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Accurate Extraction of Maximum Current Densities from the Layout

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SUMMARY

A module for efficient extraction of maximum current densities from the layout has been developed and implemented within the CAD package PARIS. A parameterized model for corner-rounding dependence on technology parameters, such as numerical apperture (NA) and acid/base diffusion, was developed. A combination of classical and meshless FEM was used to obtain accurate results taking realistic shapes of the corners into account.

PIN CURRENT CALCULATION AND EXTRACTION OF NET LEYOUTS

Electromigration as well as yield and performance loss of chips are among others caused by high current-density stress in the metallization levels. Simulation of the current density distribution within all stressed metal patterns and/or vias is important for the assessment of the reliability. Our approach for the calculation of the current density distribution is based on three main steps. The first step provides the pin current values inside the chip using a standard net list circuit simulator. The simulation stimuli include the entire range of possible input values and worst case conditions. The second step provides the layout geometry of complete nets combined with the calculated pin current values, which are determined via circuit simulation. Third, the current density distribution is calculated for critical parts of the layout by solving the electrical field equation using the finite element method. Input data are the relevant technology parameters, like wire thickness, resistivity, and pin current values combined with the extracted net layout graphs.

COMPUTATION OF REALISTIC CORNER ROUNDING

The necessary profile geometry is obtained from the IISB lithography simulation software Dr.LiTHO. A sample profile is shown in Fig. 1. The corner is approximated by a circular arc with best fitting radius. NA of the lithographic projector lens and the acid/base diffusion lengths of the resist were varied to get the radii for different process conditions. The calculated radii can then be stored in a database. Thus the simulations have to be done only once for each set of process parameters and layout pattern.

SOLUTION OF FIELD EQUATIONS

A combination of classical FEM with meshless methods, namely Element-Free Galerkin (EFG) [1] has been used to obtain accurate results in the corners of the layout. For the application addressed in this work a mesh-refinement of up to 3-4 orders of magnitude was necessary while maintaining relatively coarse meshes in the non-critical region. A quadtree strategy was used for mesh/point-set generation in order to achieve appropriate refinement in the corners. Heuristics were used for local error estimates. The geometry of a ground connection with local refinement (at critical corners only) is shown in Fig. 2 and 3.

CONCLUSION

For accurate values of the current density, the actual corner rounding effects have to be considered instead of idealized sharp corners. Otherwise errors can be in the order of 100% (Fig. 4). The problem of high peak field strengths will aggravate as advanced lithography techniques will allow further reduction of curve radii in the future.

REFERENCES

[1] T. Belytschko, Y. Y. Lu, and L. Gu, *Element-Free Galerkin Methods*, International Journal for Numerical Methods in Engineering, vol. 37, 1994, pp. 229-256

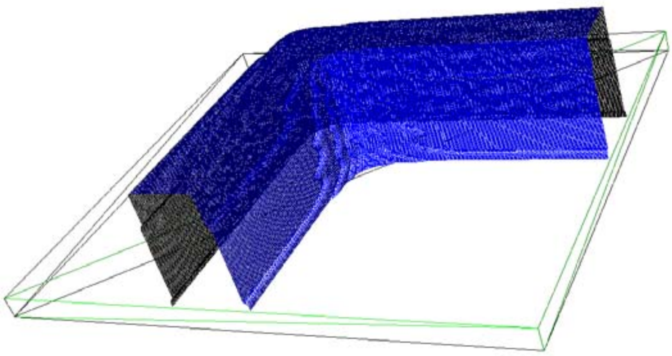

Fig. 1. Simulated resist profile with a linewidth of 120 nm used for determining the curvature radius. The process was simulated with a NA of 0.8 and an acid and base diffusion length of 20 nm and 80 nm, respectively.

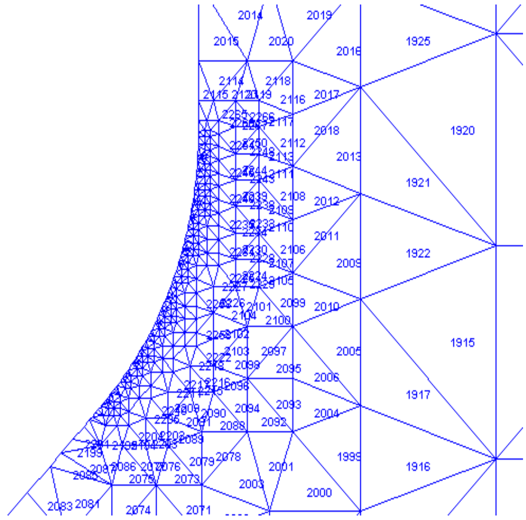

Fig. 3. Zoom from Fig. 2 of the local refinement at a critical corner.

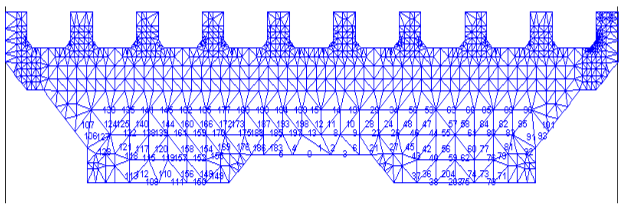

Fig. 2. Entire structure of the ground connection with different refinement levels. A zoom of the local refinement at a critical corner is shown in Fig. 3.

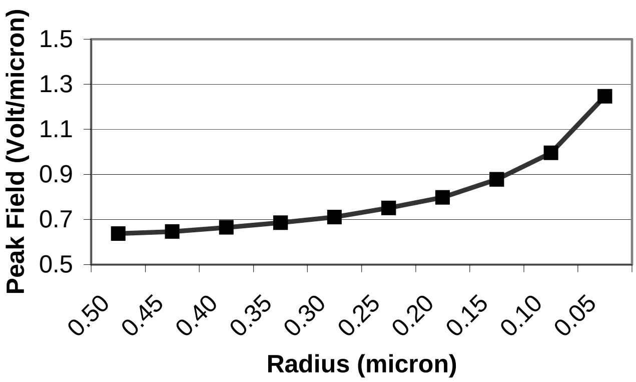

Fig. 4. Dependency of computed peak field-strength on radius of curvature of a critical corner for a given structure.