Base resistance modeling for advanced SiGe HBT process technologies

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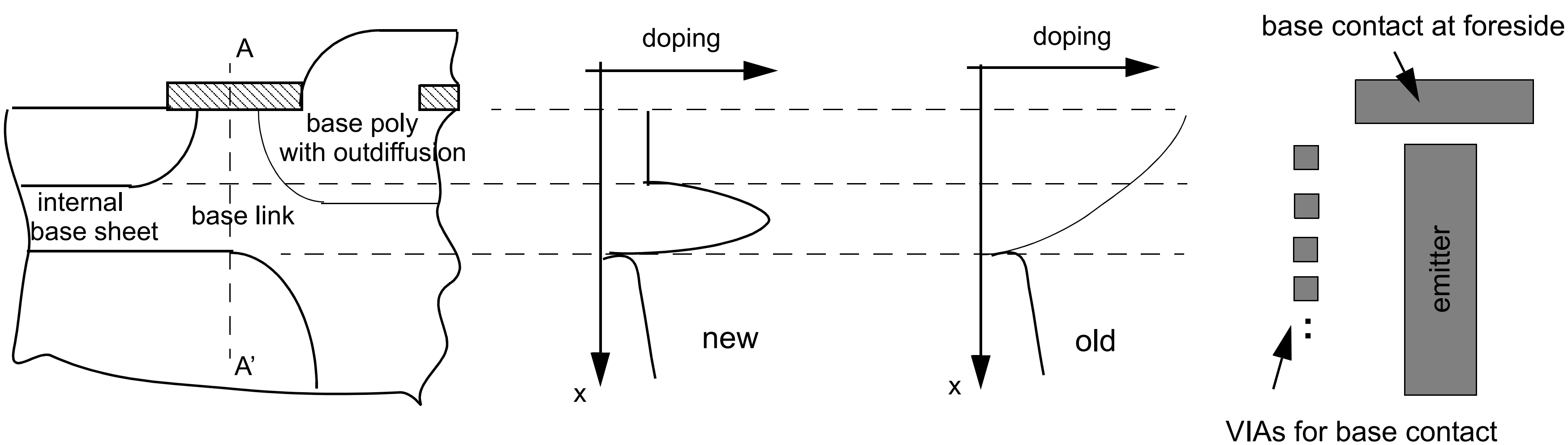
Outline

- Motivation
- Simulation principle
- Analytical equations
- Results
- Conclusion

