

Chemical Sensitive FETs



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Outlines



⌘ Introduction

⌘ Description of a ChemFET

⌘ Fabrication approach

⌘ Conclusions

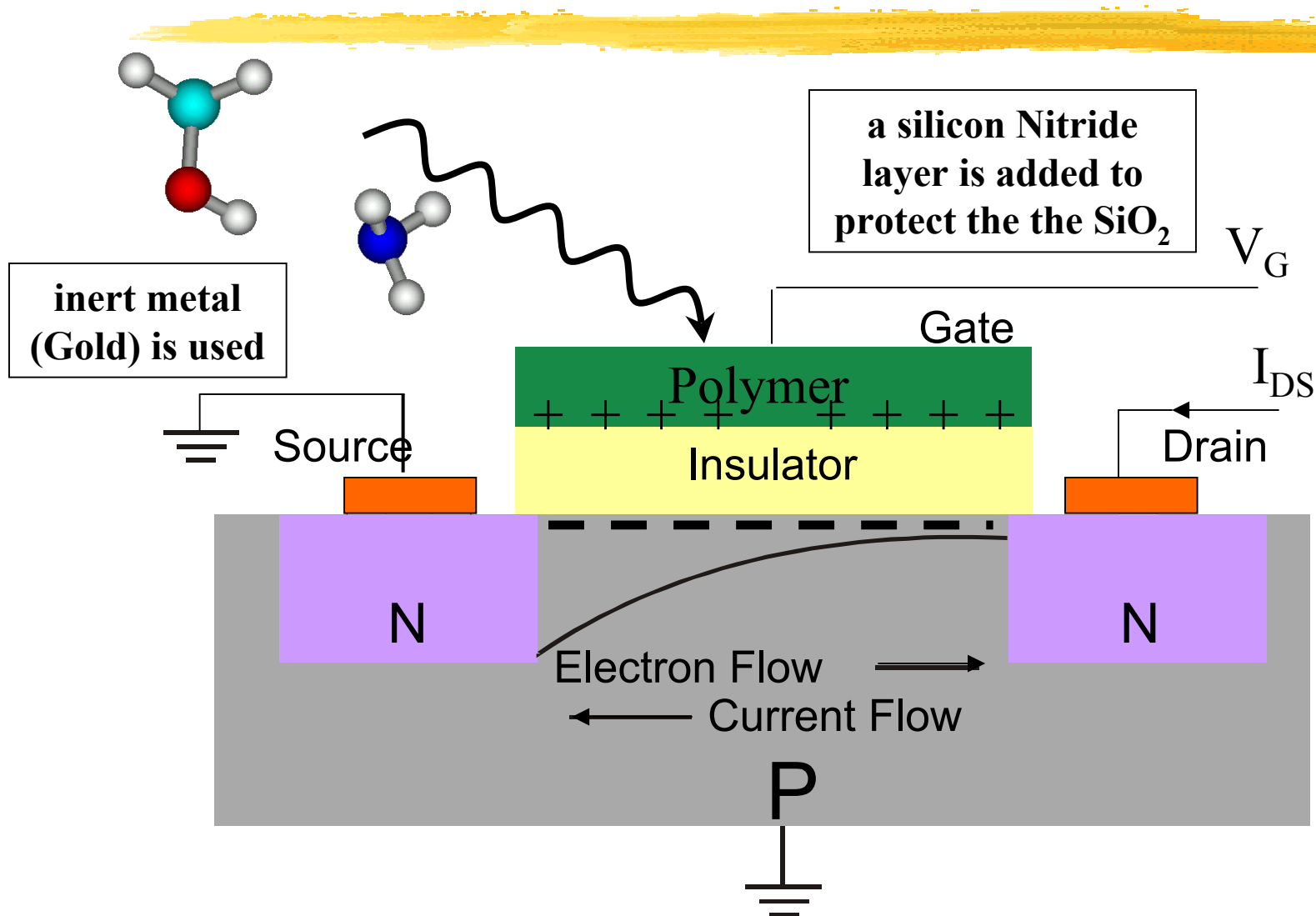
Introduction



⌘ What is a ChemFET ?

