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

Vladimír Strakoš1, Libor Vojkůvka2, Radim Špetík1
Corporate R&D, SCG Czech Design Center®, ON Semiconductor Czech Republic, B. Němcové 1720, 756 61 Rožnov pod Radhoštěm, Czech Republic

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 Polysil resistor with layout according to figure on the right for both type of impurities (Arsenic and or Boron) is shown in graphs below.

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 PolySi layer, which was contacted by bi-layer of TiW-AlCu. 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.

Dependence of Threshold Trimming Current on Contact Dimensions and Temperature

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.

Optimal Method of Measurement and Trimming of Tensivity

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.

Current Crowding Creates Nonuniform Current Density

Current crowding in vertical cross-section

Current crowding in horizontal view

2D numerical simulation of current density

(1) Kotaro Kato, Terukazu Ono, Yoshihito Amemiya: A physical mechanism of current-induced resistance decrease of heavily doped polysilicon resistor.
(3) Schneider, D.R.: Semiconductor Material and Device Characterization, John Wiley & Sons,Inc. NY 1990, pp.121-126

References

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

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 Polysil 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.