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Some Progresses of Research on Semiconductor Sensors in DUT

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Outline

1. **Infrastructure constructions**
2. **Si integrated gas sensor based on hierarchical composite nanostructures**
3. **A CMOS-compatible temperature sensor based on the gaseous thermal conduction dependent on temperature**
4. **A CMOS monolithic active pixel sensor for ionizing particle detection**

Infrastructure Constructions

- **Laboratory of Semiconductor Technology**
- **Laboratory of Microelectronic Devices and IC Characterization**
- **Laboratory of wireless Sensor Network**

Laboratory of semiconductor technology

Phase 1: Retrofit clean room

Tools: 8 inch production line
Clean room: 2000 m2, class 10-100

Phase 2: Reinstallation and recovery some of process technology

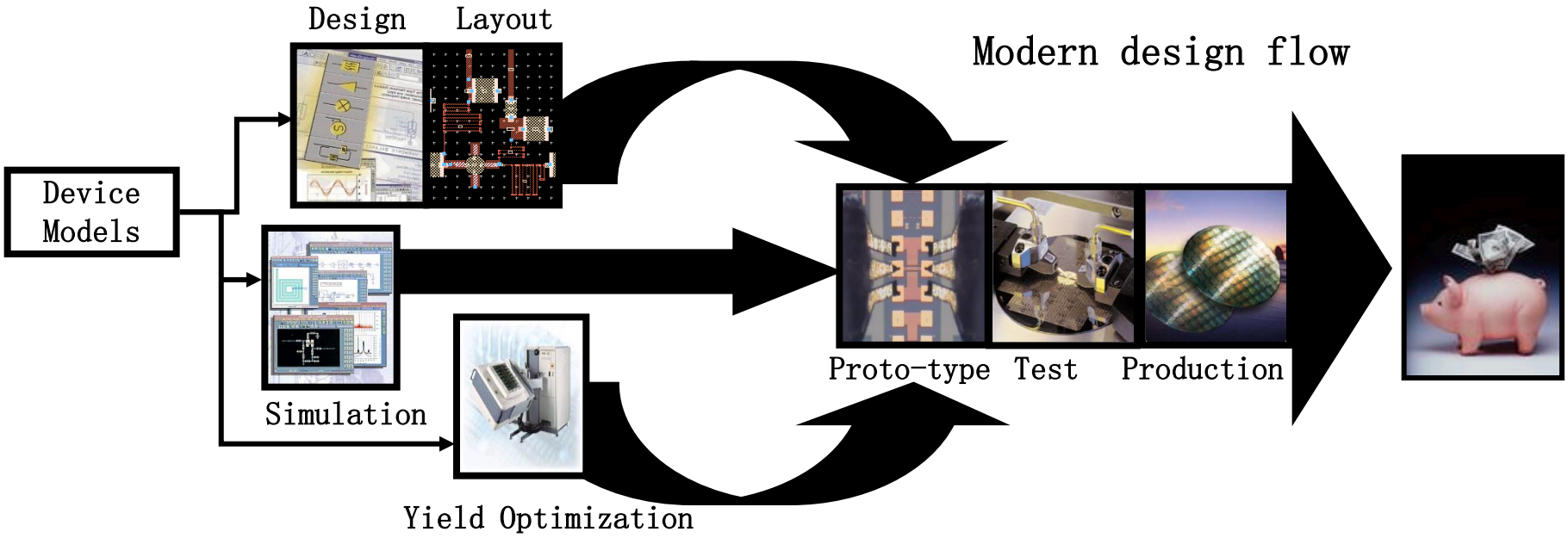
Laboratory of microelectronic devices and IC characterization

