

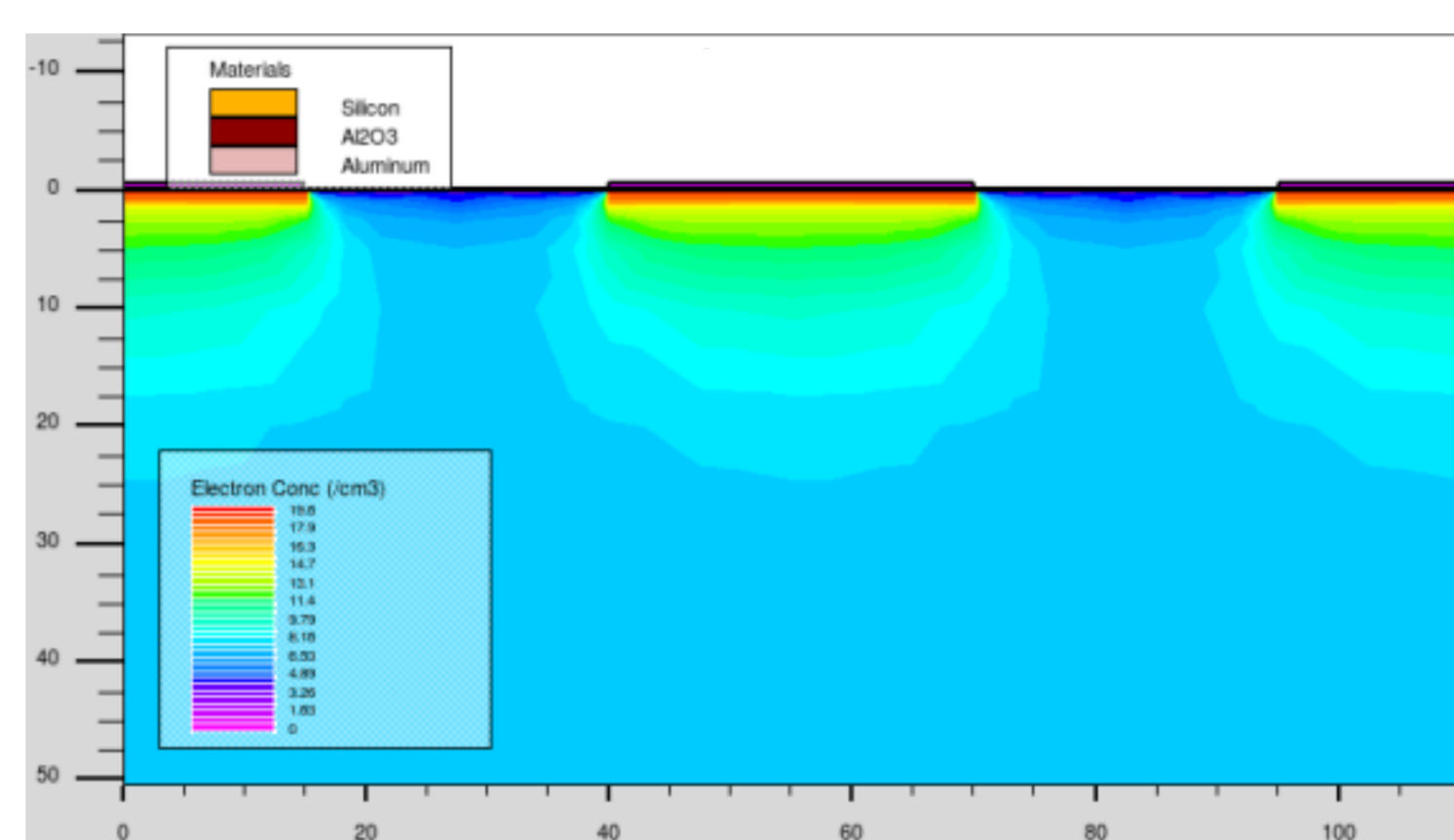
# Processing of AC-coupled n-in-p pixel detectors on MCz silicon using atomic layer deposited aluminium oxide