- ☒ Chemically Sensitive ***Field Effect Transistor***
- ☒ Detection of gas concentrations, liquid contents, etc.
- ☒ Desirable traits:
 - High selectivity (arrays)
 - High sensitivity (arrays)
 - CMOS compatible (extra circuitry can be added)
 - Low cost

Simplified ChemFET Cross Section



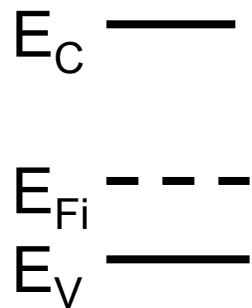
Gate Conductor



- ⌘ Conducting polymer: polypyrrole or **polyaniline**.
- ⌘ Polyaniline is more used in the modern ChemFET because:
 - Easy to synthesize electrochemically
 - Can be doped (by protonation, oxidative doping, and photochemically.)
 - High conductivity when doped
- ⌘ Doping changes the characteristics of the polymer
 - Selectivity
 - Initial Work function

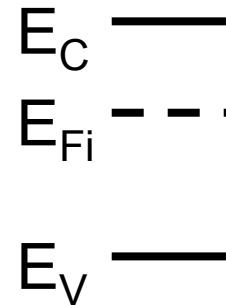
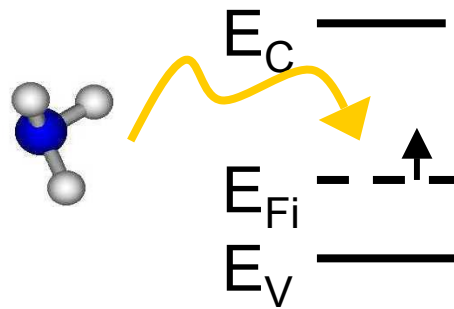
How does the ChemFET work ?

- ⌘ The chemical vapors change the Work Function (WF) of the Polymer with the respect with the concentration.



Initial Work
Function,

$$\Phi_{ini}$$



Final State,

$$\Phi_{new}$$

How the WF can be used as a sensitive parameter?

⌘ Drain current (in saturated operation)

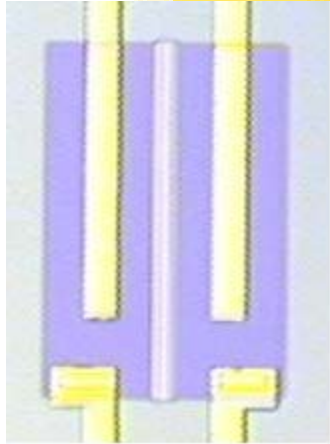
$$I_{DS} = \frac{\mu \cdot W \cdot C}{2 \cdot L} \cdot (V_G - V_T)^2$$

and

$$V_T \propto V_{FB} = \frac{\Phi_{Si} - \Phi_{PANI}}{e} \quad \text{so} \quad \Delta V_T = \frac{\Delta \Phi_{PANI}}{e}$$