DUT-Agilent IC Test Joint Lab

- **Agilent donated ￥8.5M ($1.34M)**
- **DUT invested ￥10M ($1.57M)**

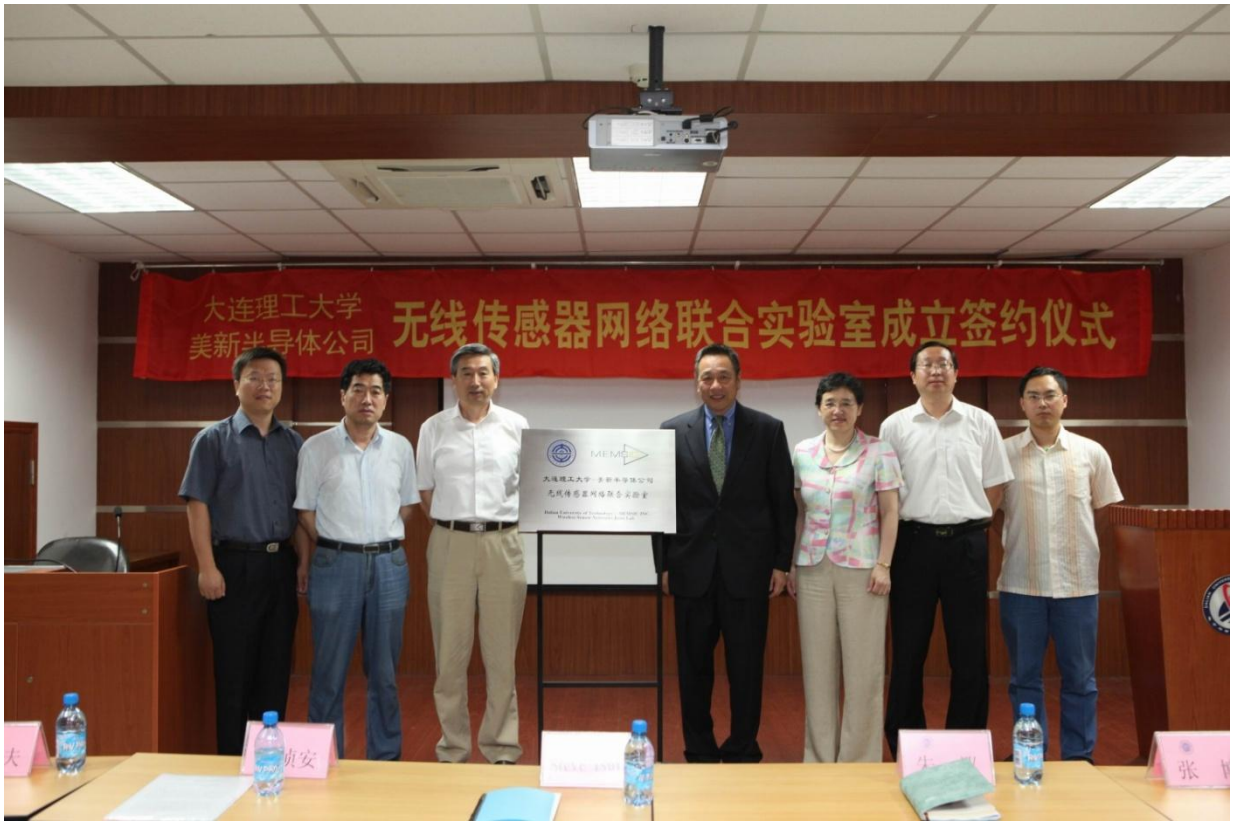
DUT-Agilent IC Test Joint Lab

- Digital circuit platform
- Analog circuit platform
- RF circuit platform
- Chip characterization system
- IC simulation platform



Laboratory of wireless Sensor Network

MEMS IC Ltd donated me some wireless routers and scholarship for studying wireless sensor network.