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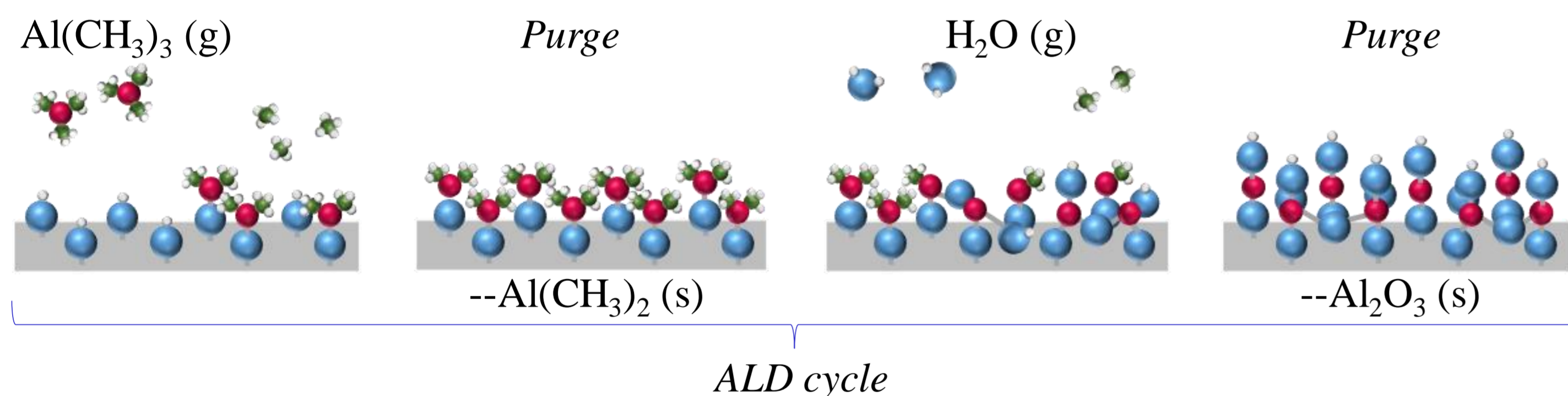
## Introduction

- Magnetic Czochralski (MCz) silicon has been proposed as substrate material for silicon detectors in very high-radiation environments [1]
- AC-coupling of pixels with titanium nitride (TiN) would provide a superior signal-to-noise ratio even in irradiated sensors, as the signal is separated from the leakage current DC component [2]
- Aluminum oxide ( $\text{Al}_2\text{O}_3$ ) has been demonstrated in strip detectors as an alternative to p-spray/p-stop insulation between detector segments, due to its high negative oxide charge [3,4]



