Optimization of Transmission Line Measurement (TLM) Structures for Contact Resistivity Determination

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Project Objectives

Goal: To investigate the influence of Transmission Line Method (TLM) structure dimensions on the extraction of the Specific Contact Resistivity (ρ_c) .

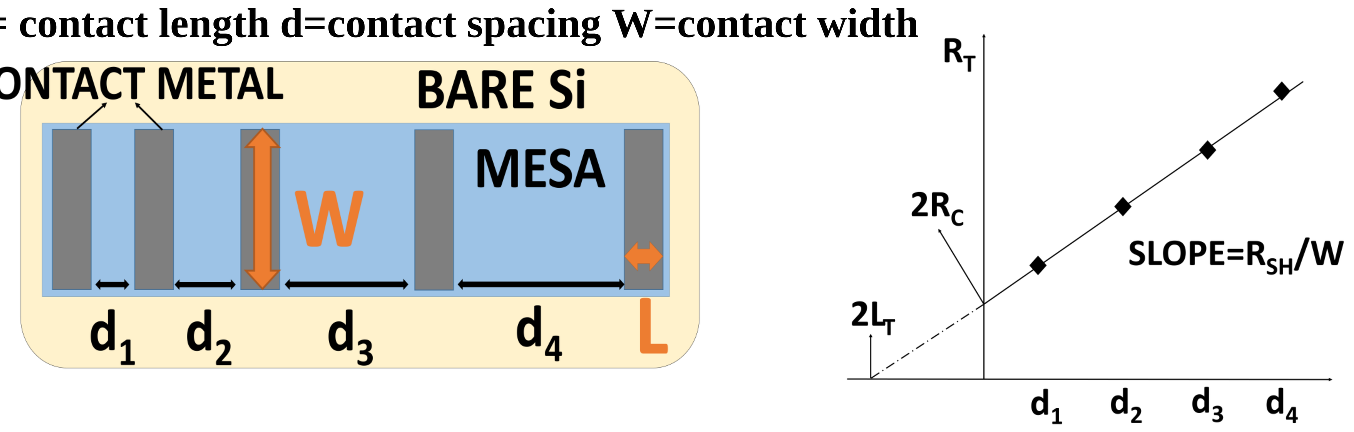
- **Study the effect of TLM geometry on systematic error and optimize TLM structure widths.**
- **Validate the use of the TLM method for applications covering wide ranges of ρ_c and R_{SH} .**

Motivation

- Low Resistance ohmic contacts are of extreme importance to semiconductor devices.
- Transmission Line Measurement (TLM) structures are most commonly used to determine ρ_c.
- Accurate determination of ρ_c is essential for characterizing semiconductor devices.
- Inconsistencies have been observed for ρ_c determination in literature .
- ρ_c determination may depend on TLM dimensions.
- TLM test geometries therefore need to be optimized for ρ_c in order to minimize error.

TLM Measurements

L= contact length d=contact spacing W=contact width



- Contacts are fabricated with different pad spacing's on diffused MESA regions of known R_{SH}.

TLM General formula: $R_C = \frac{\sqrt{R_{SH}\rho_C}}{W} \coth\left(\frac{L}{L_T}\right)$ L_T = Transfer Length

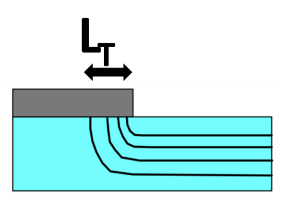
Two limiting cases:

(1) $L < 0.5L_T \rightarrow \coth\left(\frac{L}{L_T}\right) \approx \frac{L_T}{L} \rightarrow R_C = \frac{\rho_c}{WL}$

- Short contact approximation

(2) $L > 1.5L_T \rightarrow \coth\left(\frac{L}{L_T}\right) \approx 1 \rightarrow R_C = \frac{\rho_c}{WL_T}$

- Long contact limit



- Case (2) is commonly applied for ρ_c determination.
- Not an accurate depicter for varying TLM geometries.