Summary 1

- **The infrastructure construction reaches a higher level but a big budget is also necessary to keep it running smoothly.**
- **The infrastructure is good enough for our current research interesting that mainly focused on semiconductor sensors, sensors and on chip circuits, and wireless sensor network.**

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Electronic noses of IMEC

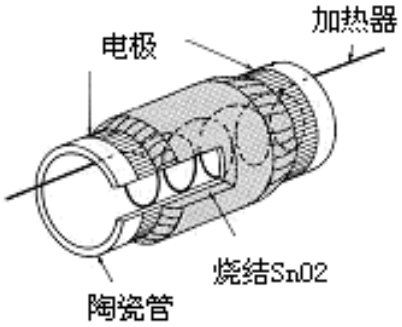
IMEC is developing the integrated e-nose, electronic nose for the application of low power consumption wireless sensor network

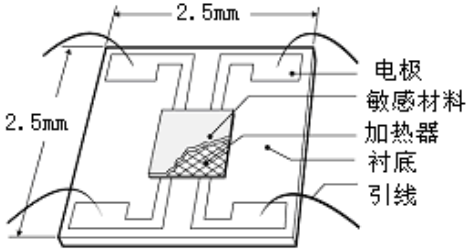
http://www2.imec.be/be_en/press/imec-news/archive-2010/gassensor.html

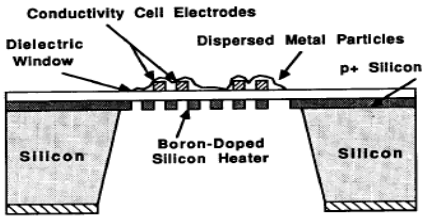
Key parameters of gas sensors

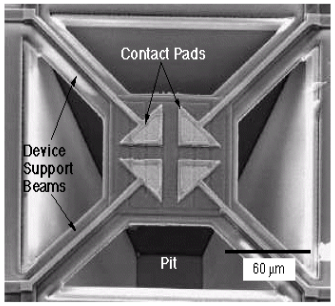
- **3S:**
  - **Sensitivity**
  - **Selectivity**
  - **Stability**
- **In general, semiconductor gas sensors use a heater to enhance sensitivity, catalyst and additives to enhance selectivity and stability**
- **Therefore, studying on gas sensors are all focus on 3S to search the best heater and the best sensing materials.**

History of microheater of gas sensors









Ceramic tube heater~1W

Ceramic plate heater~300mW

MHP~100mW

MHP~50mW

Low power, small size, integration, and smart

Compatible to standard CMOS process

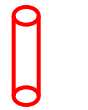
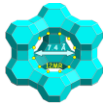
History of gas sensing materials

- **In 1960s， metal oxides such as ZnO or SnO_2 are main sensing materials.**

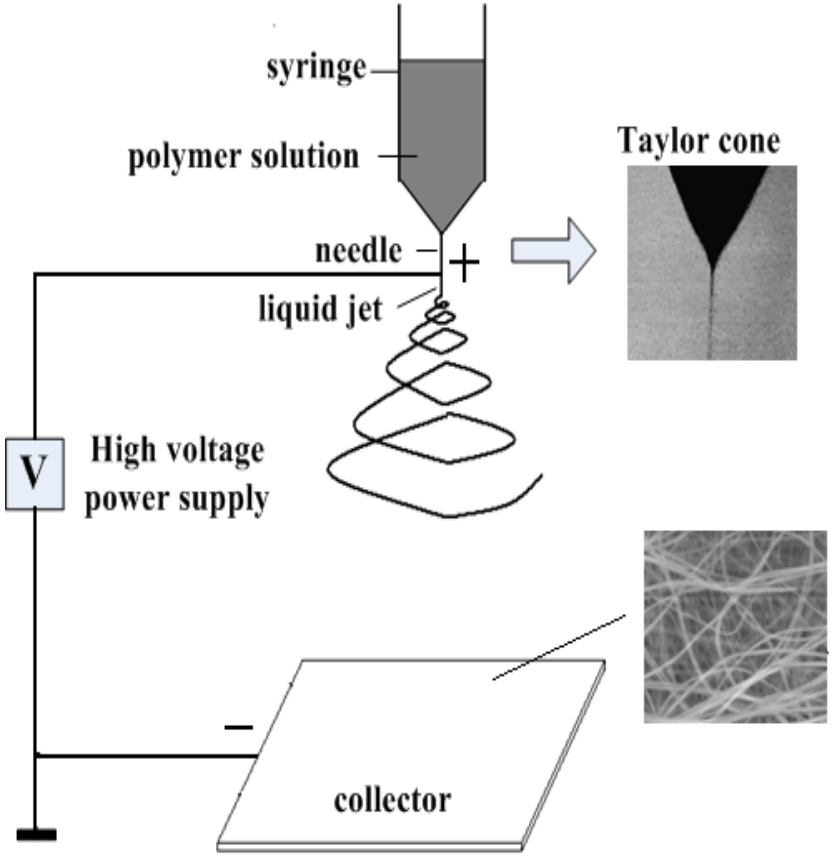
- **In 1990， The studying were focused on controlling the microstructure of sensing materials.**