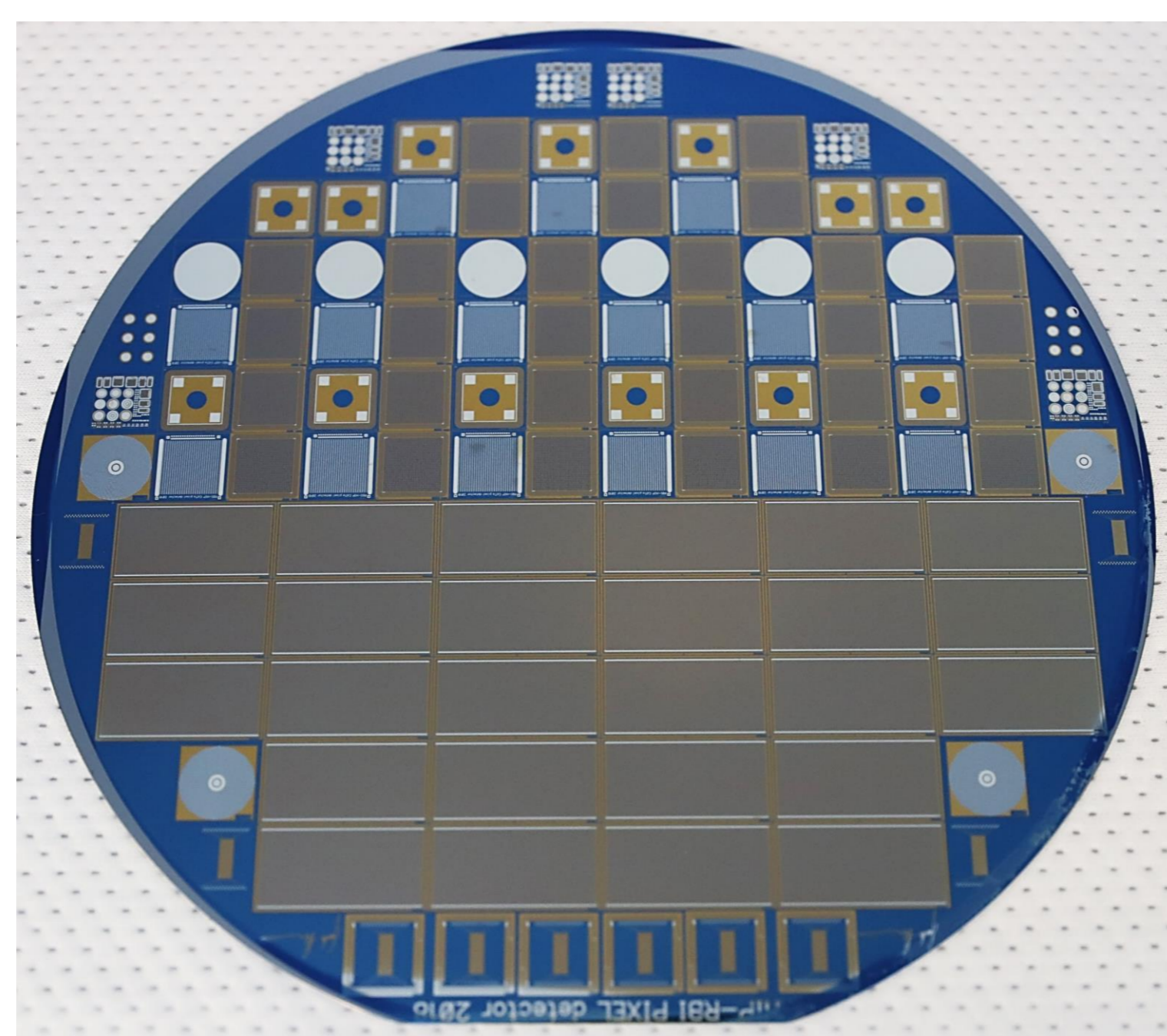
