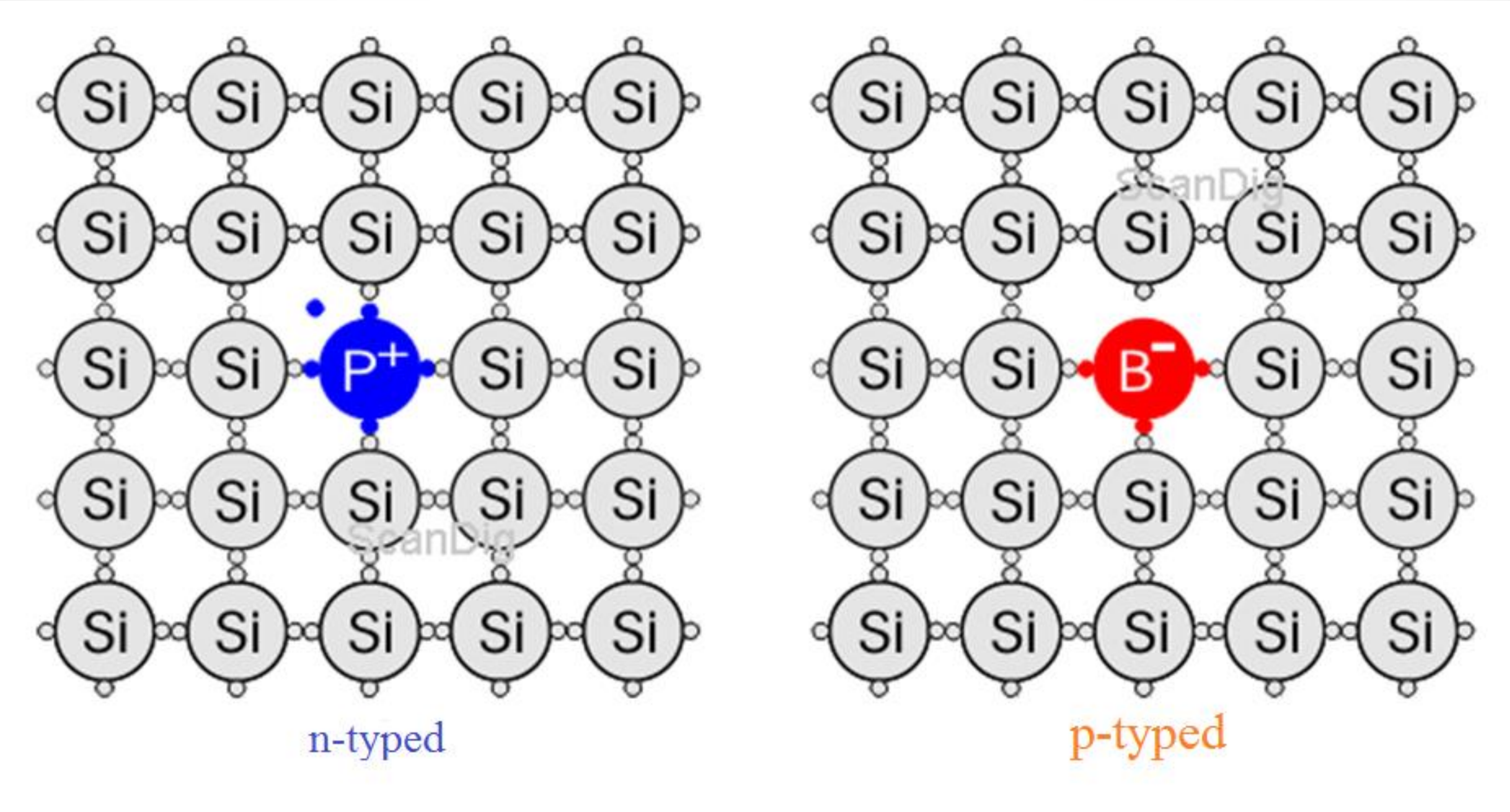
CONDUCTIMETRIC SENSORS

- Semiconducting metal oxides (SnO_2, ZnO, Fe_2O_3) are commonly used (e.g., SnO_2 for CO, alcohol, H_2, H_2S, …etc)