- **Since 2000, hierarchical composite nanostructures brings a new chance.**

Some hierarchical composite nanostructures

Basic elements	multilevel nanomaterials
	
	
	
	
	

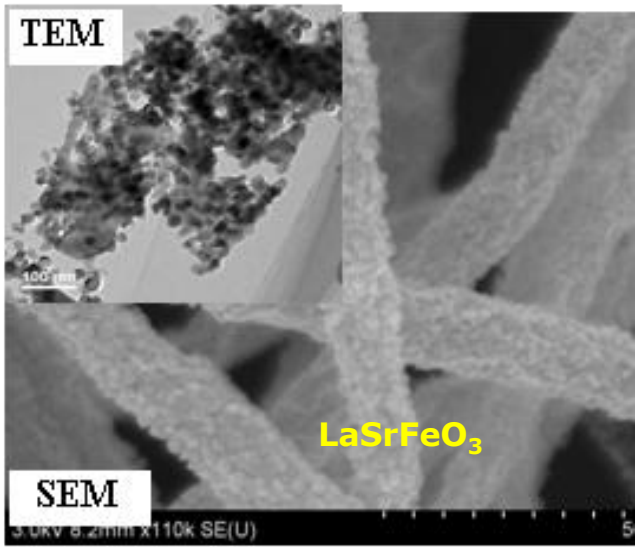
Process of hierarchical composite nanostructures by electrospun

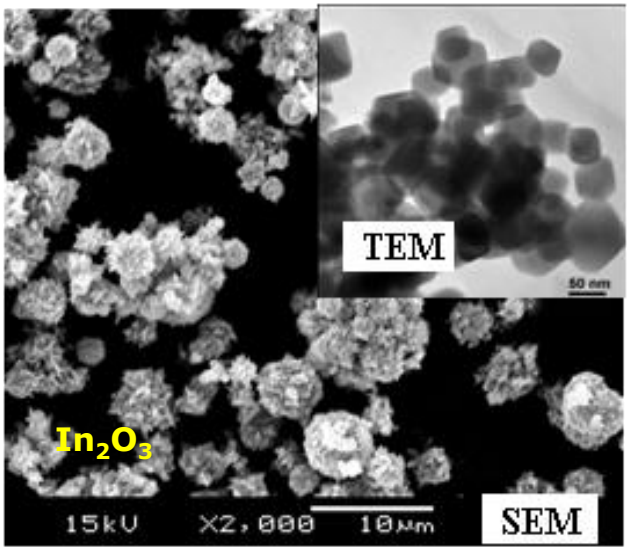


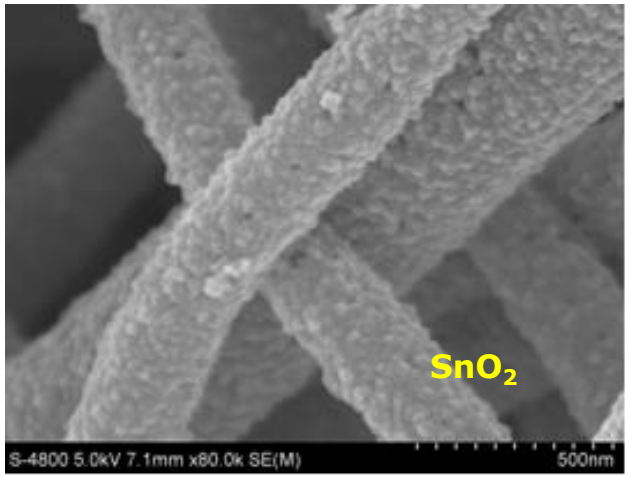
- The polymer solution is advanced through a syringe to form a Taylor Cone.