ERROR ANALYSIS

The equation for relative uncertainty due to systematic error is given by

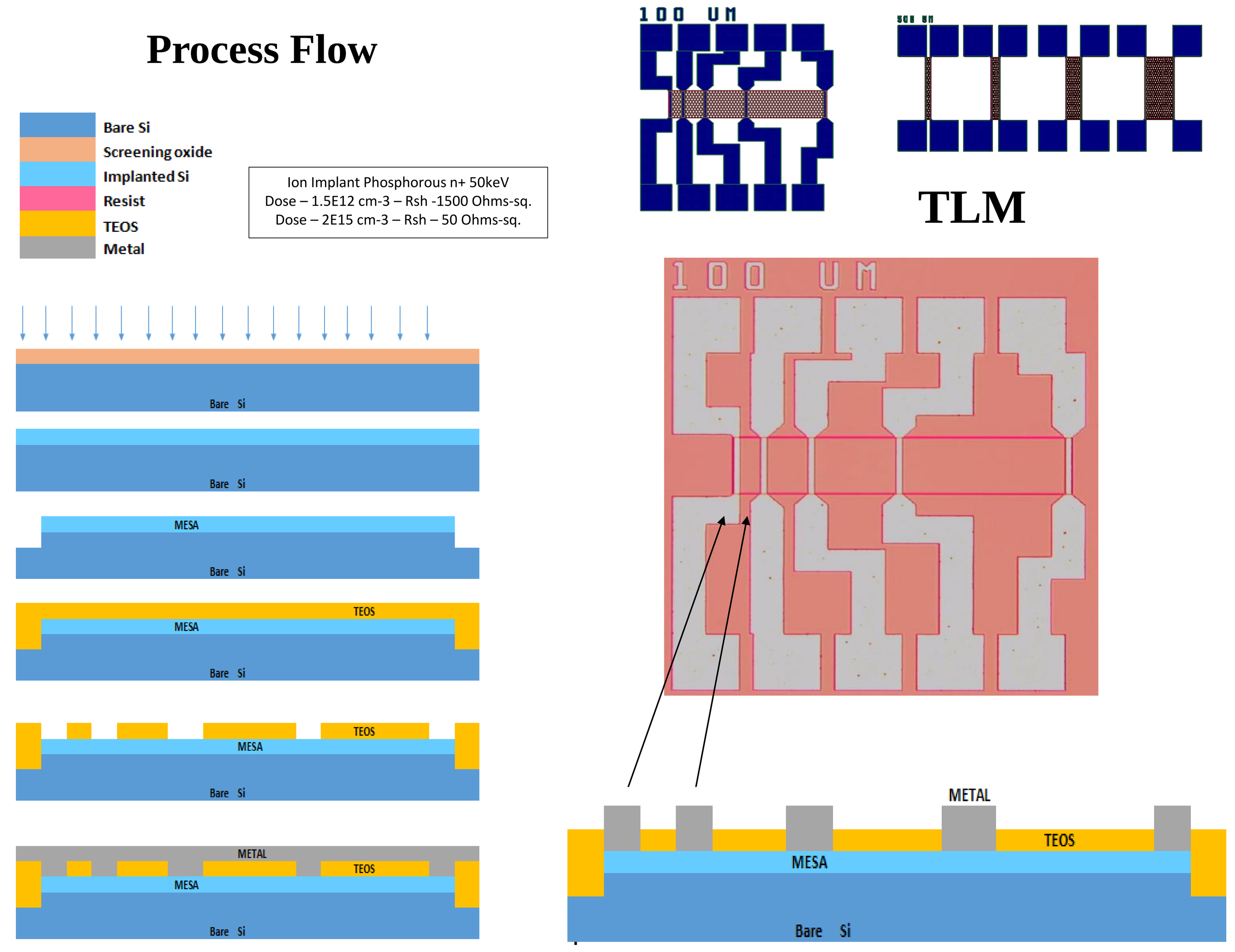
$$\frac{\delta\rho_c}{\rho_c} = \left(\frac{W}{\sqrt{\rho_c R_{SH}}}\right)\delta R + \left(\sqrt{\frac{R_{SH}}{\rho_c}}\right)\delta d + \left(\frac{4}{W}\right)\delta W$$

Optimizing above equation leads to the optimum width for minimum systematic error shown below.

$$W_{opt} = \sqrt{4(\sqrt{\rho_c R_{SH}}\left(\frac{\delta W}{\delta R}\right)}$$