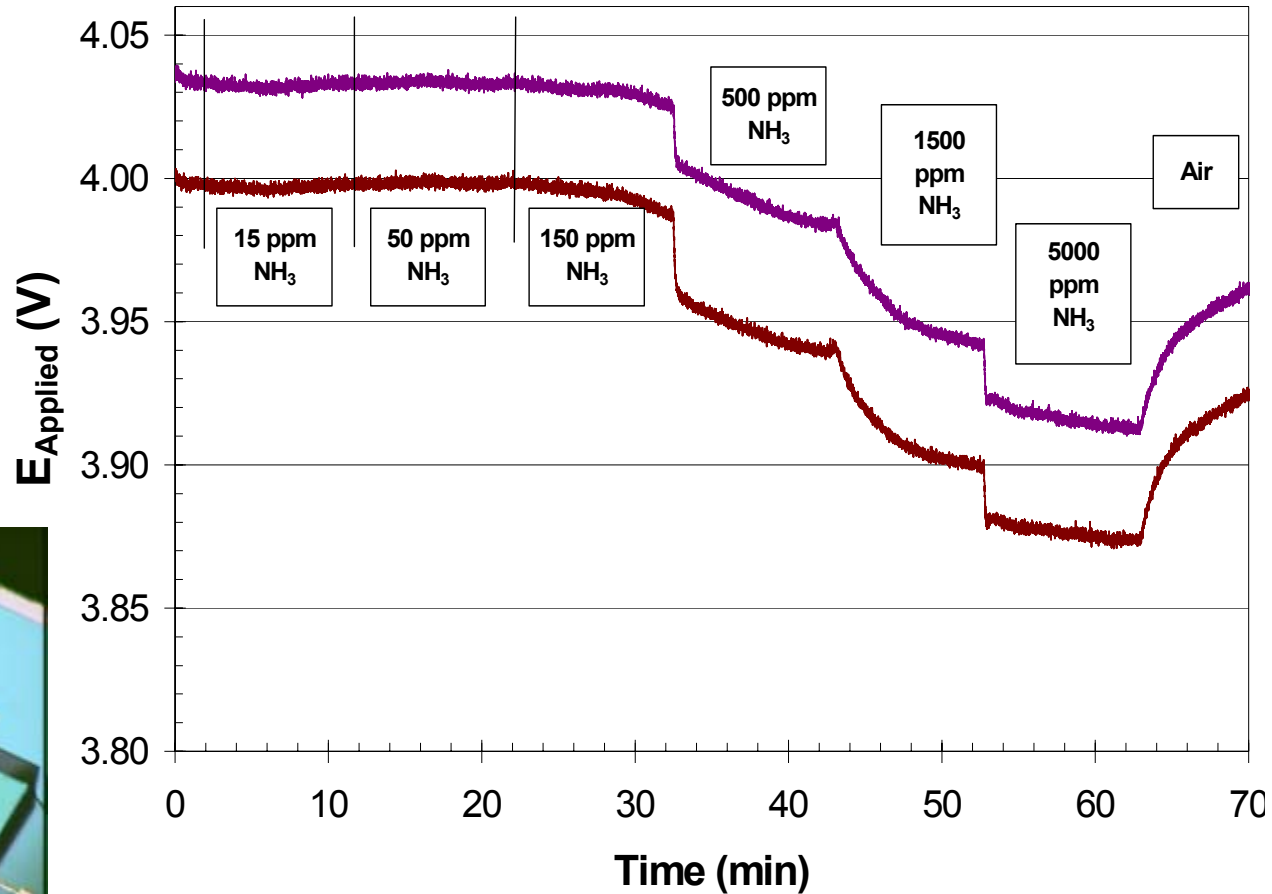
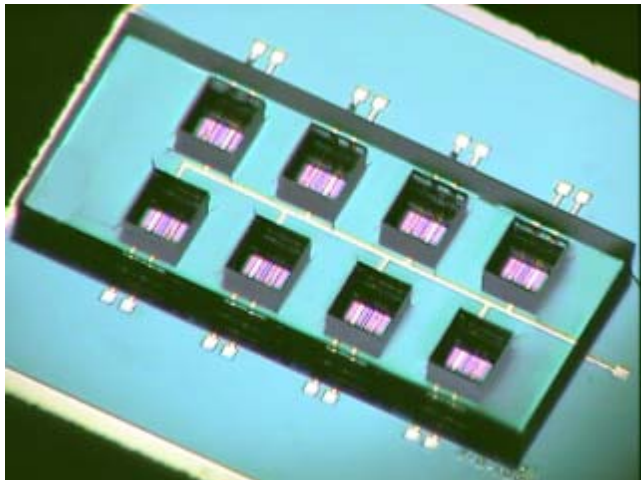
--> I_{DS} is a function of concentration of the gas in the environment.

