



A Topmetal-based and High-Performance Resistance Measurement Circuit for the Thin-Film Sensitive Gas Detection

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Introduction

We present the design and characterization of a high performance resistance measurement circuit fabricated in a standard 0.35μm CMOS process. The circuit implements two exposed metal electrodes in the topmost metal layer which can be deposited the sensitive thin-film. Test pulse is injected into one electrode, the other electrode is directly fed into a low noise charge sensitive amplifier with selective feedback capacitor. Simulations show that the circuit achieved a 100Ω~10TΩ measuring range and a 10Ω resolution. The first coating film attempt experiment is done, the following tests are ongoing. These characteristics enable its use as the accurate resistance monitoring sensor device in future thin-film sensitive gas detection applications.

Topmetal Series Sensor

The Topmetal series sensors are designed by the PLAC's IC team, fabricated in a standard 0.35μm CMOS process, main features:

- ◆ Direct charge collection by the 'Topmetal' that is implemented with a topmost and exposed metal patch/electrode;
- ◆ Novel 'Guardring' structure is established for enhancing the charge collection efficiency and realizing tests by the pulse injection;
- ◆ Low Equivalent Noise Charge (ENC): 13.9e- (Topmetal-II-) and 12.4e- (Topmetal-IIa);
- ◆ Aiming at the direct charge collecting and measuring in the low background and low noise experiments.

