Workshop on sapphire detector construction

# Strip resistivity

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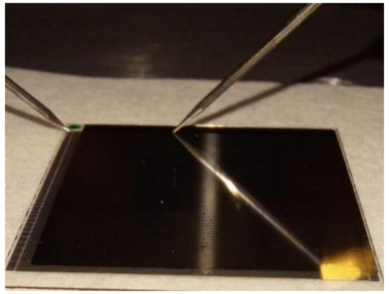
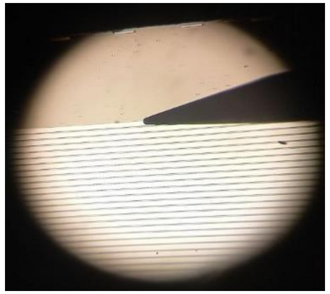
# Samples and Experimental setup

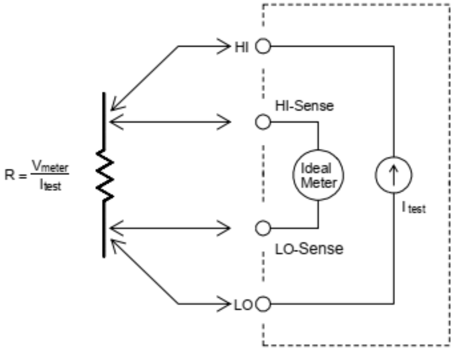
| 192-strips GBP prototypes | | |
|---|---|---|
| **Sensor production** | **Tomsk State University (TSU)** | **Fondazione Bruno Kessler (FBK)** |
| **Sapphire production** | Wuppertal (Germany) | University Wafer (USA) |
| **Strip size** | 20 mm x 80 μm | 20 mm x 80 μm |
| **Strip material** | Chromium (~60 nm) | Chromium + Aluminum (~30 + 200 nm) |

