



# Influence of Contact Resistivity and Temperature on Current Trimming of Heavily Doped Polysilicon Resistors

Vladimír Strakoš<sup>1</sup>, Libor Vojkůvka<sup>2</sup>, Radim Špetík<sup>1</sup>

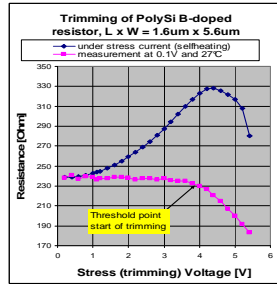
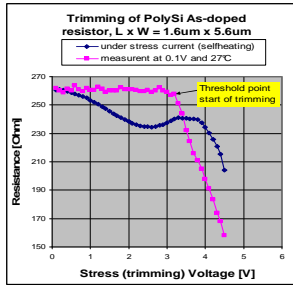
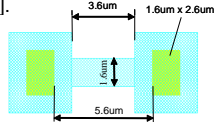
Corporate R&D<sup>1</sup>, SCG Czech Design Center<sup>2</sup>, ON Semiconductor Czech Republic, B. Němcové 1720, 756 61 Rožnov pod Radhoštěm, Czech Republic

ON Semiconductor

## Standard Current induced Trimming Effect

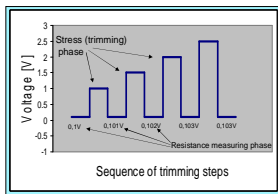
Current-Induced Resistance decrease of highly doped Polysilicon resistors is well known [1]. Also the use of this phenomenon for resistor trimming has been described and published [2].

A typical trimming of PolySi resistor with layout according to figure on the right for both type of impurities (Arsenic and or Boron) is shown in graphs below:



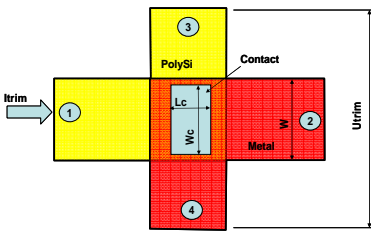
## Optimal Method of Measurement and Trimming of Resistivity

Optimal resistance setup consists of alternating phases where the resistance is measured at low voltage (~0.1V@27°C) followed by a trimming voltage pulse. The voltage of the trimming pulse is gradually increased increasing current densities in resistor above the trimming threshold.



## Influence of Contact PolySi to Metal on Trimming Effect

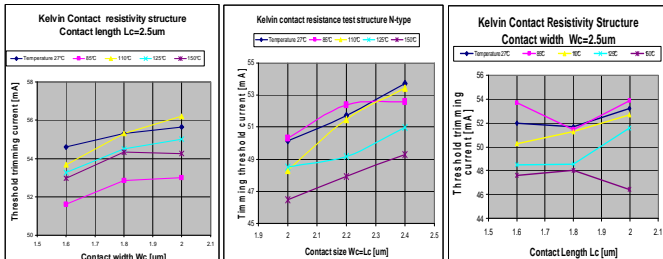
The analysis of contact resistivity trimming has been made by using Kelvin test structures (figure below) on N-type of Poly-Si layer, which was contacted by bi-layer of TiW-AiCu. Square contact windows (2.4um x 2.4um; 2.2um x 2.2um and 2um x 2um) have been used and also the rectangle-like contact windows (2um x 2.5um, 1.8um x 2.5um and 1.6um x 2.5um) have been used in our experiment.



The forced current flows between terminals 1 and 2 and the voltage drop is measured on the sense terminals 3 and 4. This measurement allows to rotate the terminals by 90 degrees and alternate the direction of the current along the shorter and the longer sides of the contact window.

The measurement of contact resistance PolySi-Metal on Kelvin test structures shows the characteristics similar to characteristics of simple PolySi resistors.

## Dependence of Threshold Trimming Current on Contact Dimensions in Temperatures

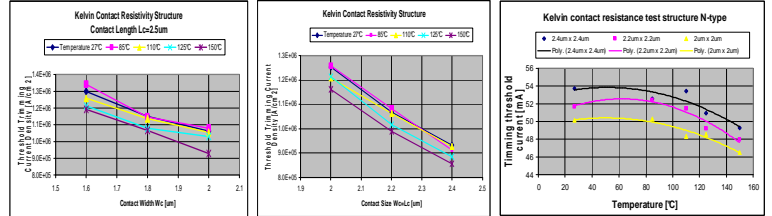


Threshold trimming current in Kelvin contact resistivity structure depends on contact width (current is flowing perpendicularly to width) regardless if contact is square or rectangular. The threshold trimming current decreases with the increase of the temperature.