Motivation

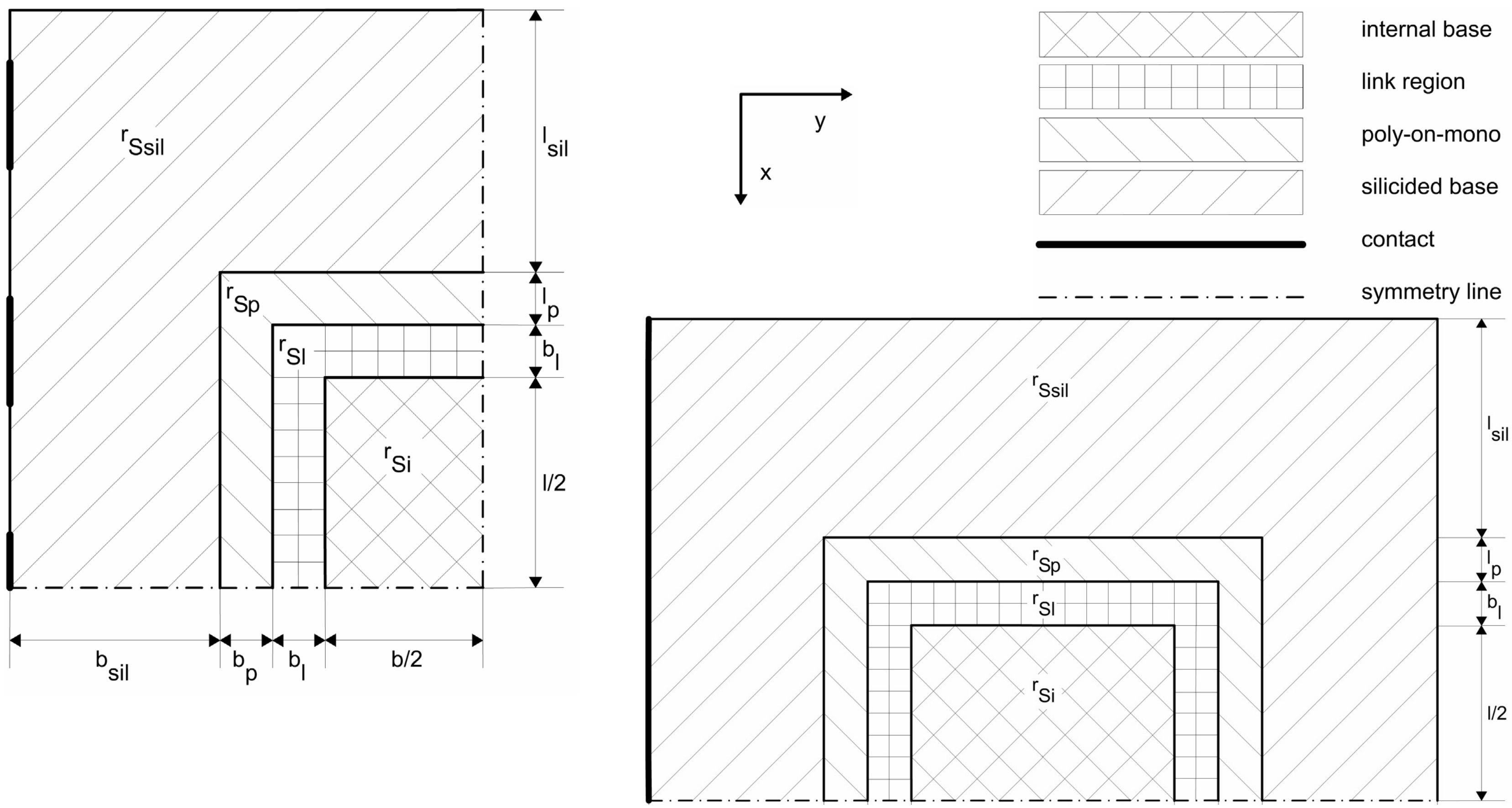
Verification of existing geometry equations with respect to advanced bipolar technology

- Change of the sheet resistance values of the components
- Investigation of the influence of the use of VIAs
- Foreside placement of the base contact to shrink device size



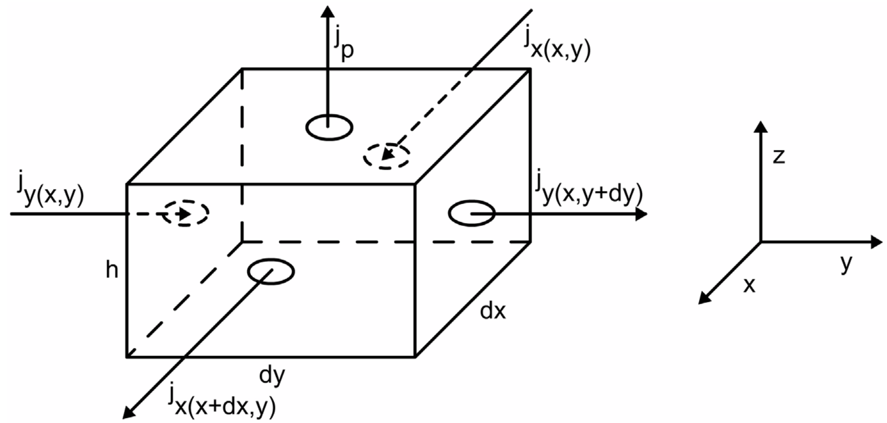
Simulation principle

External base resistance



- Simulation of a quasi-3D structure => 2D simulation of the top view of a transistor with different sheet resistance areas (represented by constant p-doping, depth, and resp. mobility)
- For determination of only the external base resistance an ideal contact at the base link has been placed