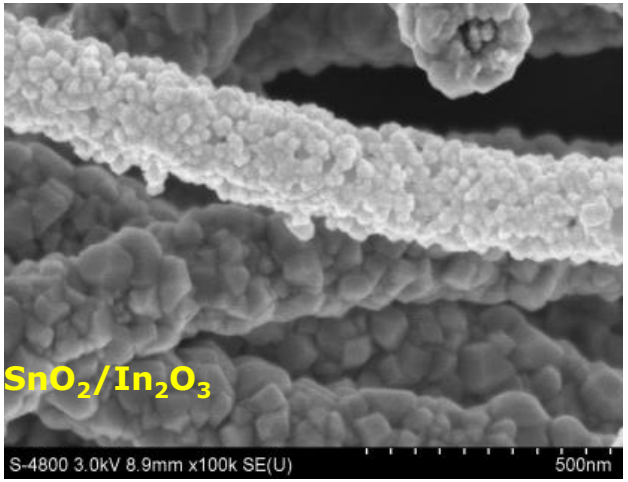
- When the voltage is high enough, the electrostatic force is able to overcome the surface tension force of the cone, and a thin jet will form and fall to the collector.

Several sorts of hierarchical composite nanostructures formed by electrospun









Si integrated gas sensor based on hierarchical composite nanostructures

- **Obviously, combination of the si integrated substrate and the hierarchical nanostructure sensing materials is a reasonble proposal.**

- **NIST and Cambridge University are pioneers in this doamin since 2000.**

- **Some key science and technology problems are still not solved so far.**

One of our considerations

- **One of key problems:**

  How to process of hierarchical composite nanostructures onto the central area of MHP?

- **One of our considerations:**

  Combining the electrodes between an electrospun apparatus and a MHP substrate to self-alignmently spun the hierarchical composite nanostructures on the target electrodes on MHP.

Summary 2

- **Our studying on Si integrated gas sensor based on hierarchical composite nanostructures is just get started now.**
- **The project is financially supported by NSFC with a fund of ￥2.8M ($450,000).**
- **The MHP and on chip circuits have been sent to a foundry with 0.35 CMOS process.**
- **Several sorts of hierarchical composite nanostructures are studied by different process.**
- **The first test will be started in July or Aug, 2012.**

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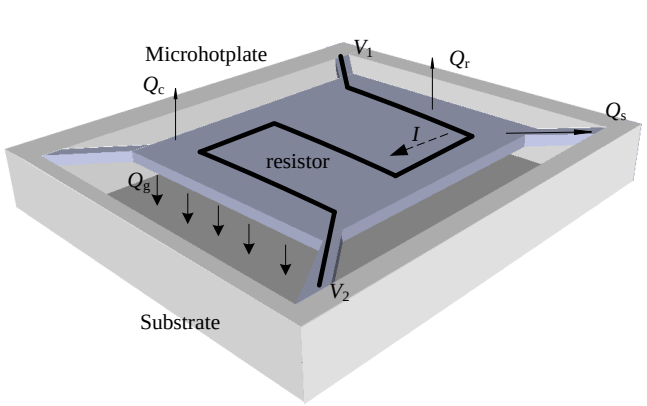
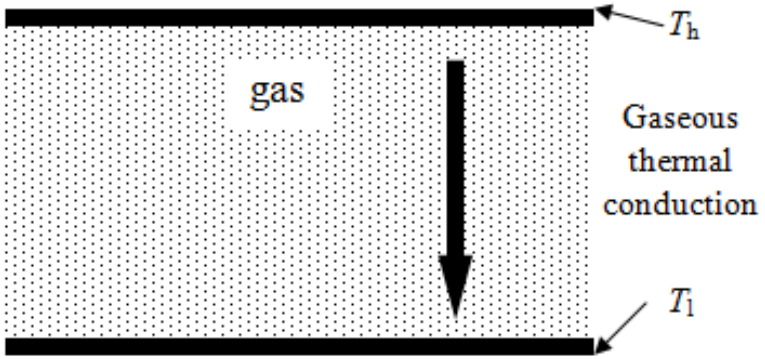
The operational principle of the sensor