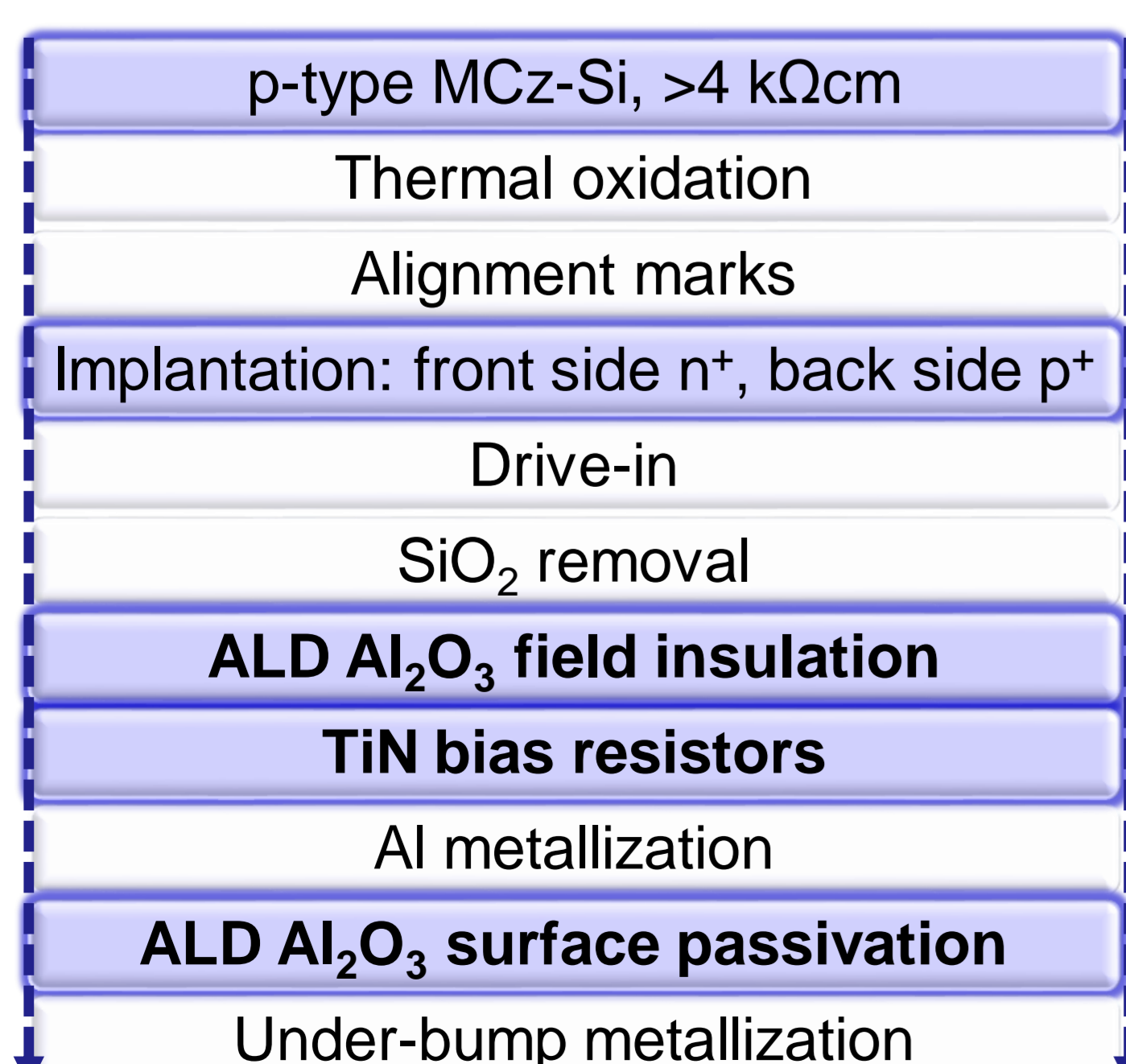
## Atomic Layer Deposition of Alumina