**Probes on the sample**





**Test scheme**




**Agilent 34401A 6 ½ Digit Multimeter**
Range: 100 μΩ – 100 MΩ

# Result

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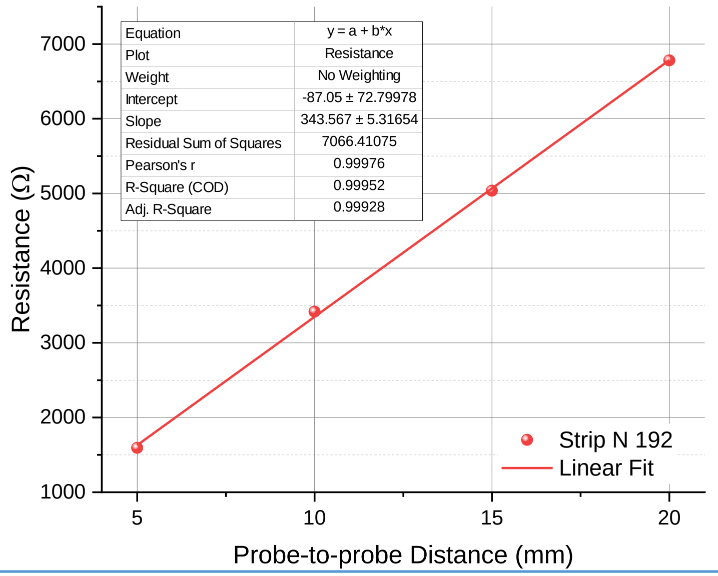
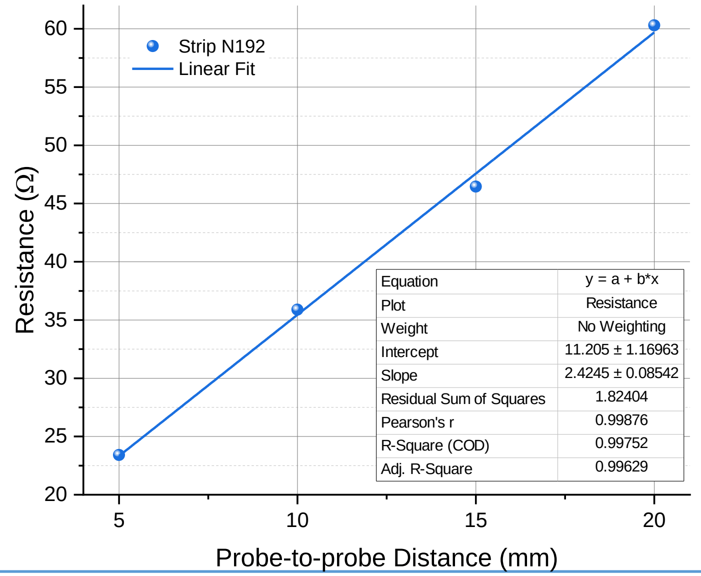
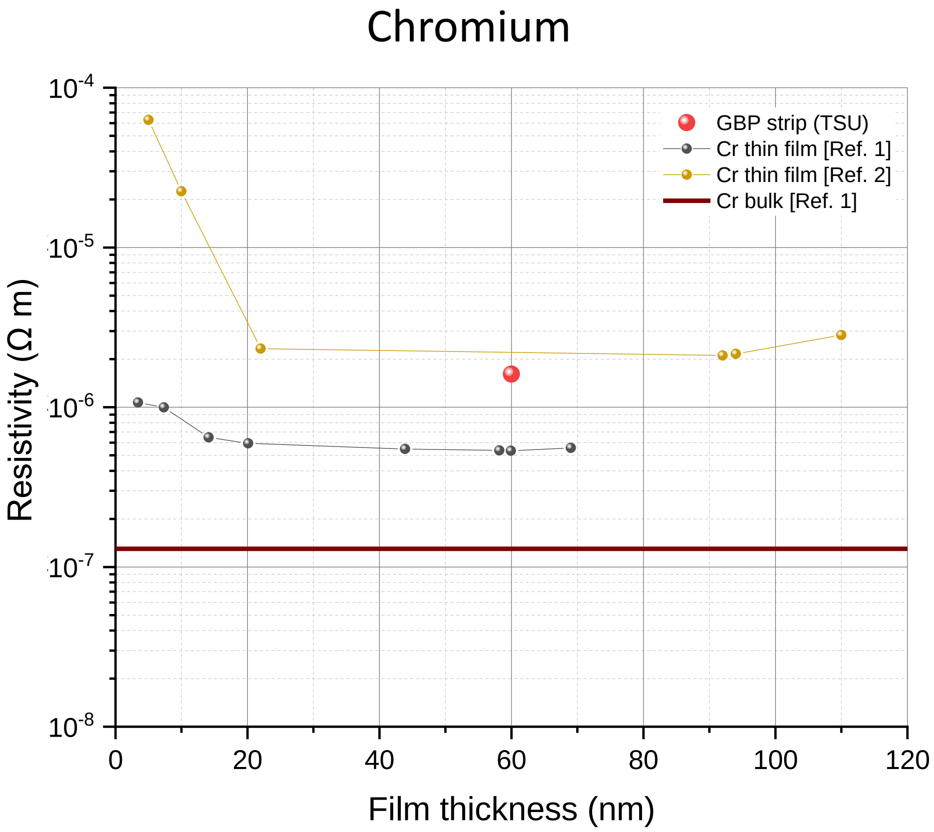
| **Strip material** | Chromium (~60 nm) | Chromium + Aluminum (~30 + 200 nm) |
| **Strip resistivity (20 mm)** | $1.61*10^{-6}$ Ω·m | $5.46*10^{-8}$ Ω·m |