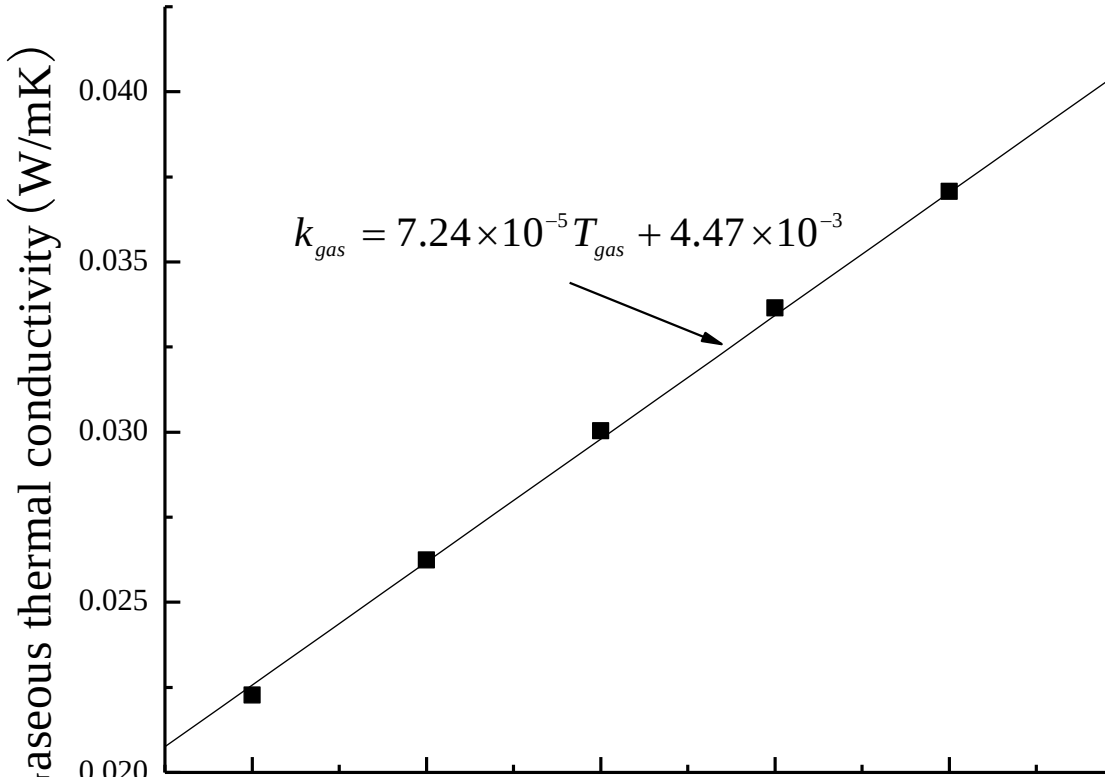


$$I^2 \times R_0 \left[1+\alpha(T_h - T_0)\right] = k_{gas}(T_{gas}) A_g \frac{T_h - T_l}{d} + k_{solid} A_s \frac{T_h - T_l}{L}$$

k_{gas} and k_{solid} are the thermal conductivities for the gas and the solid beams, and A_g and A_s are the area of the thermal conduction for the gas and the beams, respectively. L is the length of the supporting beam and d is the gap between the MHP and the substrate.