- Atomic layer deposition (ALD) allows precise, layer-by-layer growth of thin films with excellent conformality over large surface areas [5,6]
- Deposition of  $\text{Al}_2\text{O}_3$  from trimethylaluminium (TMA) and water is one of the most studied ALD processes [6], but requires optimization for detector applications



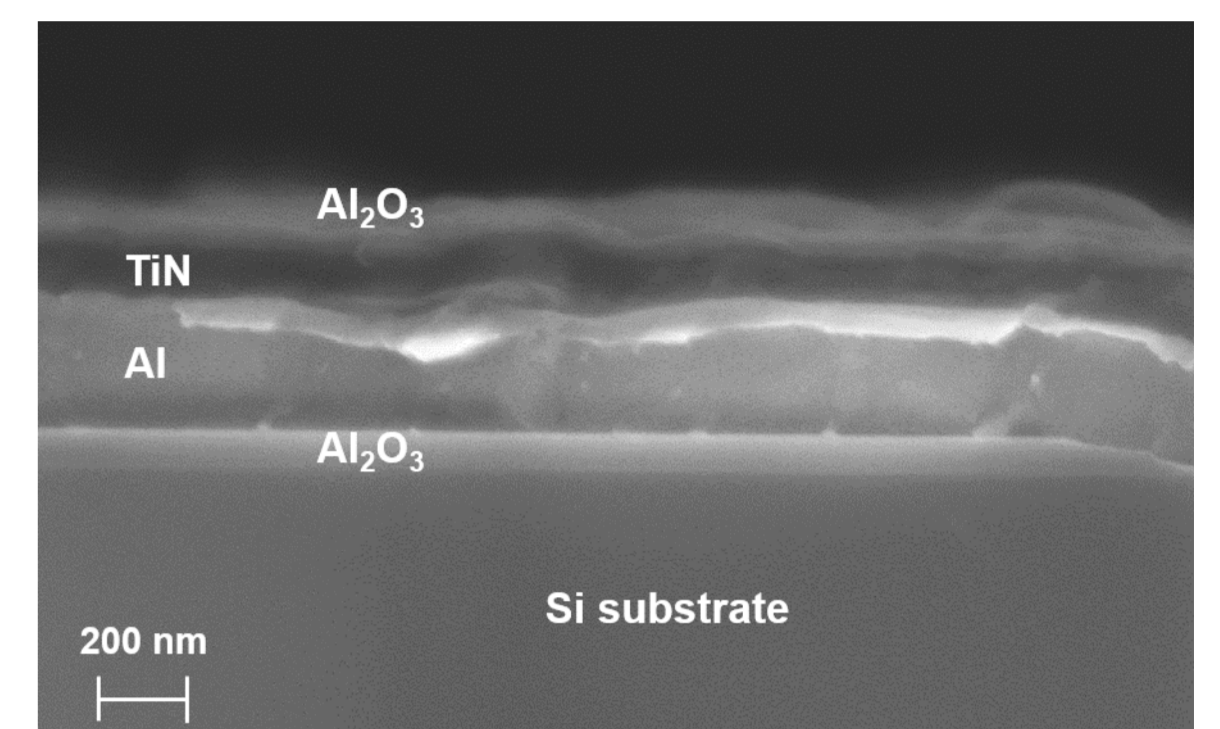
## Process flow

- Starting material: p-type MCz silicon, 6", 320  $\mu\text{m}$ , 4-8  $\text{k}\Omega\text{cm}$
- Only one lithography step and drive-in anneal is needed for ion implantation; no additional p-spray/p-stop
- ALD- $\text{Al}_2\text{O}_3$ :
  - Grown at 200 C from TMA and water, with additional ozone pulse to increase negative charge and avoid unwanted interface effects
  - Wet-etched with standard Al etchant
  - Stabilized by subsequent anneal at 370 C