### REFERENCES

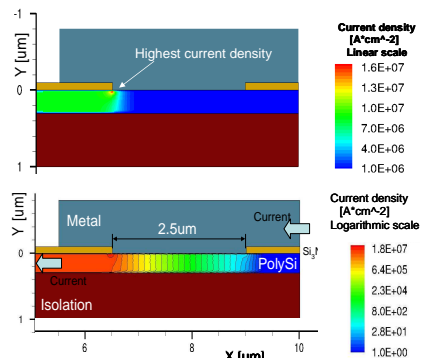
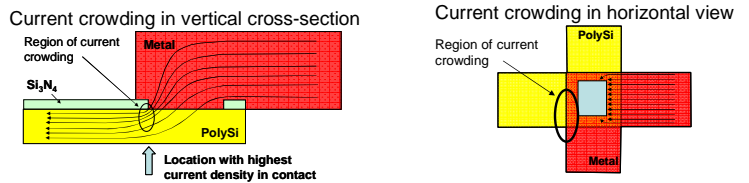
- [1] Kotaro Kato, Terukazu Ono, Yoshihito Amemiya: A physical mechanism of current-induced resistance decrease in heavily doped polysilicon resistor. IEEE Transaction on Electron Devices, Vol. ED-29, NO.8, August 1982, pp1156-1161.
[2] Babcock, J.A., Feldbaumer, D.W. and Mercier, V.M.: "Polysilicon Resistor Trimming for Packaged Integrated Circuits", IEDM 93-247-250.
[3] Schroder, D.K.: Semiconductor Material and Device Characterization, John Wiley & Sons, Inc. NY 1990. pp. 121-126

## Dependence of Threshold Trimming Current Density on Contact Dimensions and Temperature



Threshold trimming current density increases with the decrease of the contact width. Threshold trimming current density decreases for temperatures higher than ~ 100°C.

## Current Crowding Creates Nonuniform Current Density [3]

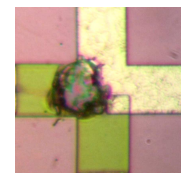
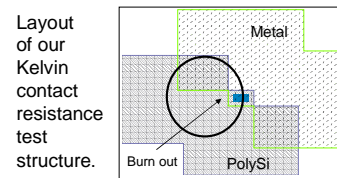


## 2D numerical simulation of current density

(on the left) in PolySi layer in contact with Metal, thickness of metal ~ 0.7um, thickness of PolySi ~ 0.3um, Contact window L x W = 2.5um x 2um, Rs(PolySi) ~ 80 Ohm/sq. Current through contact for evaluation is 50mA. Note that current doesn't flow neither through whole contact area in lateral direction nor in whole area of vertical cross-section (given by width of contact window times PolySi thickness).

Numerical simulations are virtually the only way for the determination of the current density distribution.

The highest current density in our example (on the left end of contact in figure) is 18MA/cm^2



Optical microscopy photo of the location where overcritical current density created the burn-out dot in the PolySi layer.

The PolySi burn-out is located on the left side of the contact window and was exposed to an overcritical current flowing in the horizontal direction. This position corresponds also to the place where trimming of contact resistance started. The contact area where the trimming current exceeds the threshold value is much smaller than the contact size due to current crowding. This is reason why average threshold current density is less important. The contact trimming starts in the location where the current density exceeds the threshold value.

## Conclusions and Recommendations

All resistors including resistors dedicated for trimming have to be properly characterized. The process of trimming changes the temperature coefficients of resistivity - in both the PolySi body of the resistor and in the PolySi contact to Metal. Trimming of the resistor body is easy to describe and to characterize while the trimming of the PolySi in the contact is nonlinear and hard to describe.

### Proposal:

The resistors for trimming at the wafer level and/or after assembly should be designed in a way excluding the contact regions from the trimming. In the first approximation it is reasonable to require for the current density in contacts to be at least 2x lower than it is in the linear resistor body. The four contacts version allows to separate the active resistor contacts from trimming contacts. This solution fully excludes the trimming of active resistor contacts. An example of layouts respecting the above mentioned criteria is shown on the right.