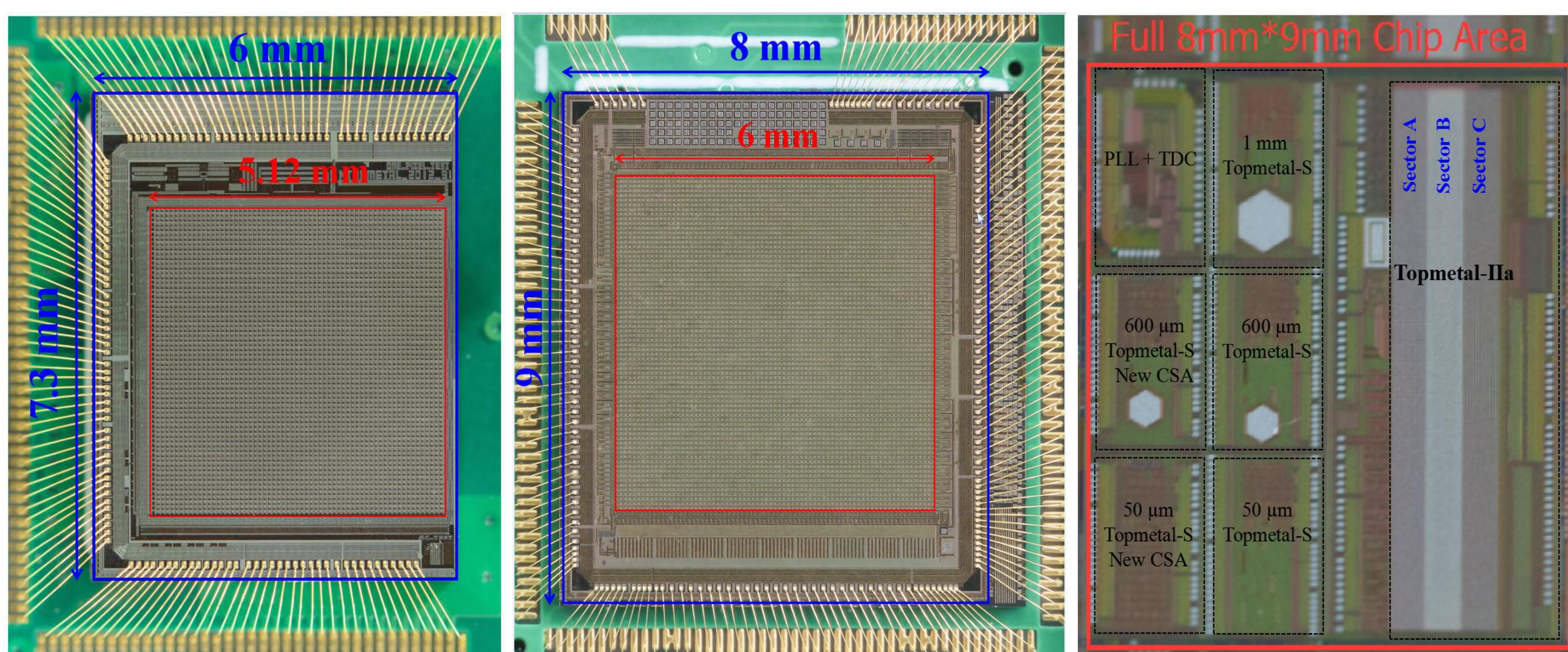


Fig 1: Photographs of several fully fabricated Topmetal sensors. From left to right are Topmetal-I [1], Topmetal-II- [2] and Topmetal-S&Topmetal-IIa (Tape-out in the same MPW), respectively.

Table 1: TOPMETAL Sensor Chip Family

Tape-out Date	Chip's Name	Size [mm ²]	ENC [e ⁻]	Application background
2012.9	Topmetal-I	6 × 7.3	200	Low background, low noise High
2014.7	Topmetal-II-	8 × 9	13.9	Energy Physics Experiments
2016.5	Topmetal-IIa	4 × 9	12.4	Energy Physics Experiments
2016.5	Topmetal-S	3 × 2	28.7	Neutrinoless Double Beta Decay (0νββ)
TBD	Topmetal-II	TBD	< 10	TBD
TBD	Topmetal-S v2	TBD	< 15	Neutrinoless Double Beta Decay (0νββ)

Thin-Film on Topmetal

Based on the prototype of a series Topmetal pixel sensor with directly charge collection and excellent low noise performance, the front-end of this resistance measurement circuit implements two exposed metal electrodes (Both 'Topmetal' and 'Guardring') which can be deposited the sensitive thin-film on the surface.