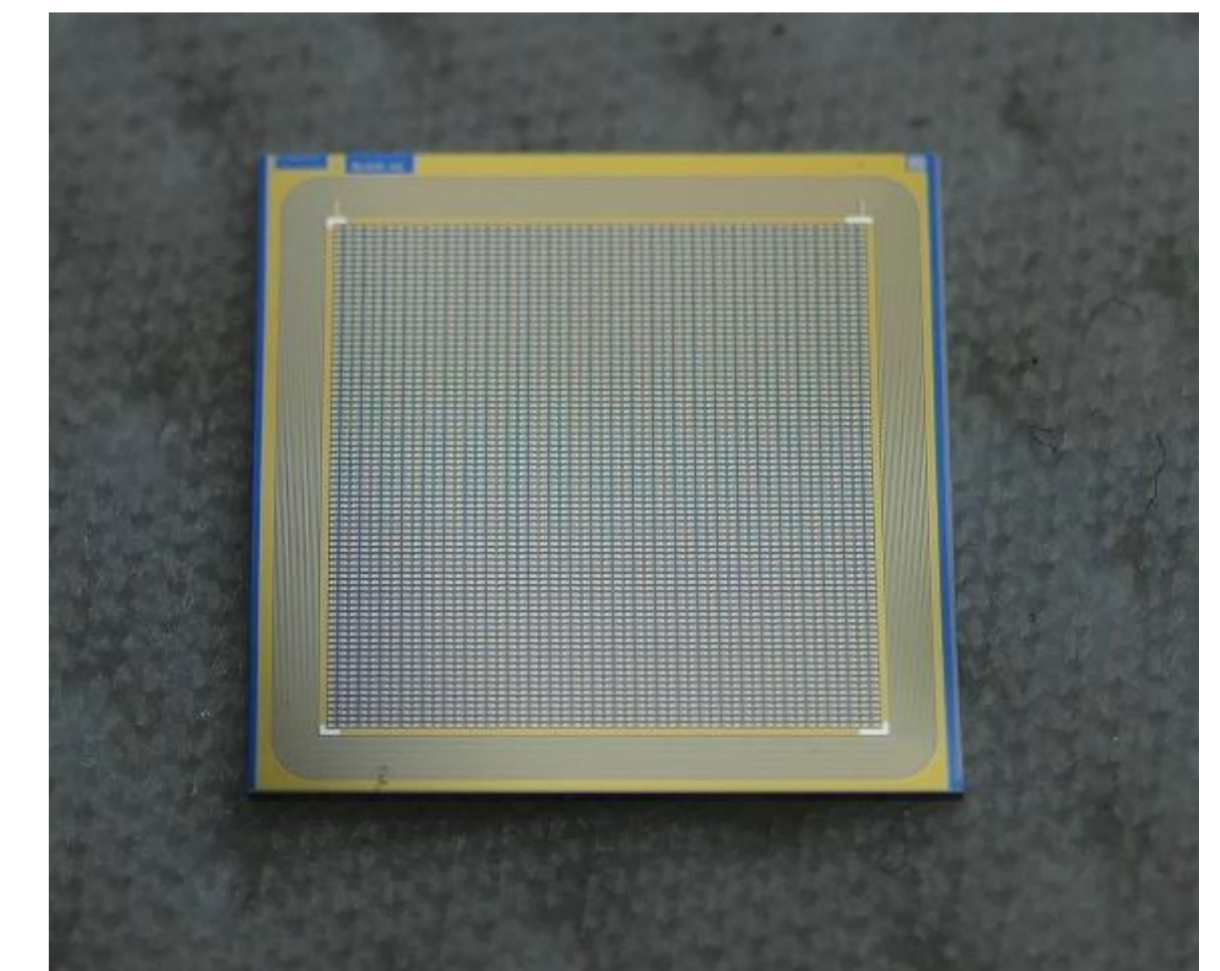
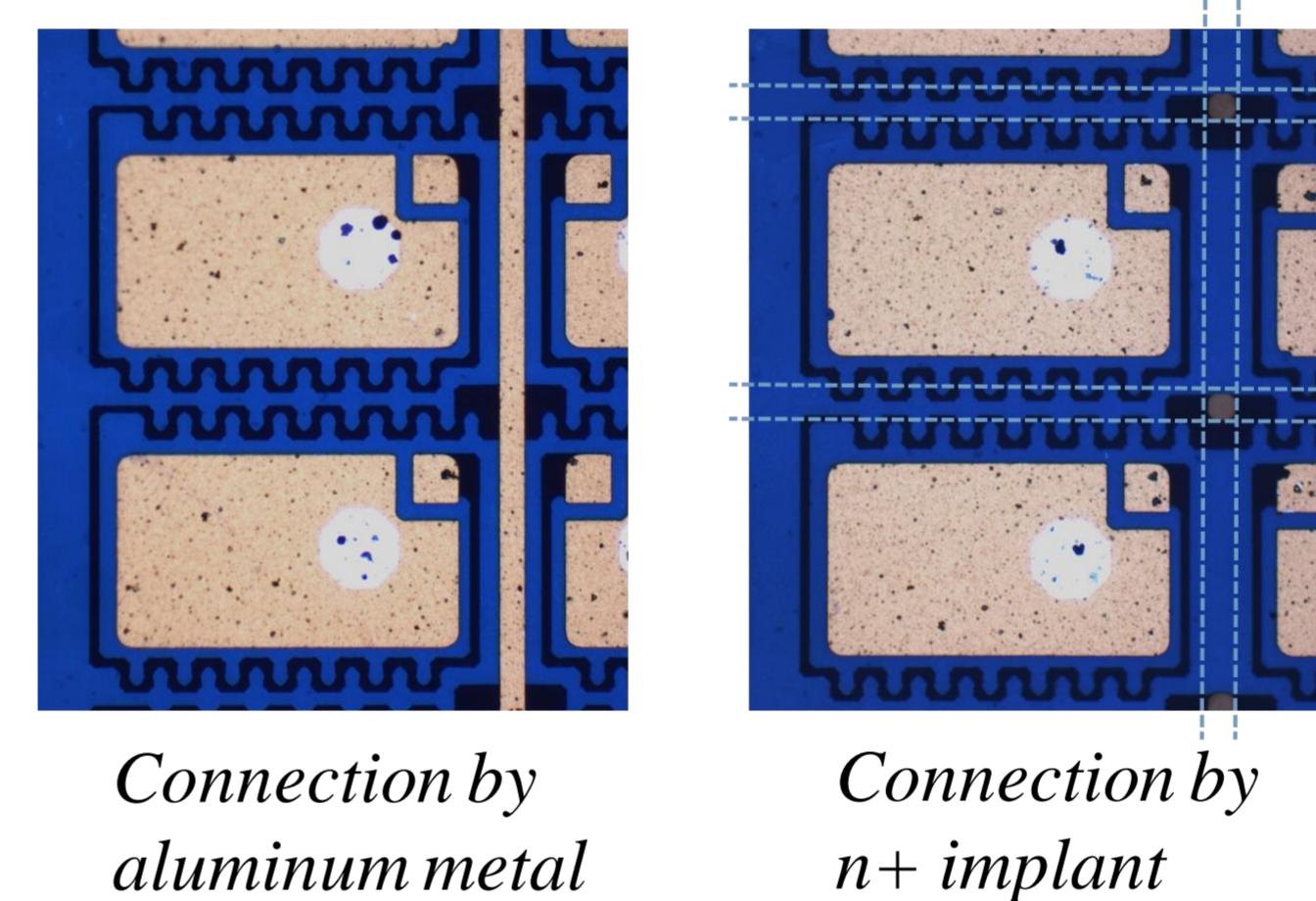
## Electrical characterization