Internal base resistance



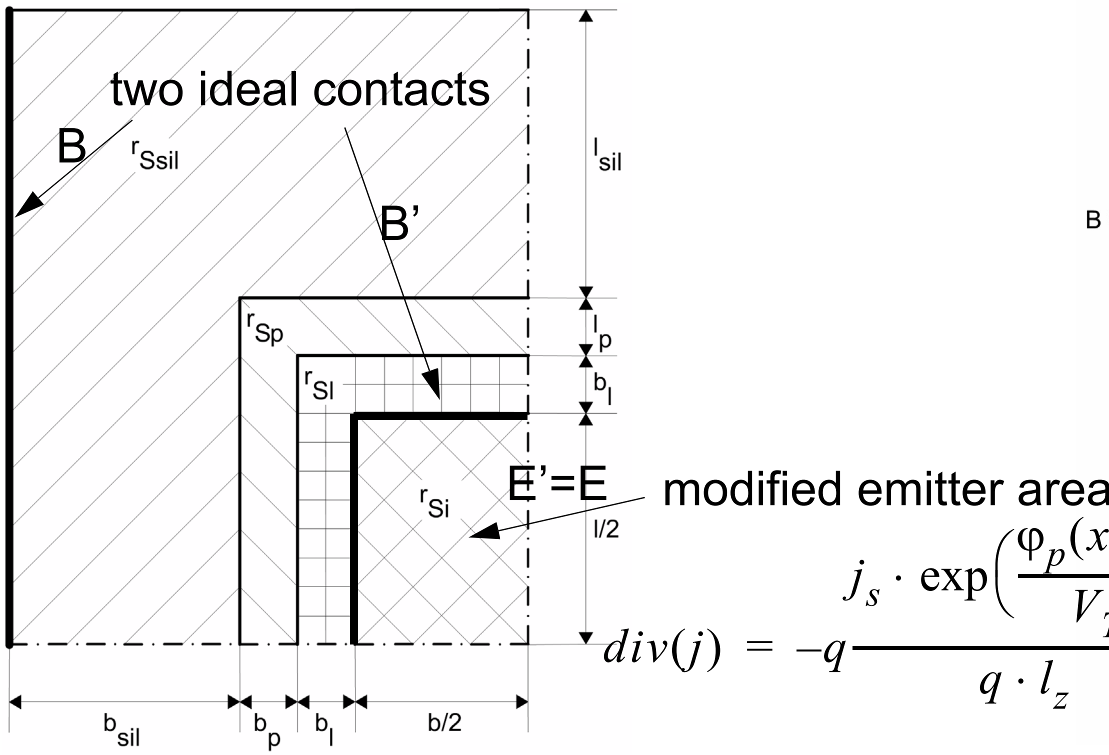
- Based on an infinitesimal element of the internal base, the hole current j_p into the emitter can be written as

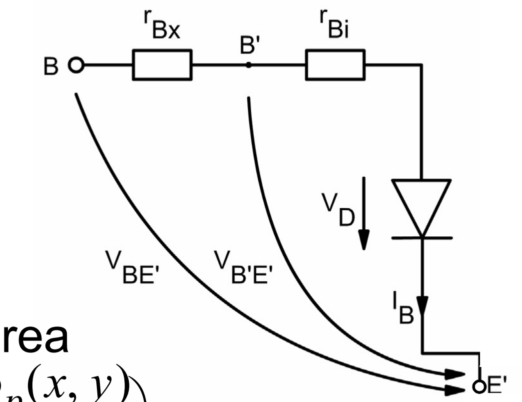
$$\frac{j_x(x,y)-j_x(x+dx,y)}{dx}+\frac{j_y(x,y)-j_y(x,y+dy)}{dy} = \frac{j_p(x,y)}{l_z} = -div(j)$$

- In the continuity equations the recombination term is substituted by the voltage dependent base current (here the quasi-fermipotential of the holes equals the BE voltage for the simulated element)

$$div(j) = -q\cdot R = -q\frac{j_p(x,y)}{q\cdot l_z} = -q\frac{j_s\cdot\exp\left(\frac{\varphi_p(x,y)}{V_T}\right)}{q\cdot l_z}$$