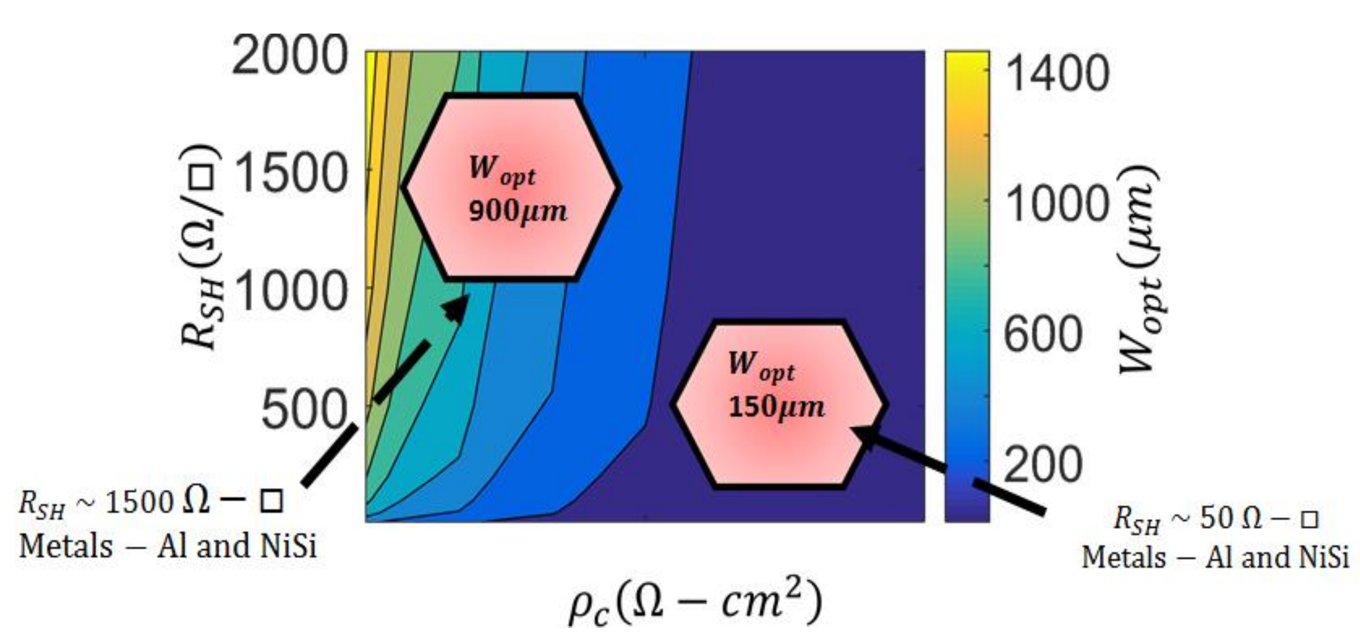
Experimental Strategy

- A 3 level mask design was implemented to fabricate TLMs. Levels for
  - MESA Definition
  - Contact Cut
  - Metal Etch
- Mask design included the following
  - TLM's : Widths 10um – 2000um.
    - Pad spacing(d) increments: 30 μm to 240 μm.
  - Cross Bridge Kevin Resistors (CBKR)
  - Van Der Pauw's (VDP)
- Low and high values of sheet resistance (50-1500 Ohms/sq) investigated with two different metals (Aluminum and NiSi)
  - Sheet resistance is application specific
  - Emitter Rs in silicon photovoltaics (50-100 Ohmssq)
  - Well Rs in CMOS (1000-3000 Ohms-sq.)