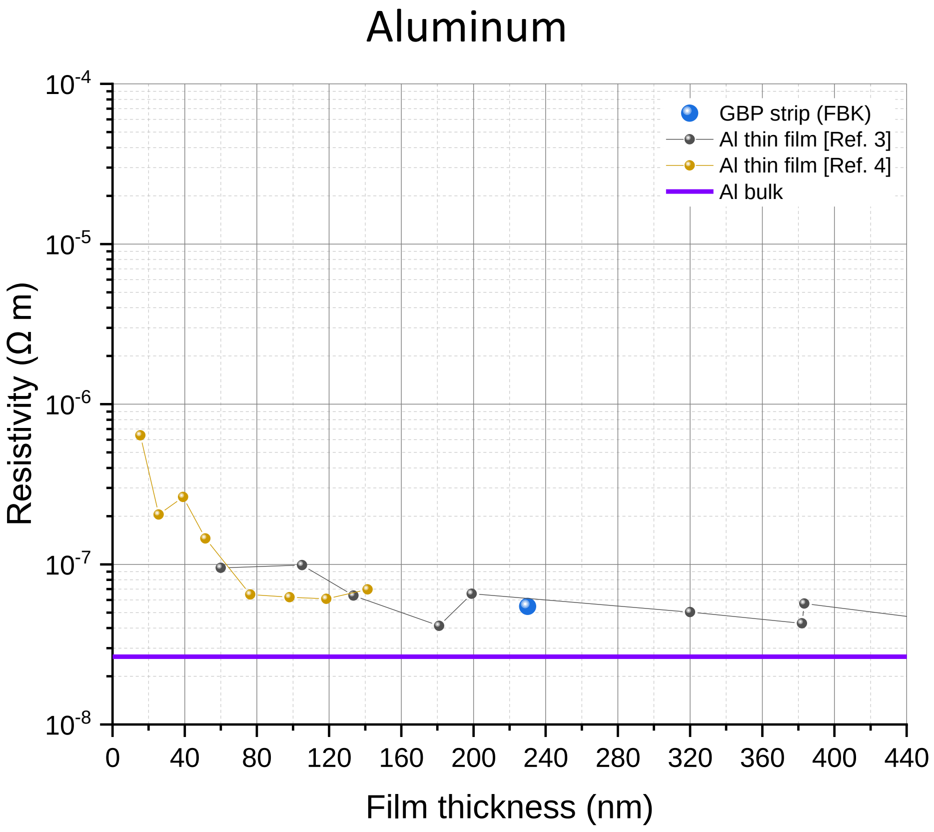
**Resistance along strip**



# Strip resistivity: Cr and Al





Ref.:

1. L.A. Udachan et. al., Phys. Stat. Sol. (a) 60, p. K191-K194 (1980)
2. V. Lozanova et. al., Journal of Physics: Conference Series 514 (2014) 012003
3. A. F. Mayadas, Journal of Applied Physics 39, 4241 (1968)
4. A. Karoui, The Electrochemical Society ECS Transactions, Volume 41, Number 4, p. 21-28 (2011)

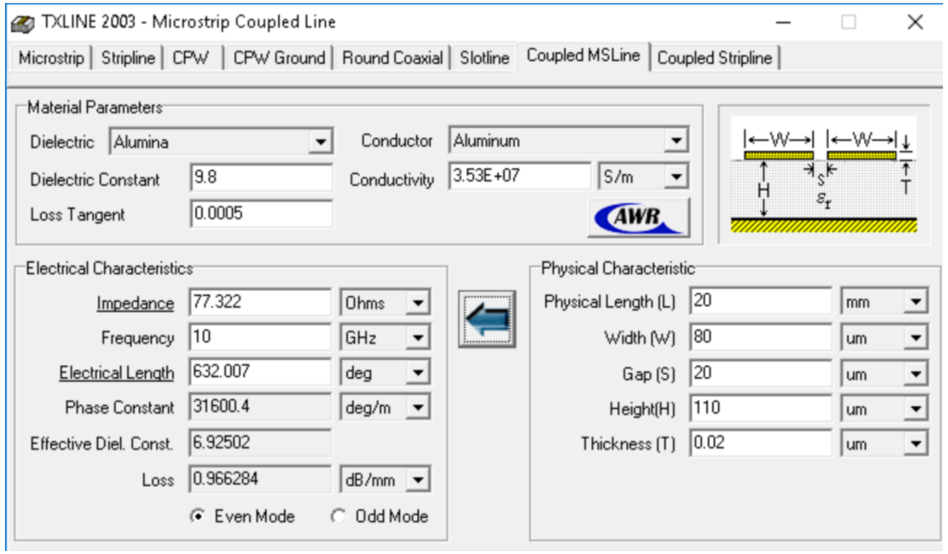
# High strip resistivity and beam profile reconstruction
# a case study from CLEAR's TB 28-31/03/2023