Interpretation of the simulations





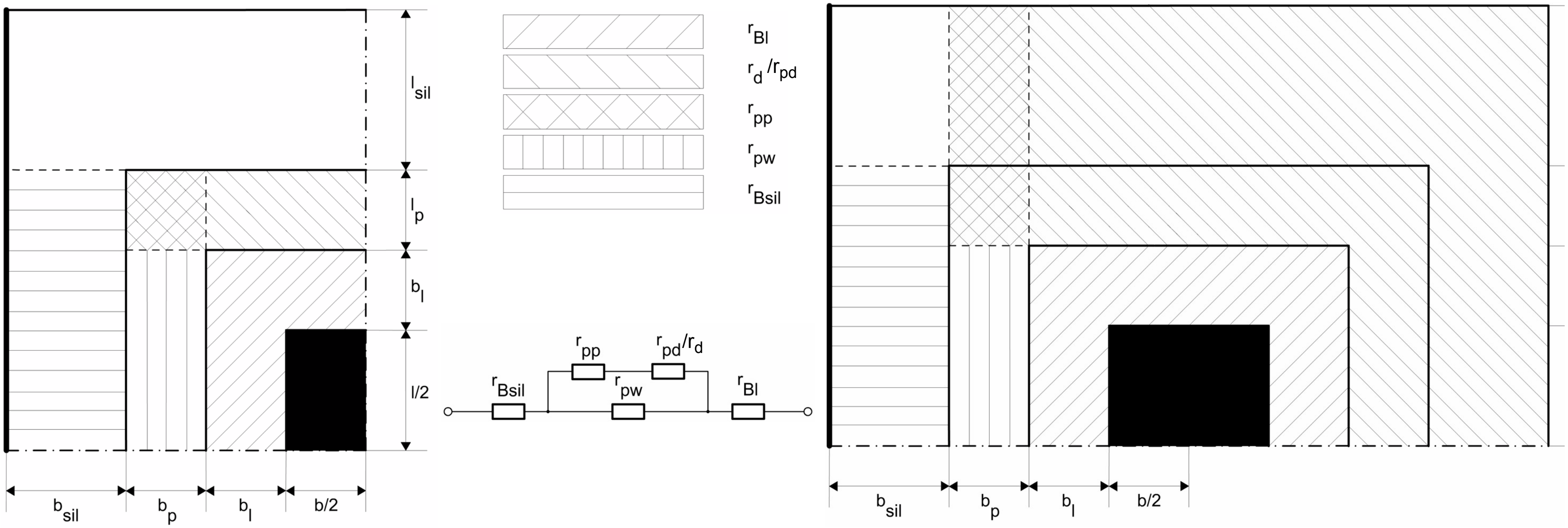
$$div(j) = -q\frac{j_s \cdot \exp\left(\frac{\varphi_p(x,y)}{V_T}\right)}{q \cdot l_z}$$

- Two ideal contacts => simulation of the external base resistance only => $r_{Bx}\left(\frac{b}{l}\right) = \frac{V_{BB'}}{I_B}$
- One ideal contact and modified emitter

  => complete resistance $r_B = r_{Bi} + r_{Bx} = \frac{V_{BE} - V_T \ln(I_B / I_{BS})}{I_B}$

Analytical equations

External base resistance r_{Bx}



- r_{Bsil}, r_{pp} and r_{pw} are calculated as "ideal" resistances $r_{xx} = r_{Sxx}\dfrac{b_{xx}}{l_{xx}}$
- r_{Bl} is calculated as resistance with an average length $l = 2(l + b + 2b_l)$
- r_{pd} / r_d are of distributed character, e.g. $r_{pd} = \dfrac{r_{Sp}}{4}\sqrt{\dfrac{\delta}{1-\delta}}\coth\dfrac{b/2 + b_l}{l_p\sqrt{\delta(1-\delta)}}$; δ=0.15

Internal base resistance r_{Bi}

$$r_{Bi} = r_{Bi0} \cdot \phi(\eta) = r_{Bi0} \frac{\ln(1+\eta)}{\eta}$$

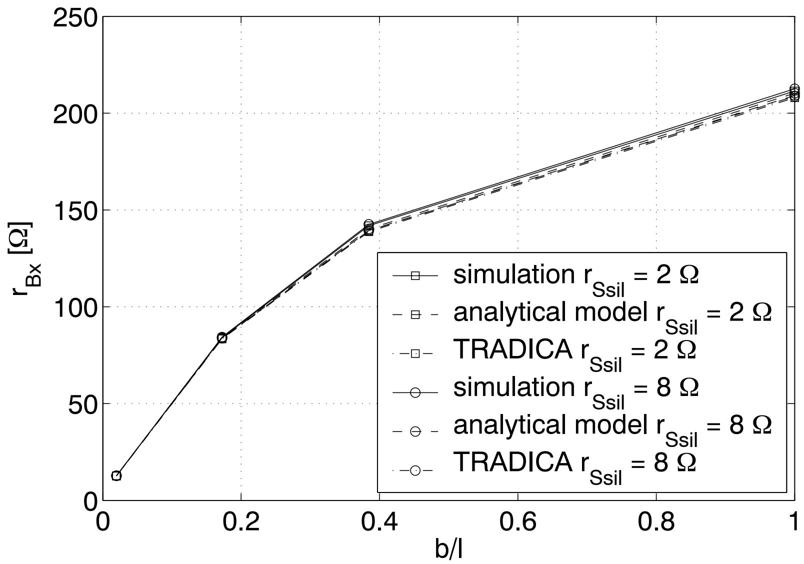
$$r_{Bi0} = \frac{r_{Si} b}{l} \cdot g_i(b/l) \quad \text{and} \quad \eta = \frac{r_{Si}}{g_\eta(b/l)} \cdot \frac{b}{l} \cdot \frac{I_B}{V_T}$$