Measure of the ambient concentration of NH_3

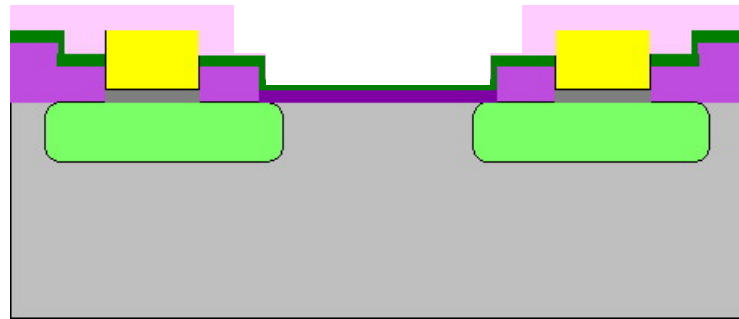


A single ChemFET

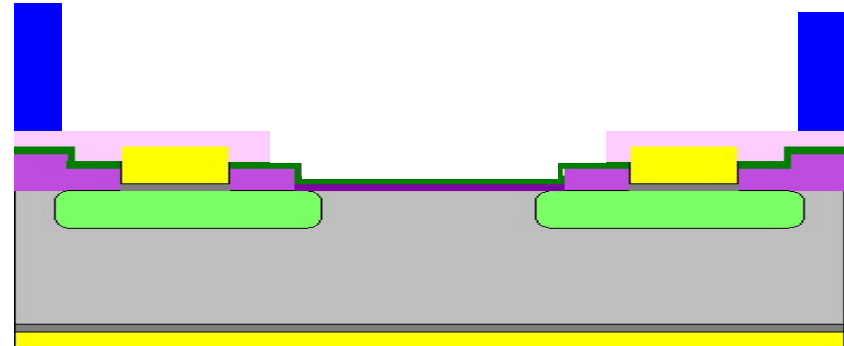
Array of ChemFET



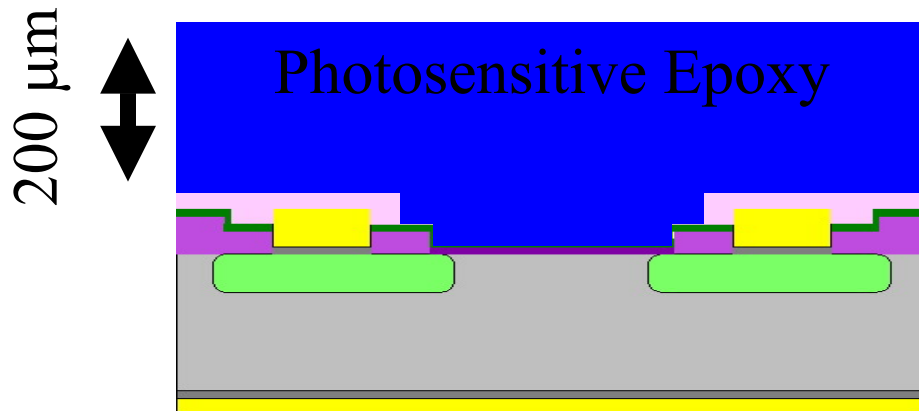
Post CMOS Process



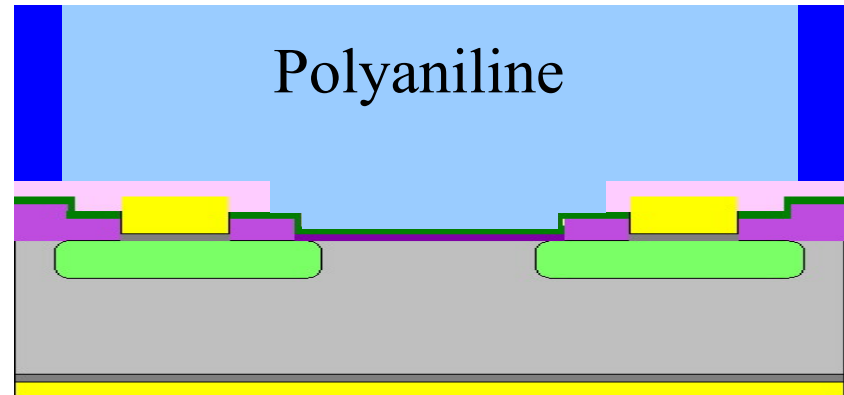
Quasi typical CMOS Process



Opening of Epoxy layer

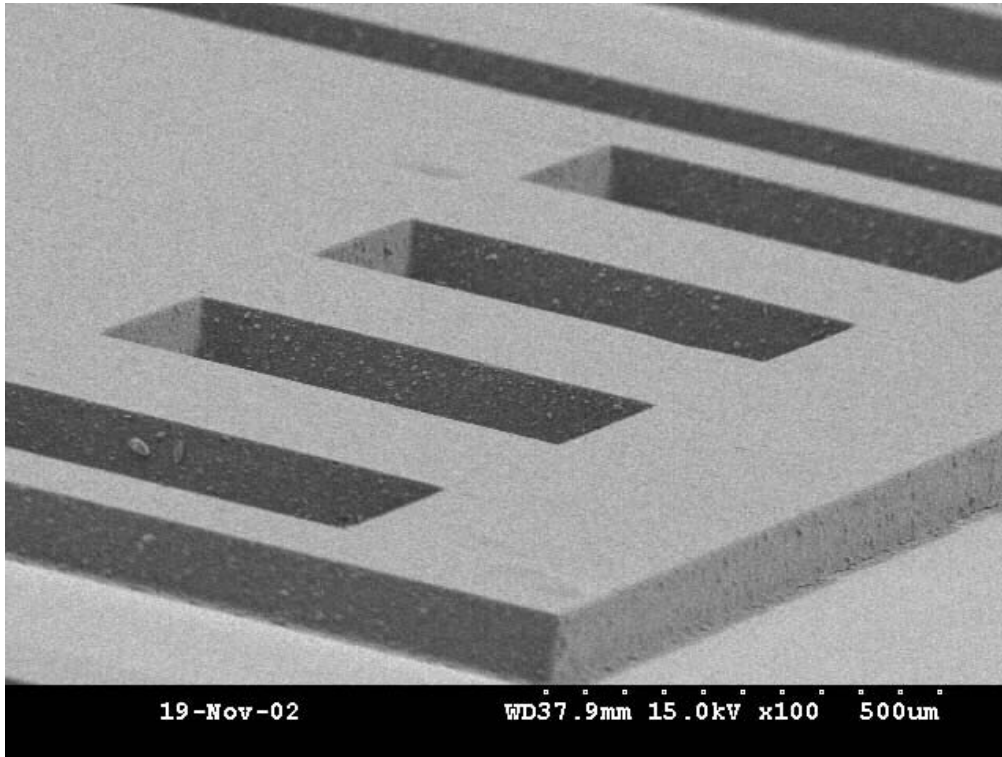


Spin thick epoxy film



Polymer is deposited with a syringe

New Epoxy



- Taiyo PSR
- Negative tone
- High Profile (300um)
- Developer:
Carbonate Sodium

Conclusions



⌘ Applications

☒ Biomedical

- O₂ in blood

☒ Military

- Nerves Gas, NH₃

☒ Quality Assurance

- CO₂
- Sensor to used oils

⌘ How makes the difference ?

- ☒ Array configuration: High selectivity

Photochemical Doping



- Polyaniline can be doped by a weak acid.
- Triphenylsulfonium triflate (PhT) salts is used as the photoacid generator
- When irradiated with ultraviolet light these salts undergo irreversible photolysis with rupture of the carbon-sulfur bond
- Photoacid like triflic acid ($\text{CF}_3\text{SO}_3\text{H}$) is generated