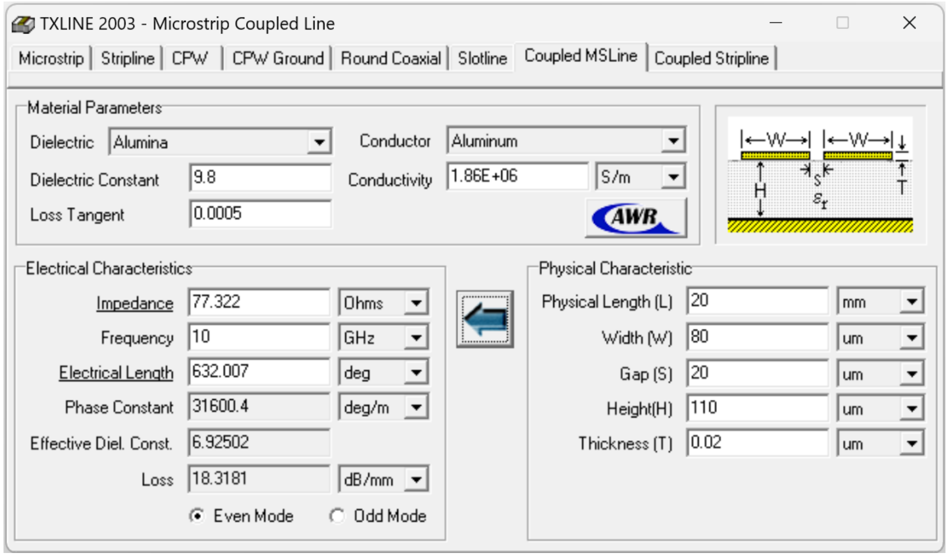
- Typical strip resistance ($l$=20mm) for **Tomsk** sensors is measured to be **6.7kΩ** for a strip, while **60Ω** for the **FBK** sensors.

- Typical strip even-mode impedance, assuming a signal rise time of 100ps, is approx. **77Ω** and **93Ω** for the **110um** and **150um** thickness of the GBP sensors (respectively).

- **Two key-points**
  1. high-strip resistivity implies signal attenuation (**loss**), whose intensity depends on the beam vertical position on the strip;
  2. lossy-line ($6.7k\Omega \gg 77\Omega$) means frequency-dependent termination: improper matching and signal **reflections.**

- **Case study:** signal from even/odd strips vs. beam pos. at CLEAR



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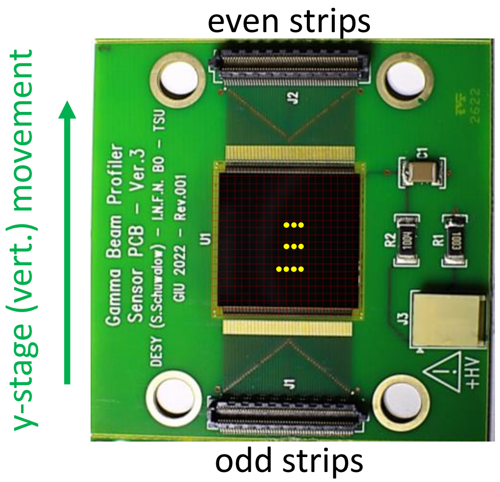



- The **test** consists of moving the beam **along the strip** and measure the effect by looking at the asymmetry between the beam charge from the reconstructed beam profile (gaus + const fit) using either the even or the odd strips