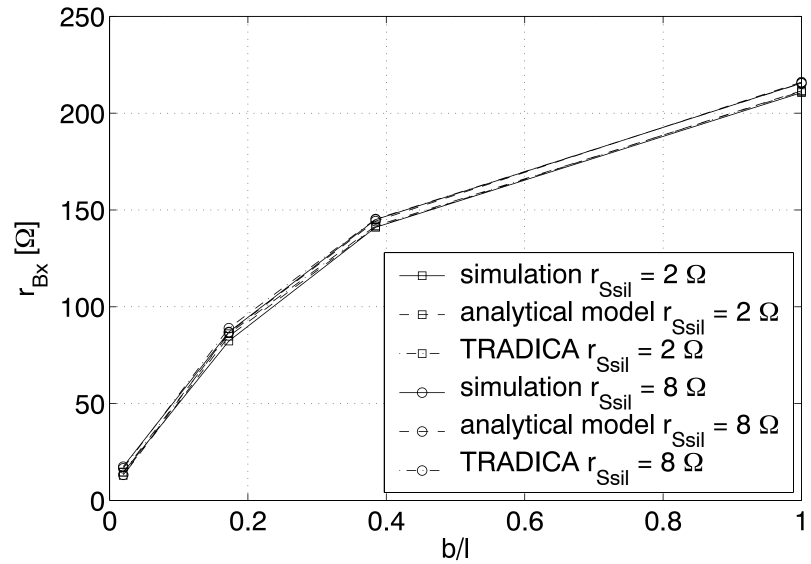
$$g_i = \frac{(1+3f_i)}{12} - \left(\frac{1}{12} - \frac{1}{28.6}\right)\frac{b}{l}(1-f_i) \quad \text{and} \quad g_\eta = \frac{18.3}{1+3f_i} - \left[12.2\frac{b}{l} - 19.6\left(\frac{b}{l}\right)^2\right](1-f_i)$$

with f_i as function of the ratio r_{Sp}/r_{Sl}

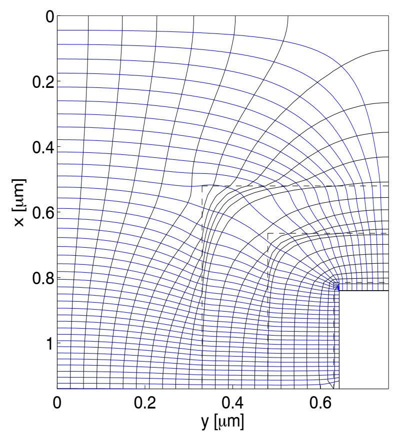
Results

External base resistance r_{Bx} only, double/single continuous base contact

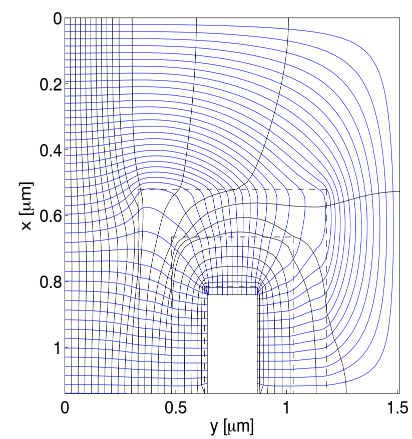




double base contact (DBC)