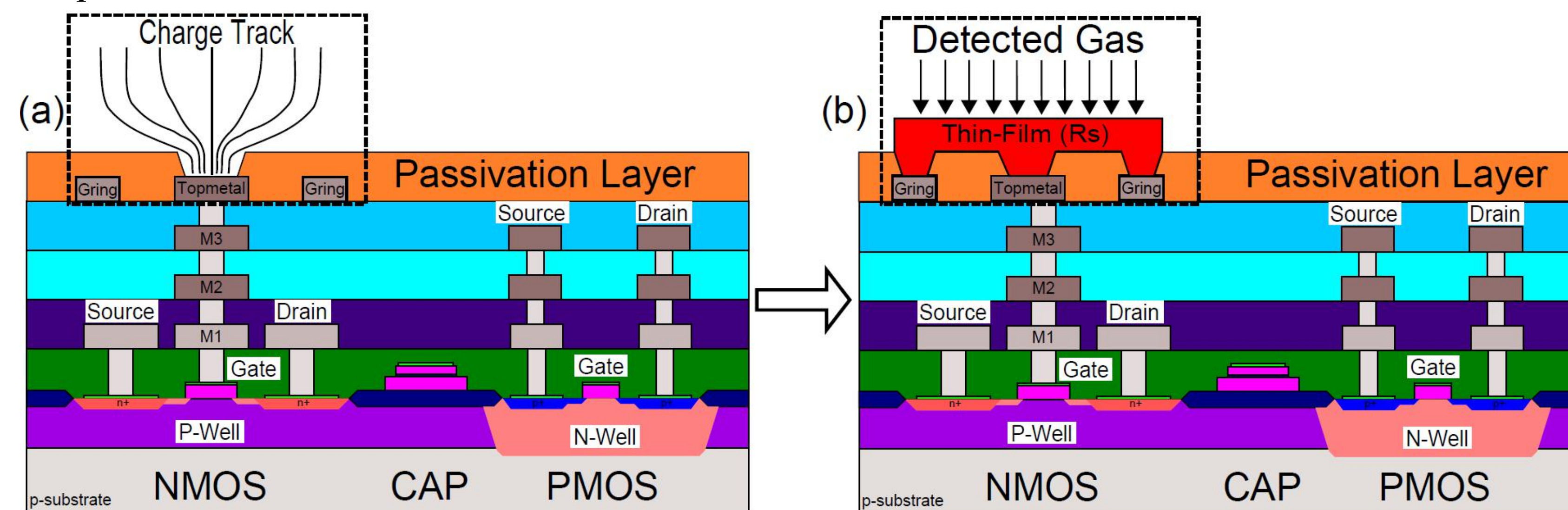


Fig 2: Cross section diagram of the process. (a) Topmetal series sensor's cross section; (b) Coating film on the 'Topmetal' and 'Guardring'.

The measured resistance is:

$$R_s = (V_{TP} * \Delta t) / (V_{OM} * C_f)$$

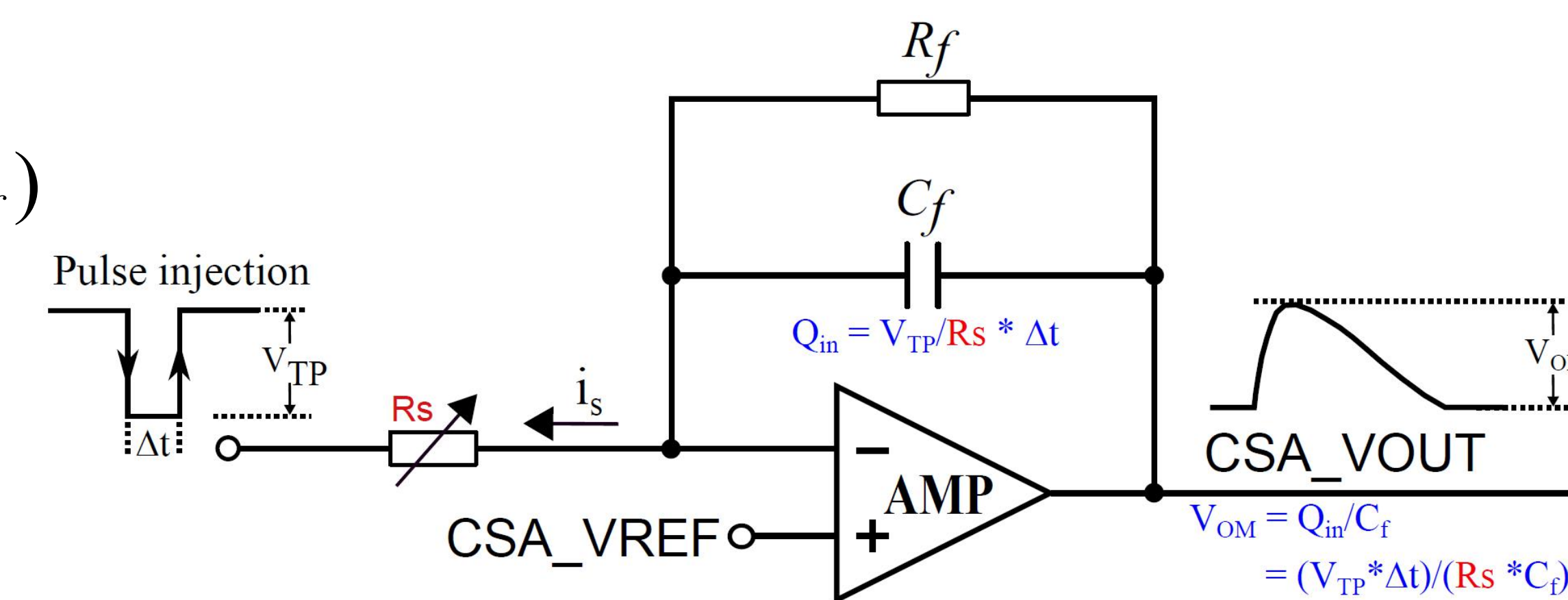


Fig 3: Simplified equivalent model of the front-end circuit

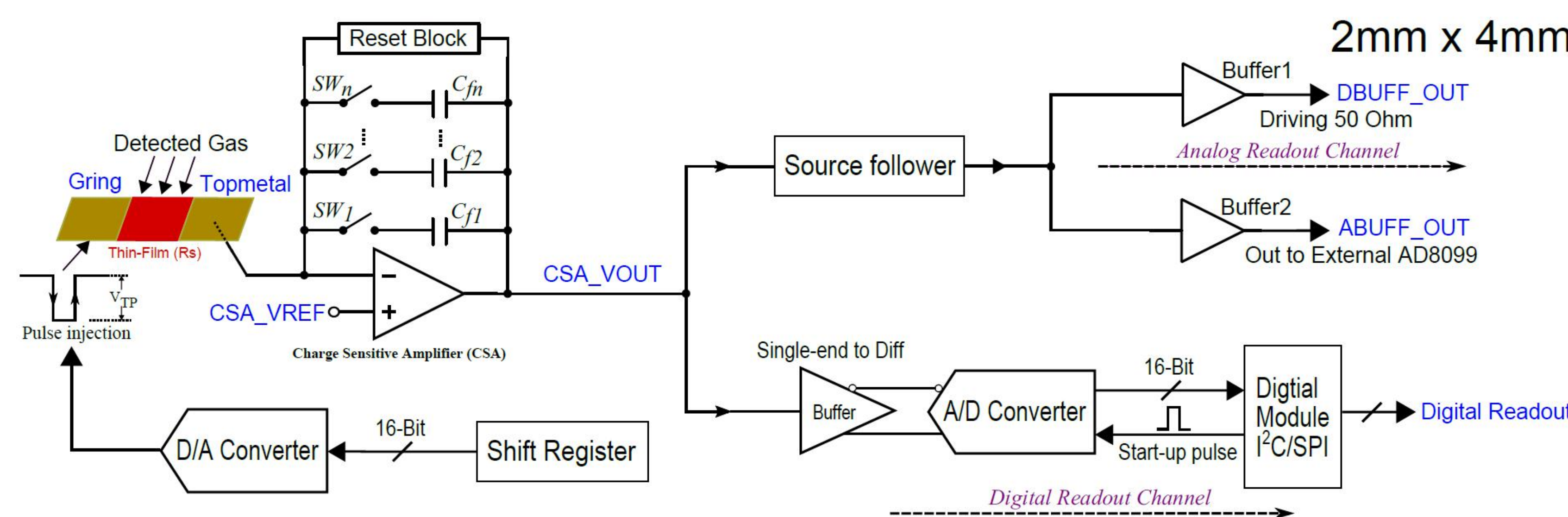


Fig 4: Overall design of the thin-film sensitive gas sensor device in the future

Preliminary research and Film Coating experiment

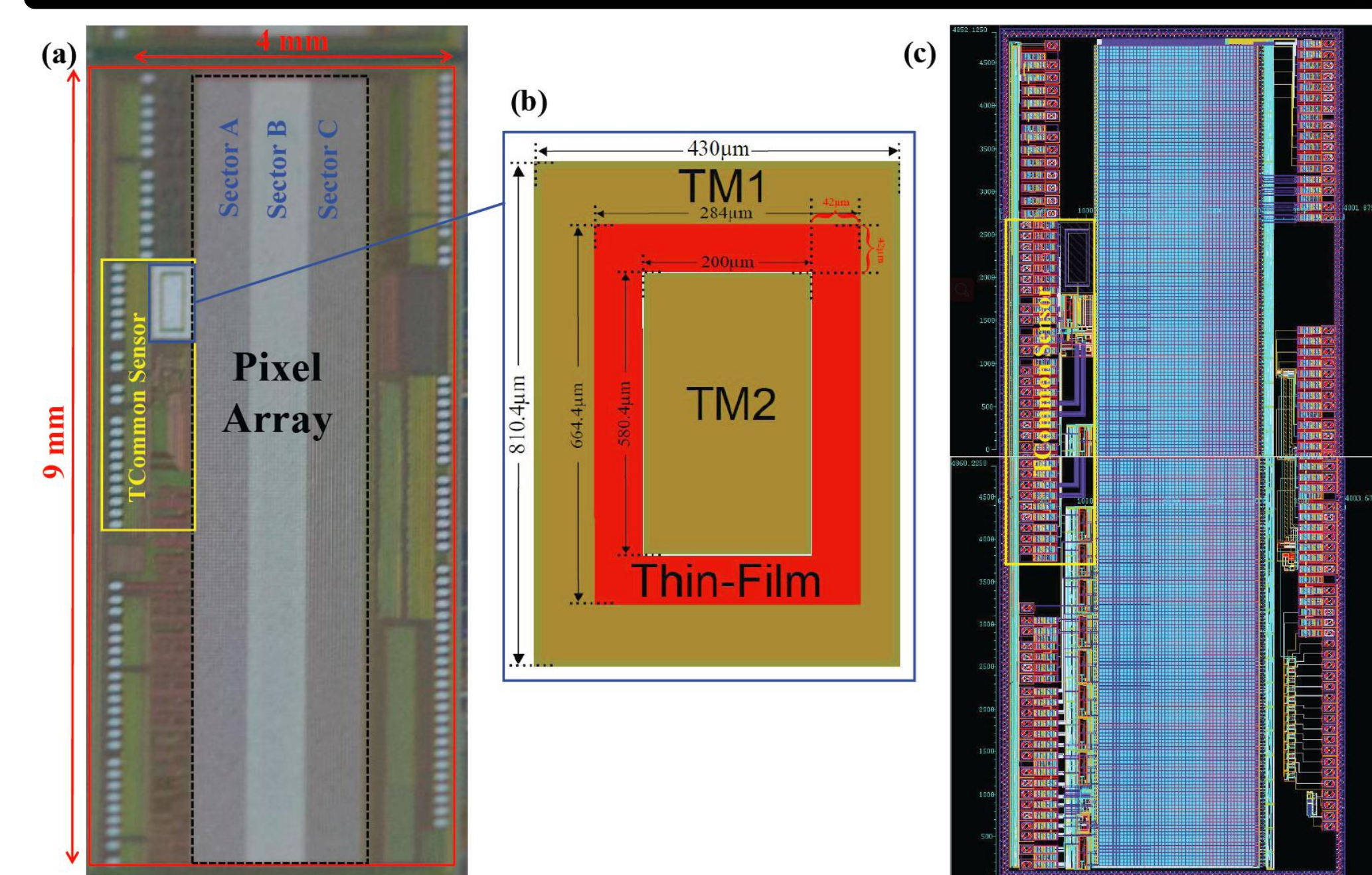


Fig 5: A test module designed in the Topmetal-IIa chip

As shown in Fig 5, an independently simplified test module including the two exposed electrodes and the analog front-end is designed in the Topmetal-IIa chip for the preliminary research.

The first attempt experiment of coating the thin-film is shown in Fig 6. The coating process is executed on a Magnetic Sputtering Platform and using the Zinc Oxide (ZnO) material.