The operational principle of the sensor

- **According to above equation, the thermal conductivity of air is linear to the temperature. Therefore, the output voltage is also linear to the temperature.**



The experimental setup

The experiments were carried out in three aspects.:

- **First, for the same type of gas, the gas temperature is changes while the gas pressure is constant.**

- **Second, for the same type of gas, the gas pressure changes while the gas temperature is constant.**

- **Third, the different types of the gas are introduced in the constant temperature and gas pressure.**

The potential applications

- **Due to the sensory component of temperature is the gas in the tiny gap, the potential application of the sensor is to immerge it in gas or liquid pipe so that it can measure ambient temperature.**

- **The initial purpose of the studying is to check the microscale heat conductivity of gas in a small gap.**

Summary 3

- **We proposed a new type of temperature sensor that employs the gas between the MHP and its substrate as the temperature sensing component.**
- **The sensor has a good response to the temperature from**

  -20 to 70 degree C.
- **The sensor can be used to evaluate the microscale heat conductivity of gas in a small gap.**

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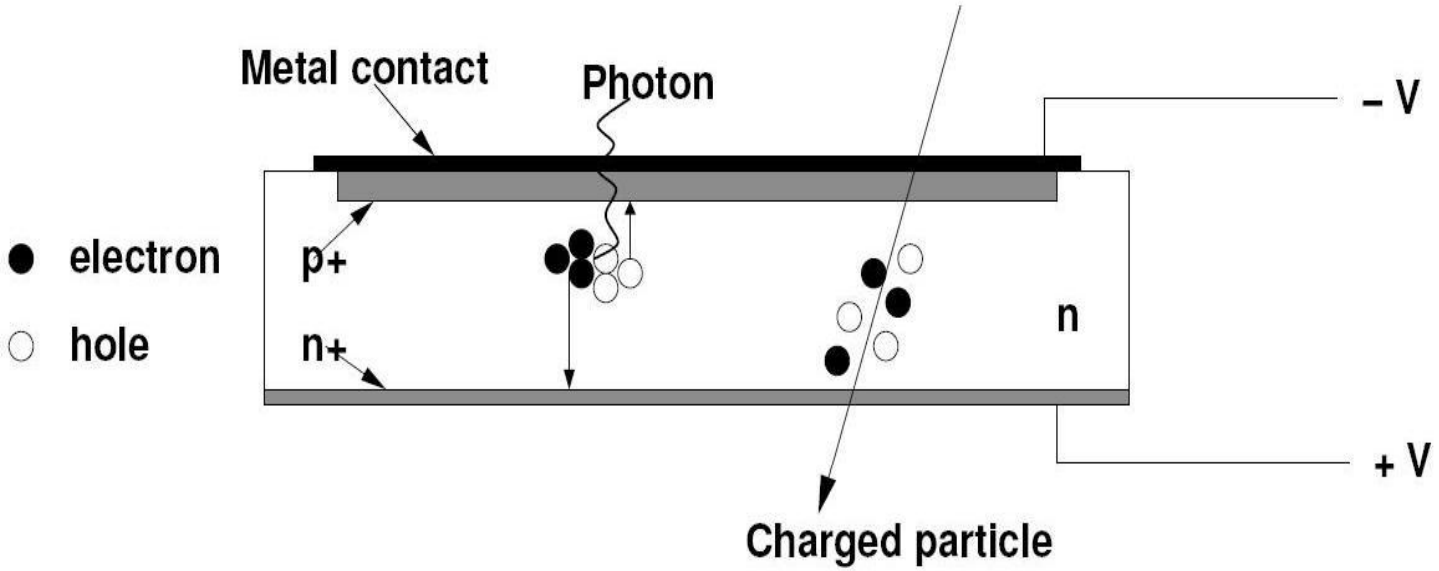
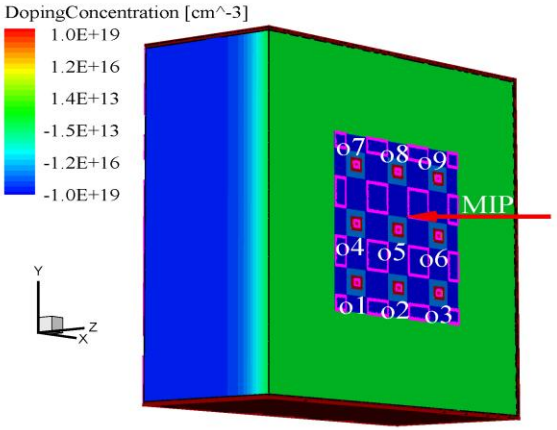
France China Particle Physics Laboratory (FCPPL)