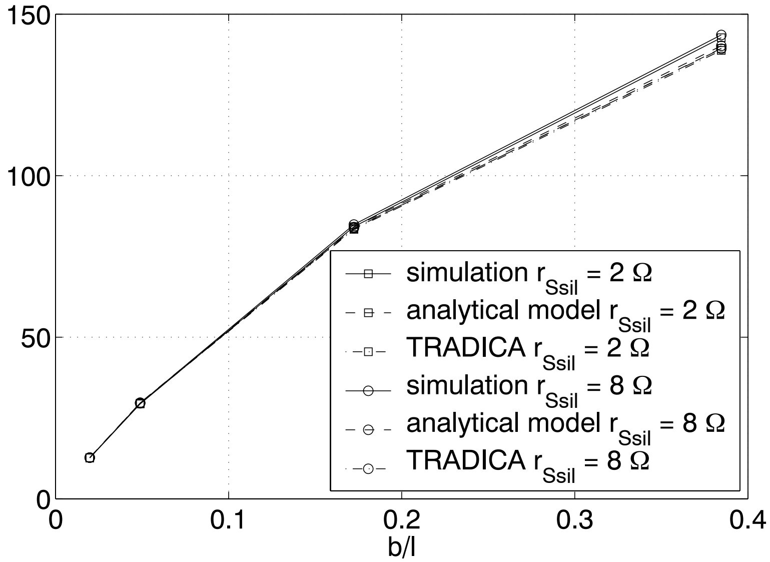


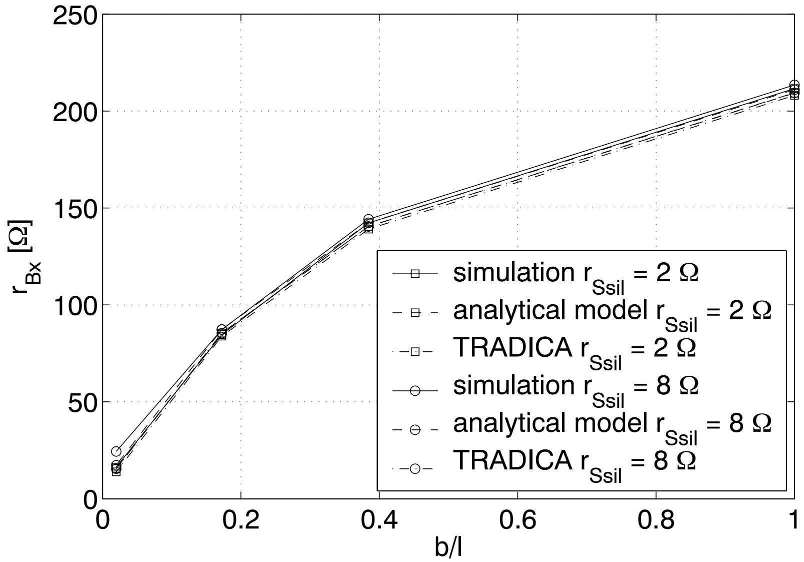
single base contact (SBC)

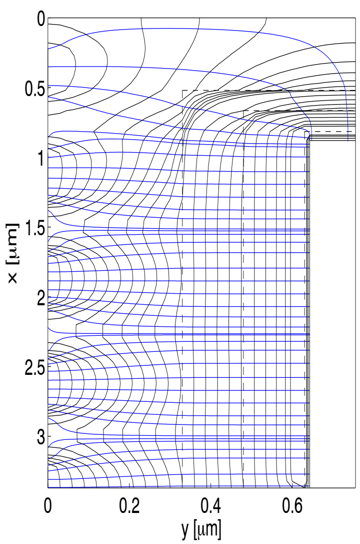


- The results show very good agreement for different silicide sheet resistances (error<2.5%)

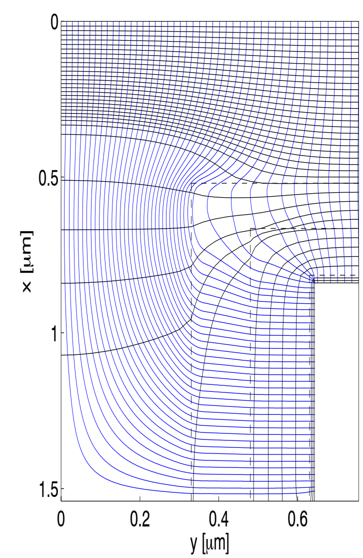
External base resistance r_{Bx} only, double base contact, VIA and foreside





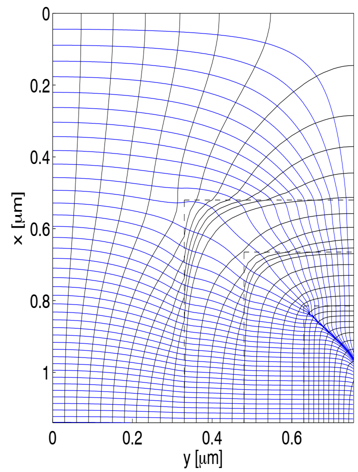


- very good agreement for chosen placing of VIAs due to very low sheet resistance of the siliceded region (2/8Ω)
  => method could be used for determination of critical placement of VIAs
- placement of the base contact at the foreside and using the analytical equations with interchanged b and l gives good results up to b/l>0.18 (investigated device with $0.25 \times 1.45 \mu m^2$)
- influence of shrinking the silicided base on the results of the foreside contact has to be investigated

