Probleme bei der Parameterextraktion an Raumladungskapazitäten?

Werner Graudszus
Bipolar-Arbeitskreis 2002
Junction capacitance formula

\[ C_j(V) = \frac{C_j(0)}{(1 - \frac{V}{V_J})^{M_J}} \]

\[ \lg C_j(V) = \lg C_j(0) - M_J \cdot \lg \left( 1 - \frac{V}{V_J} \right) \]

To check for correct junction capacitance behaviour (slope \( M_J \) (=derivative) should be constant)
Junction capacitance formula

\[ C_j(V) = \frac{C_j(0)}{M_J} \left(1 - \frac{V}{V_J}\right) + Cox \]

\[ C_j(V) = C_j(0) \cdot \left(1 - \frac{V}{V_J}\right)^{-M_J} + Cox \]

Y

X

optimize VJ + MJ, calculate linear regression

\[ \text{slope} = C_j(0), \quad y(0) = Cox \]

to determine constant capacitance contributions

(overlap capacitance, pad + interconnect contributions)
CBE: CJ0 + Cox determination

example: BE capacitance, resulting from S-parameter measurements

reasonable results: CJ0 = 25.31 fF  VJ = 1.061 V  MJ = 0.5113  Cox = 1.28 fF
R coefficient = 0.999975
CBE: C-V behaviour

CBE: C-V behaviour

RMS error = 0.0895%
CBE: linearized data

-0.40 -0.35 -0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00
-log10(1-Vbe/VJ)


log10(Cbe-Cox)

MJ = 0.511

MJ is constant
C-V curve: standard parameter extraction

Junction capacitance:
C-V behaviour with standard parameter extraction

example: special test structure (100x100 µm²) measured with LCR meter

Results: CJ0 = 9.926 pF  VJ = 0.9166 V  MJ = 0.3599
RMS error = 0.1328%
Junction capacitance: linearized data

-11.35 -11.30 -11.25 -11.20 -11.15 -11.10 -11.05 -11.00 -10.95 -0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0.0

-log10(1-Vbias/VJ)  log10(Cj)  MJ

MJ is not constant!
questionable results: $CJ_0 = 13.497 \text{ pF}$  $V_J = 0.6765 \text{ V}$  $M_J = 0.2124$  $Cox = -3.528 \text{ pF}$  
$R$ coefficient = 1

although fit is excellent ($R=1!$) the resulting Cox is negative!

what is the reason??
Cj: C-V behaviour including Cox contribution

Junction capacitance:
C-V behaviour after Cox determination

RMS error = 0.00737%
Cj: linearized data including Cox

**Junction capacitance:**
linearized data after Cox determination

![Graph showing linearized data and MJ constant]

- **MJ = 0.212**
- **MJ is constant!**
Junction parameter extraction based on simulated data

Cj parameter extraction with simulated data:
  sweep VJ + optimize MJ

![Graph showing R coefficient and RMS error vs. VJ]

- to check optimizer reliability: sweep VJ + optimize only MJ
- find VJ with smallest error
Junction parameter extraction based on simulated data

Cj parameter extraction with simulated data: MJ + Cox results

input data: CJ0 = 19.44 fF  VJ = 0.824 V  MJ = 0.379  Cox = 15 fF

these data can be extracted exactly!
Junction parameter extraction based on real data

Cj parameter extraction with real data:
sweep VJ + optimize MJ

example is already mentioned BE capacitance
Junction parameter extraction based on real data

Cj parameter extraction with real data:
MJ + Cox results

- dashed lines show the results gained with the original Cox determination method as described before
- results from the two methods are not exactly identical