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SIMULATION OF FERROELECTRIC MATERIALS WITH MINIMOS-NT. Klaus Dragosits, Siegfried Selberherr, Institute for Microelectronics, TU Vienna, AUSTRIA.

During recent years a special type of nonvolatile memory cells became more and more attractive, which takes advantage of the hysteresis properties of ferroelectric materials. To allow rigorous analysis of these devices several models were entered into our simulator MINIMOS-NT, which allow a general transient two-dimensional simulation of arbitrary device structures. MINIMOS-NT provides a rigorous approach to describe the static hysteresis properties of ferroelectric materials including the accurate modeling of subcycles according to Preisach hysteresis<sup>1</sup>. By now two different shape functions are implemented for the locus curves, based on  $\tanh$  and  $\arctan$ , respectively. Increasing clock frequencies lead into a regime where the frequency dependence of basic material parameters like coercive voltage and remanent polarization can no longer be neglected. Simulation in the frequency regime would be numerically cheap, but leads to reduced capabilities in comparison with the time regime. Especially in the context of arbitrarily shaped signals and relaxation effects the rigorous approach of our simulator MINIMOS-NT is mandatory. By introducing three transient terms into the basic material equation, simulation of ferroelectric capacitors in a wide range of frequencies is now possible. This enables the calculation of Q/V characteristics, the extraction of frequency dependent material parameters like e.g. the coercive voltage and the analysis of the signal response in the time regime. Simulation results for a capacitor show good agreement to measurements in a range beginning from 1Hz up to 1MHz. The application of the new simulation tool to circuit simulation is very promising. It can immediately be used for the extraction of specifications for the read and write cycles or the geometry of ferroelectric memory cells.

### References

<sup>1</sup>F.Preisach, "ber die magnetische Nachwirkung," *Zeitschrift für Physik*, vol. 94, pp. 277-302, 1935.

<sup>2</sup>K. Dragosits, M. Knaipp, and S. Selberherr, "Two-Dimensional Simulation of Ferroelectric Nonvolatile Memory Cells," in *Simulation of Semiconductor Processes and Devices* (K. D. Meyer and S. Biesemans, eds.), pp. 368-371, Leuven, Belgium: Springer, Sept. 1998.