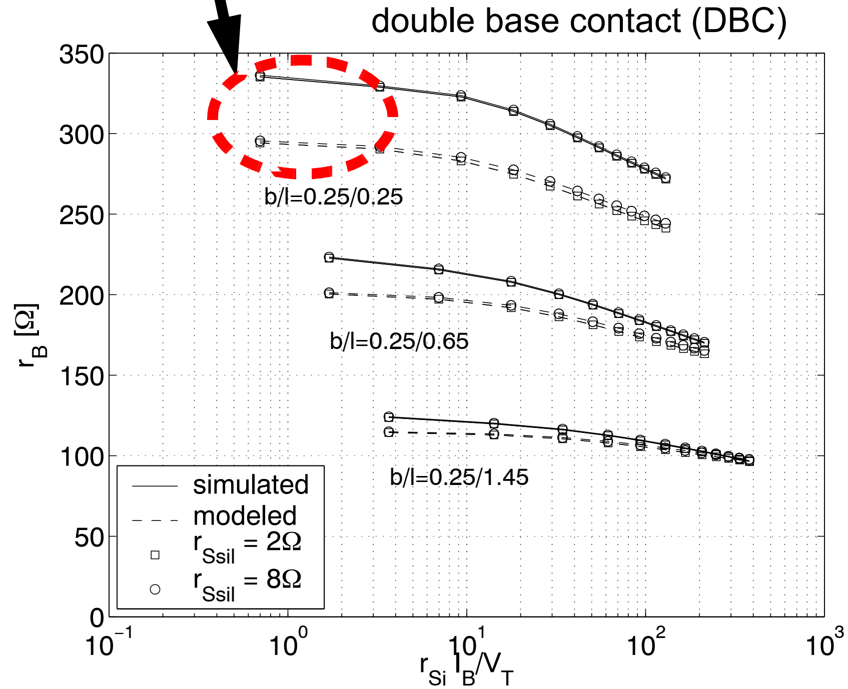


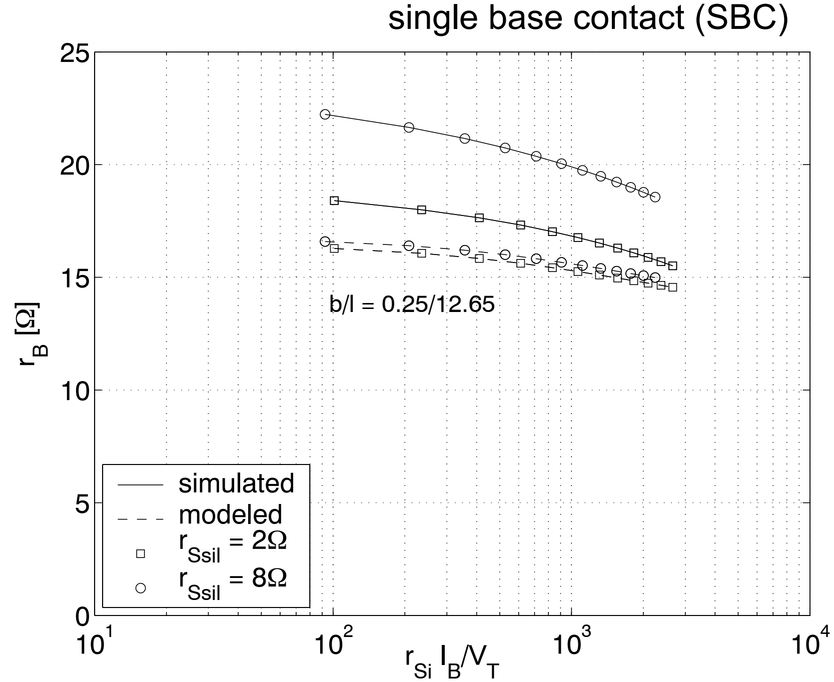
Complete base resistance r_B

- b=l gives significant deviations with respect to analytical equations
- SBC, VIA and foreside contact show in principle the same behavior



