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 $\mu\Omega$ – 100 M $\Omega$



## Result

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Strip size	20 mm x 80 μm	20 mm x 80 μm					
Strip material	Chromium (~60 nm)	Chromium + Aluminum (~30 + 200 nm)					
Strip resistivity (20 mm)	1.61*10 <sup>-6</sup> Ω <sup>.</sup> m	5.46*10 <sup>-8</sup> Ω·m					
Resistance along strip	C plating weight No Weighting Residual Sum of Squares 7066.41075 Pearson's r 0.99976 Adj. R-Square (COD) 0.99952 Adj. R-Square 0.99928 Adj.	60 60 60 60 60 60 60 60 60 60					

## **Strip resistivity: Cr and Al**



### Chromium

### Ref.:

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

# 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

- 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

ficrostrip   Stripline   C	PW CPW Ground	Round Coax	ial   Slotline	Coupled MSLine Cou	pled Stripline	
Material Parameters						
Dielectric Alumina	-	Conducto	r Aluminum	•	←V	/→   ←\//→
Dielectric Constant	9.8	_ Conductivity	, 3.53E+07	S/m 💌	3	⇒rsk
Loss Tangent	0.0005			AWR		S <sub>I</sub>
Electrical Characteristic	\$			Physical Characterist	tic	
Impedance	77.322	Ohms 💌		Physical Length (L)	20	mm
Frequency	10	GHz 💌		Width (W)	80	um
Electrical Length	632.007	deg 💌		Gap (S)	20	um
Phase Constant	31600.4	deg/m 💌	[	Height(H)	110	um
Effective Diel. Const.	6.92502			Thickness (T)	0.02	um
Loss	0.966284	dB/mm 💌	[			
TXLINE 2003 - Mic	rostrip Coupled Lir	C Udd Mode				· .
TXLINE 2003 - Mic     Icrostrip   Stripline   C     Material Parameters	(• Even Mode rostrip Coupled Lir PW   CPW Ground	C Udd Mode ne I Round Coaxi	ial   Slotline	Coupled MSLine Cou	upled Stripline	· 🗆
TXLINE 2003 - Mic ficrostrip   Stripline   C Material Parameters Dielectric   Alumina	(• Even Mode rostrip Coupled Lir PW   CPW Ground	C Udd Mode	ial Slotline	Coupled MSLine Cou	 ipled Stripline   1   ← W	· • • • • • • • • • • • • • • • • • • •
TXLINE 2003 - Mic         flicrostrip       Stripline       C         Material Parameters       Dielectric       Alumina         Dielectric Constant       Dielectric Constant	(* Even Mode rostrip Coupled Lir PW CPW Ground	C Udd Mode	al Slotline r Aluminum , 1.86E+06	Coupled MSLine Cou	 ipled Stripline   ] ]	
TXLINE 2003 - Mic ticrostrip Stripline C Material Parameters Dielectric Alumina Dielectric Constant Loss Tangent	(* Even Mode rostrip Coupled Lir PW   CPW Ground 	C Udd Mode	al Slotline Aluminum 1.86E+06	Coupled MSLine Cou		· □ × · · · · · · · · · · · · · · · · · · ·
TXLINE 2003 - Mic         ticrostrip       Stripline       C         Material Parameters       Dielectric       Alumina         Dielectric Constant       Loss Tangent       Electrical Characteristic	(* Even Mode rostrip Coupled Lir PW   CPW Ground 9.8 0.0005	C Udd Mode	ial Slotline	Coupled MSLine Cou		/→   ←₩→  ≯ <sub>S</sub> k <sup>S</sup> r
TXLINE 2003 - Mic ficrostrip Stripline C Material Parameters Dielectric Alumina Dielectric Constant Loss Tangent Electrical Characteristic Impedance	(* Even Mode rostrip Coupled Lir PW CPW Ground 9.8 0.0005	C Udd Mode	al Slotline r Aluminum , 1.86E+06	Coupled MSLine Cou S/m Physical Characterist Physical Length (L)		/→I I←W→I <sup></sup> →I <sub>S</sub> k <sup></sup> S <sub>r</sub>
TXLINE 2003 - Mic         ticrostrip       Stripline       C         Material Parameters       Dielectric       Alumina         Dielectric       Constant       Loss Tangent         Electrical Characteristic       Impedance       Frequency	(* Even Mode rostrip Coupled Lir PW   CPW Ground 9.8 0.0005 	C Udd Mode	al Slotline Aluminum 1.86E+06	Coupled MSLine Cou S/m Physical Characterist Physical Length (L) Width (W)		$(\rightarrow)$ $(\leftarrow) (\forall)$ $\forall_S k$ $\mathcal{S}_x$ mm um
TXLINE 2003 - Mic ficrostrip Stripline C Material Parameters Dielectric Alumina Dielectric Constant Loss Tangent Electrical Characteristic Impedance Frequency Electrical Length	(* Even Mode rostrip Coupled Lir PW CPW Ground 9.8 0.0005 25 77.322 10 632.007	C Udd Mode	al Slotline Aluminum 1.86E+06	Coupled MSLine Cou S/m Physical Characterist Physical Length (L) Width (W) Gap (S)		/→   ← \//→  →  ↓ ≫  ↓ 𝑘 𝑘 µm µm
TXLINE 2003 - Mic         ficrostrip       Stripline       C         Material Parameters       Dielectric       Alumina         Dielectric       Constant       Loss Tangent         Electrical Characteristic       Impedance       Frequency         Electrical Length       Phase Constant       Constant	(* Even Mode rostrip Coupled Lir PW CPW Ground 9.8 0.0005 25 77.322 10 632.007 31600.4	C Udd Mode	al Slotline Aluminum 1.86E+06	Coupled MSLine Cou S/m Physical Characterist Physical Length (L) Width (W) Gap (S) Height(H)		/→   ←₩/→  →  <sub>S</sub> k ≈ <sub>r</sub>  mm  um  um
TXLINE 2003 - Mic         ficrostrip       Stripline       C         Material Parameters       Dielectric       Alumina         Dielectric       Constant       Loss Tangent         Electrical Characteristic       Impedance       Frequency         Electrical Length       Phase Constant       Elfective Diel. Const.	(* Even Mode rostrip Coupled Lir PW CPW Ground [9.8 [0.0005 [77.322 [10 [632.007 [31600.4 [6.92502	C Udd Mode	Aluminum 1.86E+06	Coupled MSLine Cou S/m Physical Characterist Physical Length (L) Width (W) Gap (S) Height(H) Thickness (T)		/→   ←-₩→  → sk Sr / / / / / / / / / / / / /
TXLINE 2003 - Mic         ficrostrip       Stripline       C         Material Parameters       Dielectric       Alumina         Dielectric Constant       Loss Tangent       E         Electrical Characteristic       Impedance       Frequency         Electrical Length       Phase Constant       E         Electrical Length       Phase Constant       E	(* Even Mode rostrip Coupled Lir PW CPW Ground 9.8 0.0005 77.322 10 632.007 31600.4 6.92502 18.3181	C Udd Mode	al Slotline Aluminum 1.86E+06	Coupled MSLine Cou S/m Physical Characterist Physical Length (L) Width (W) Gap (S) Height(H) Thickness (T)		/→   ← W→   → Sk St

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

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  $(\alpha y) \sim 10^{-2}$ )



#### Assymetry strip (even-odd)



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## **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