Simulated Results from Error Analysis

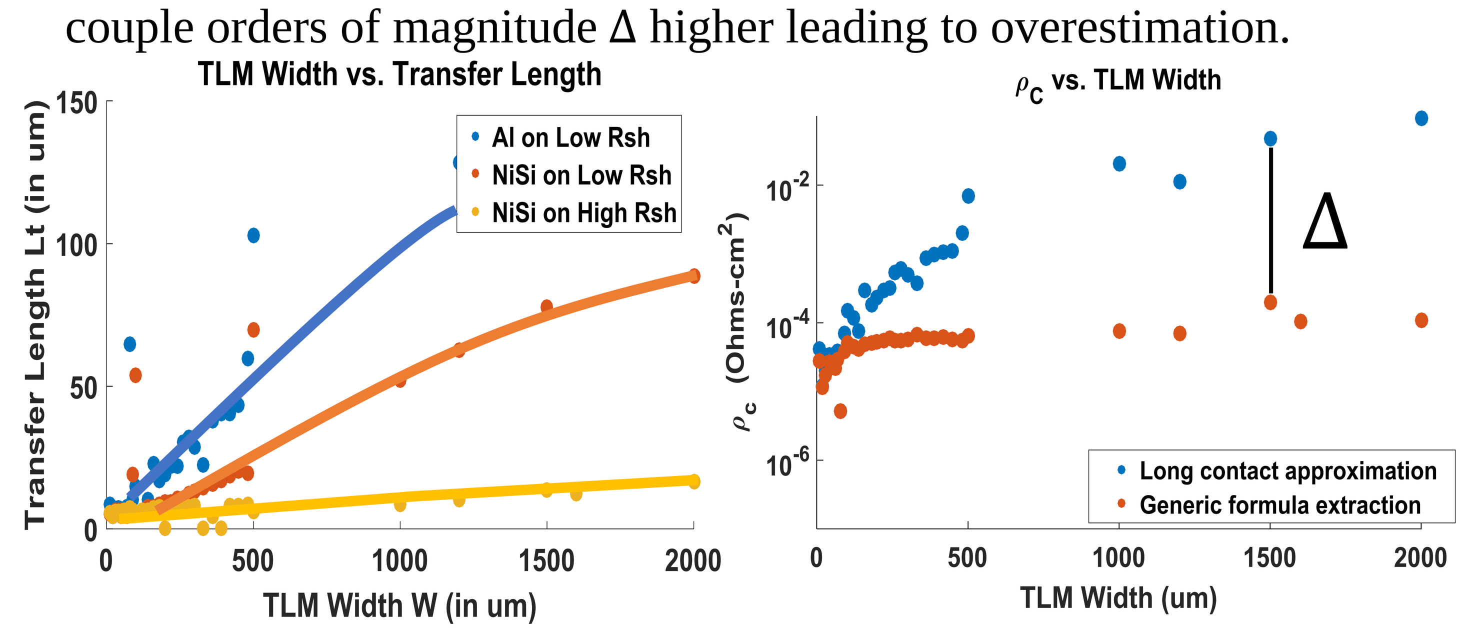
The design range for process fabrication was based on optimized width values. Optimum widths show least amount of systematic error



Aluminum on high sheet resistance wafer gave Schottky contact behavior and therefore TLM was not applied.

Experimental Results (contd.)

- A proportionality between the transfer length (L_T) and the TLM width (W) was observed.
- ρ_c extraction from Case(2) differs from general formula indicating a couple orders of magnitude Δ higher leading to overestimation.



#	Metal	ρ_c $(\Omega - cm^2)$ Anticipated	R_{SH} $(\Omega/sq.)$ Fabrication	$W_{opt}(\mu m)$ Error Analysis	$L_T(\mu m)$ Extracted	ρ_c $(\Omega - cm^2)$ Extracted
1	NiSi	$\sim 10^{-5}$	50	115	9.3	2 x10^{-5}
2	NiSi	$\sim 10^{-3}$	1500	800	9.65	1 x10^{-3}
3	Al	$\sim 10^{-5}$	50	115	10.4	4.5 x10^{-5}

Conclusions and Future Work

To conclude, a process to accurately determine ρ_c from TLM measurements is suggested.

Anticipate ρ_C and R_{SH} (Known value of L) → Obtain W_{opt} from Error analysis → $L_T = f(W)$ → Determine L_T at W_{opt} → $L_T > 2L$: Case (1) Equation; $L_T < \frac{2}{3}L$: Case (2) Equation

It is strongly recommended that the general formula is applied to calculate ρ_c.

For future work, a standardized approach needs to be developed for accurate measurement of specific contact resistivity through TLM measurements for a given application.

References

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[2] Haw-Jye Ueng, D. B. Janes and K. J. Webb, "Error analysis leading to design criteria for transmission line model characterization of ohmic contacts," in *IEEE Transactions on Electron Devices*, vol. 48, no. 4, pp. 758-766, Apr 2001.

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