- Leakage current and signal profile studied with single pad detectors
  - $I_{\text{leak}} < 10 \text{ nA/cm}^2$
- Oxide charge and capacitance based on MOS capacitors
  - $Q_{\text{eff}}$  around  $-3\text{e}12 \text{ q/cm}^2$
  - Oxide capacitance  $72 \text{ nF/cm}^2$
- Reference structures for pixel resistors
  - $\sim 15 \text{ k}\Omega$  per pixel



## AC-coupled pixel detectors

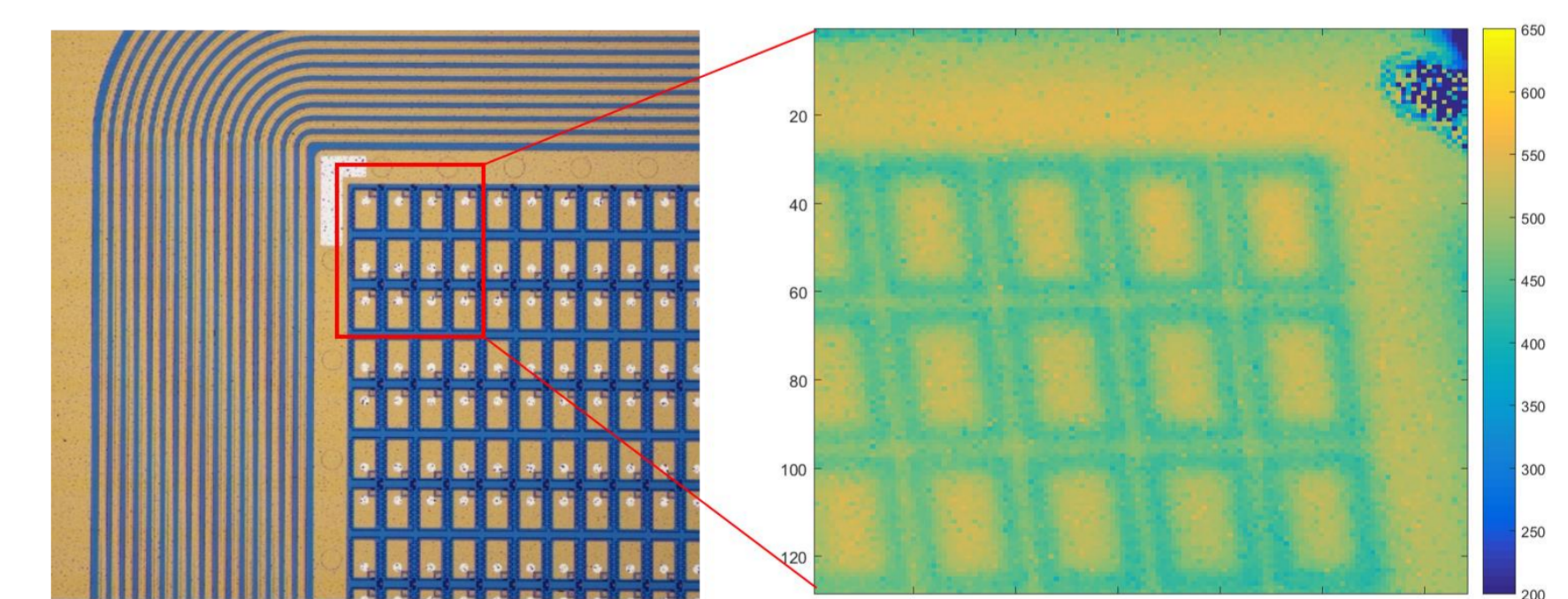
- 4160 pixels in double columns, matching the geometry of the CMS PSI46dig readout chip
- Two different schemes for connection of pixels to bias ring



## Performance estimation

- Translating measurements into properties of an individual pixel:
  - Cutoff frequency over the coupling capacitor dielectric:  $\sim 1 \text{ MHz}$
  - $C_{\text{pixel}} \ll C_{\text{coupling}}$ , factor  $\sim 2000$

- First tests with ion beam induced current using a 2 MeV proton microprobe indicate uniform charge collection



## Conclusions

- An ALD process for alumina was optimized for detector processing on high-resistivity, 6" MCz-Si with emphasis on negative charge and good surface properties
- AC-coupled pixel detectors were realized by combining ALD-grown  $\text{Al}_2\text{O}_3$  as coupling dielectric with TiN biasing resistors
- Electrical characterization through reference structures is promising; for test-beam campaigns sensors need to be flip-chip bonded to readout chip

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