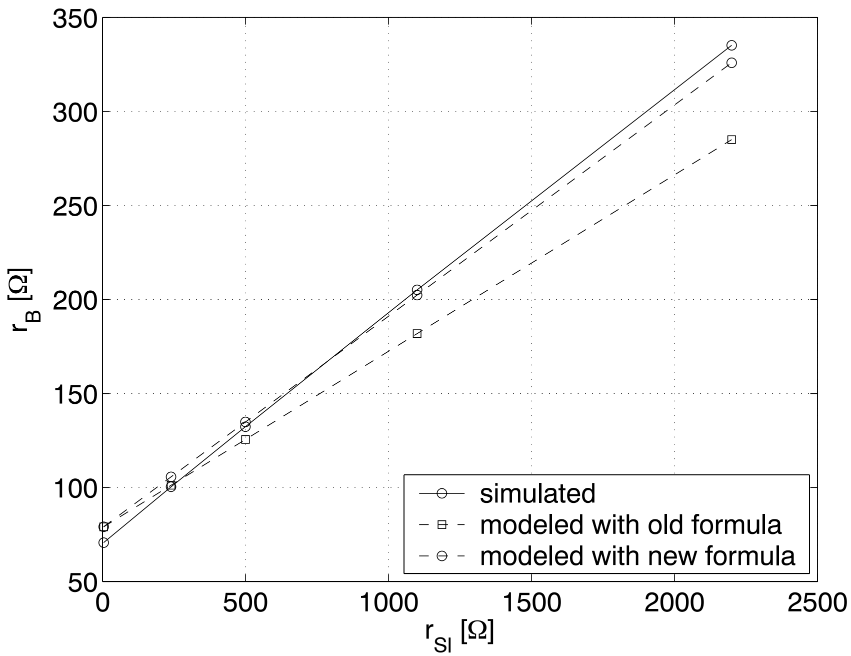
- analytical equations do not predict the behavior for higher ohmic siliceded region and large aspect ratio b/l (8Ω) very well => largest influence on SBC and foreside base contact



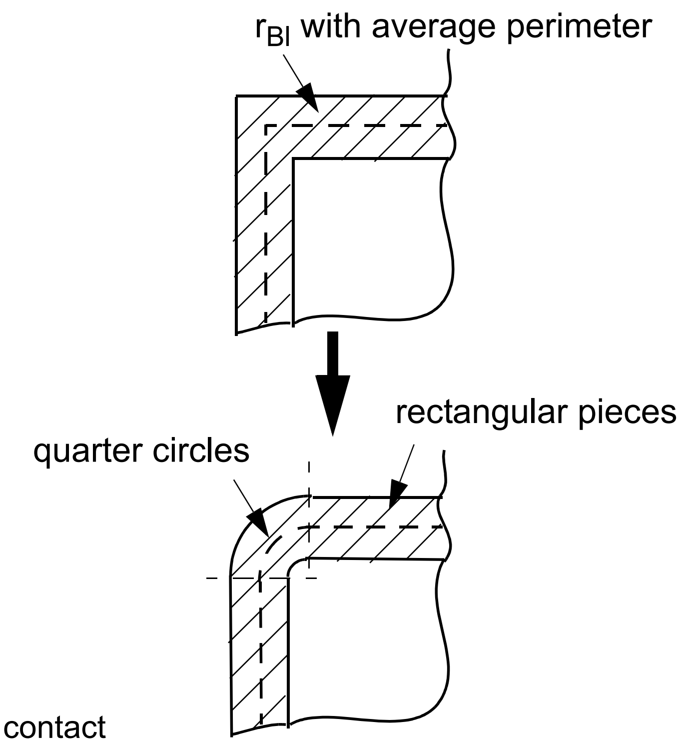


Modification of analytical equation

- The much higher link resistance r_{Sl}(=r_{Si}) has been determined as reason for the deviations of the analytical equations as well as the base resistance component with largest influence
  => calculation with the average perimeter has been replaced by a set of rectangular resistance components and quarter circles at the edges



for square emitter, double base contact



- The new formulation gives much better agreement, especially for large base link sheet resistances

Conclusion

- The original analytical equations are applicable for advanced bipolar processes with some limitations => modification allows the use even for b=l

- For proper placement of VIAs the analytical equations work very well

- For placement of the base contact at the foreside the analytical equations can be used, but the critical aspect ratio b/l has to be determined
  => for this investigation 0.18

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