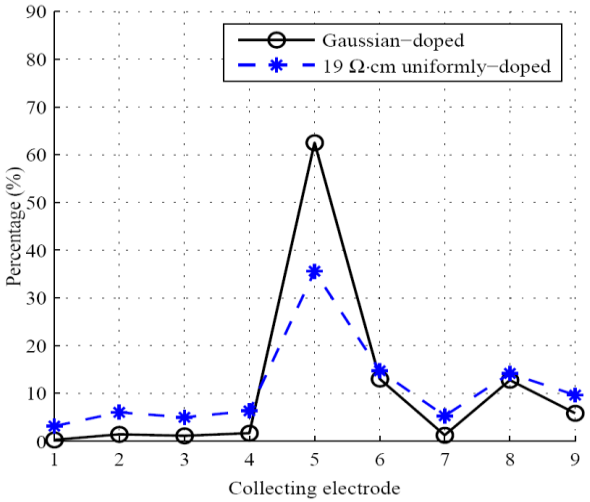
Principle of ionizing particle sensor



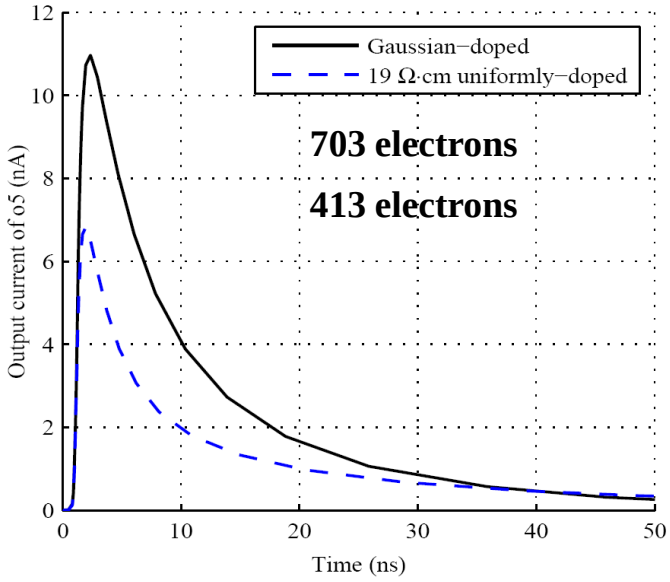
When a charged particle penetrates the substrate, a pair of electron and hole is generated and collected by electrodes, then give the electronic signal.

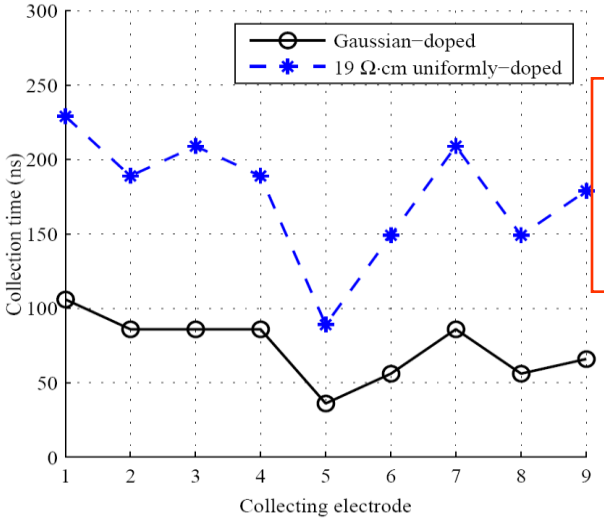
CCE and CCT of the pixel





The CCE of seed pixel increases from 36% to 63%.





CCT decreases from 159ns to 56*ns*.

Thank you very much

for your attention!