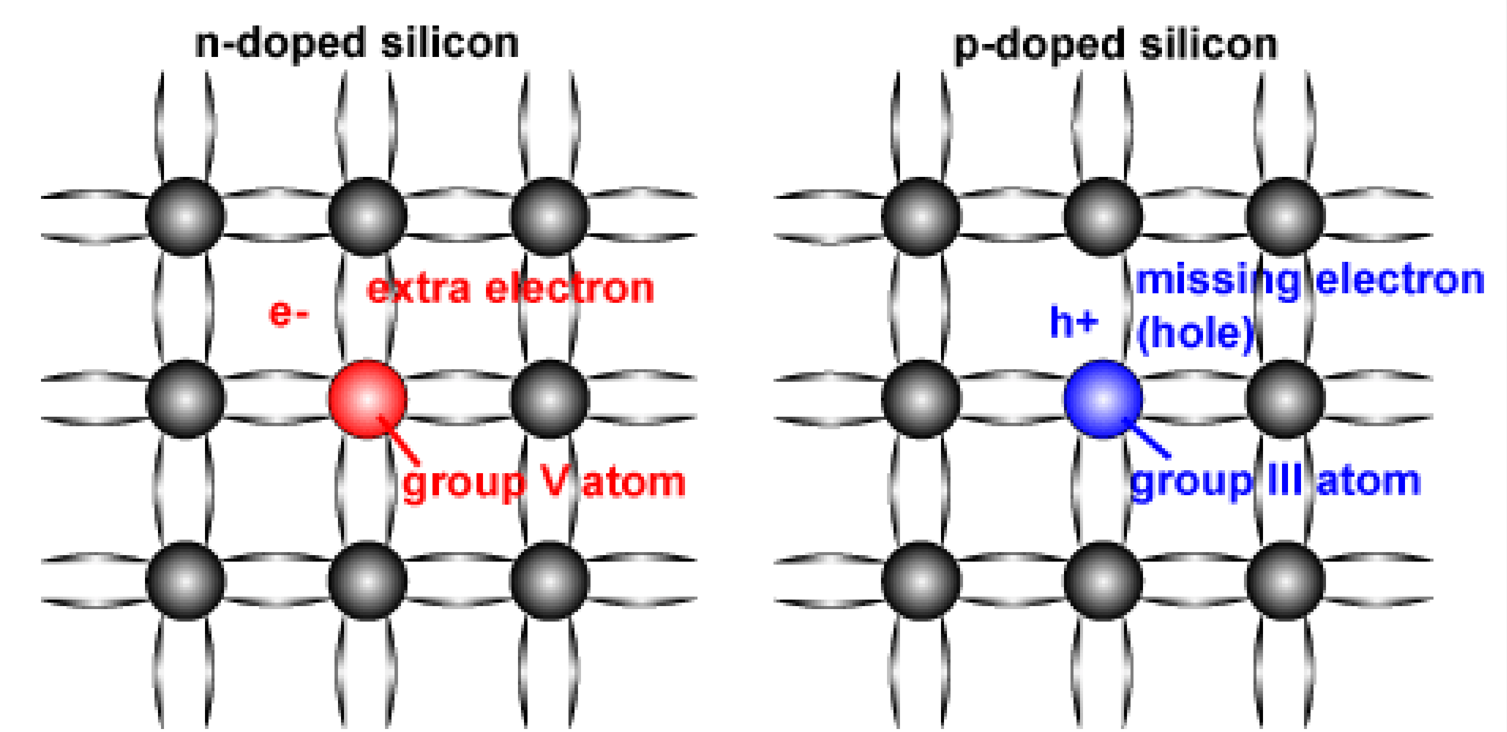
- The increase and decrease of resistance affected by:
  Adsorption of O_2 on surface: $O_2 + 2e^-$ (due to vacant sites in SiO_2) $\rightarrow 2O^-$ (then R increases)
  Reaction with combustible gases H_2: $H_2 + O^- \rightarrow H_2O + e^-$ (then R decreases)

- The devices are operated at high temperatures (typ. 300 – 400 °C)
  Speed up the chemical reaction
  Ameliorate the humidity effect
  Consume a few hundred mW

n-type and p-type



n-type and p-type



Schematic of a silicon crystal lattice doped with impurities to produce *n*-type and *p*-type semiconductor material.

	N-type (negative)	P-type (positive)
Dopant	Group V (e.g. Phosphorous)	Group III (e.g. Boron)
Bonds	Excess Electrons	Missing Electrons (Holes)
Majority Carriers	Electrons	Hole
Minority Carriers	Holes	Electrons