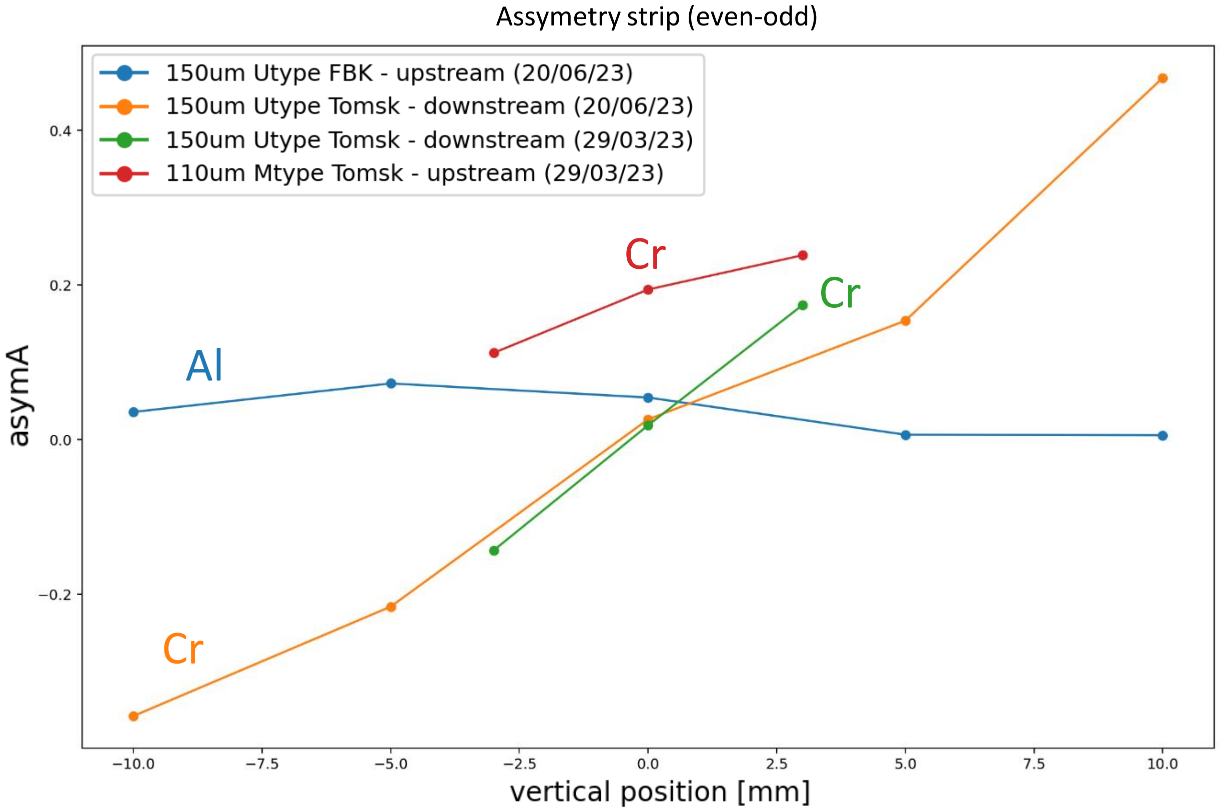
$$asymA \equiv \frac{(A\sigma)_{even} - (A\sigma)_{odd}}{(A\sigma)_{even} + (A\sigma)_{odd}}$$

- The signal attenuation depends on the path length $e^{-loss\ \Delta y}$. Readout of even strips signals is from the top, while odd from the bottom.

- If $(A\sigma)_{odd} \propto e^{-\alpha\left(\frac{d}{2}+y\right)}$ and $(A\sigma)_{even} \propto e^{-\alpha\left(\frac{d}{2}-y\right)}$, we expect

$$asymA = \tanh(\alpha y) = \alpha y - \frac{(\alpha y)^3}{3} + O\left((\alpha y)^5\right)$$

**a line** with a positive slope, as observed!
*(notice we have $(\alpha y) \sim 10^{-2}$)*



# Conclusions and open points

- **Conclusions**
  - High strip resistance – i.e., much bigger than strip impedance – should be **avoided**.
  - Quality check of strip metallization is important to ensure the layer thickness is uniform and resistivity within specifications.
  - Thicker metal layers are less affected by this issue.

    ► FBK sensors OK

- **Open points**
  - Early sapphire sensors (*UniversityWafers sapphire + strip metallization by Tomsk-University*) are affected by such issue.
  - Is it expected to have such high-resistance?
  - How well can the layer thickness be controlled in the manufacturing process?

# Thank for your attention