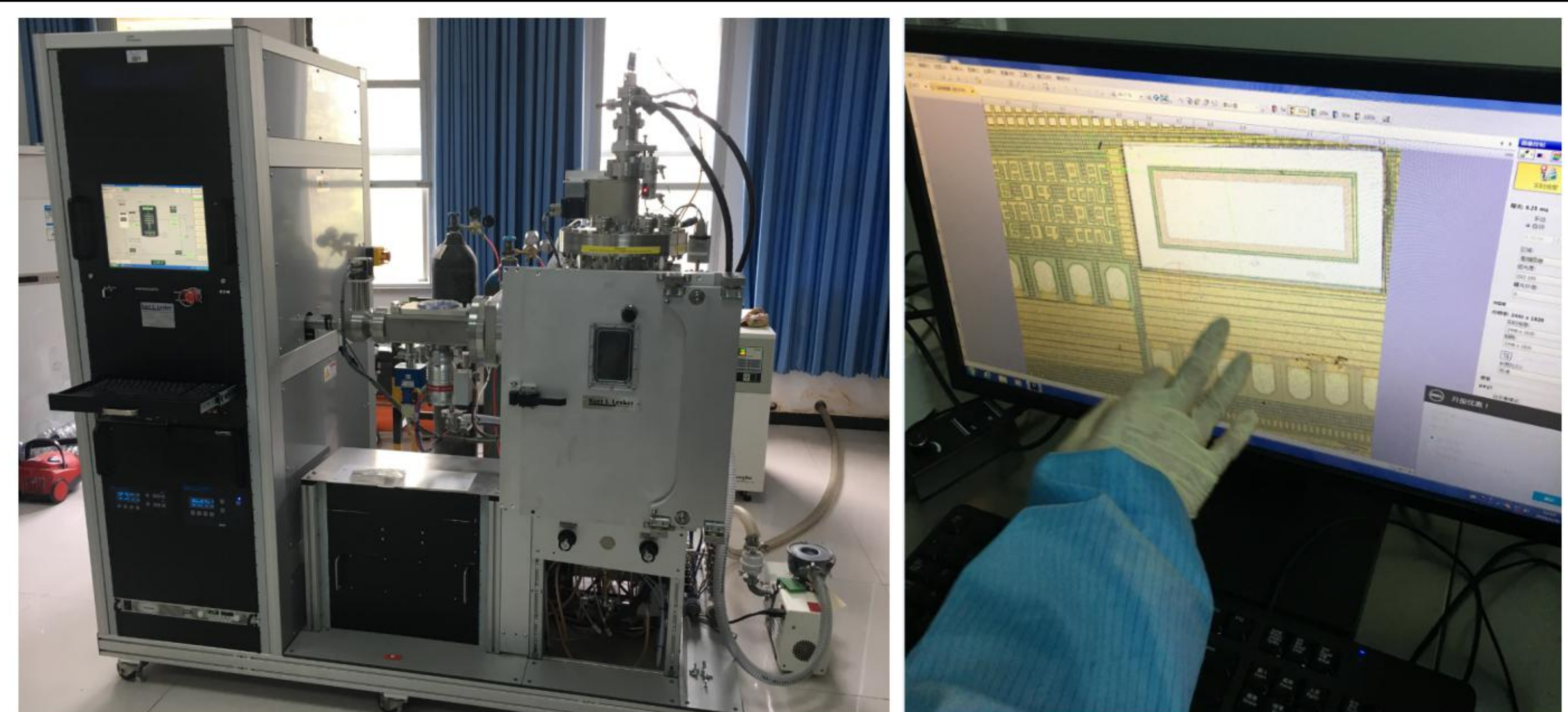


Fig 6: First attempt experiment of coating the ZnO thin-film

Summary and Outlook

Based on the prototype of a series Topmetal pixel sensor, we propose a high performance resistance measurement circuit fabricated in a standard 0.35μm CMOS process. Simulations show that the circuit achieved a 100Ω~10TΩ measuring range and a 10Ω resolution. These characteristics enable its use as the accurate resistance monitoring sensor device in future thin-film sensitive gas detection applications.

An independently simplified test module is designed in the Topmetal-IIa chip for the preliminary research. The first coating film attempt experiment is done by a Magnetic Sputtering Platform and using the Zinc Oxide (ZnO) material. Further more investigations, tests and design works are ongoing.

Acknowledgments and References

We acknowledge the supports from the Pixel Laboratory At Central China Normal University (PLAC) for providing the Topmetal sensor chips, and we also acknowledge the supports from the Key Laboratory of Low-dimensional photoelectric materials and devices in Hubei province for supporting the Thin-film coating experiments.

References:

- [1] Y. Fan et al. Development of a highly pixelated direct charge sensor, *Topmetal-I*, for ionizing radiation imaging, arXiv: 1407.3712.
- [2] M. An et al. A low-noise CMOS pixel direct charge sensor, *Topmetal-II*. Nucl. Instr. and Meth. A 810 (2016) 144-150, ISSN 0168-9002.