Session O: Circuit and Device

Wednesday, 15th March 2000 *08.00h-08.15h* *Berlin Saal 1*

Two-Dimensional Modeling of Ferroelectric Materials

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Recent development of ferroelectric devices has lead to two-dimensional and compound device designs. Even devices considered to be simple like a finger structure with a common ground plate lead to effects such as e.g. crosstalk which cannot be handled by a one-dimensional model, but are of fundamental interest. The basic goal of our approach is to set up a tool which is able to reproduce the macroscopic behavior of the device by calculating current, voltage and charge at the contacts correctly. Simulation of domains and impurities is far from trivial and needs device data like the impurity distribution, which is usually not available and furthermore specific for a singular device. According to this, the resulting domain structure differs even for devices with identical geometry and identical contact quantities. For our approach we set up the ferroelectric material as a homogeneous cluster of identical dipoles, each of them showing the macroscopic hysteresis properties. This results in a model which allows the two-dimensional analysis of ferroelectric materials, by introducing hysteresis to the polarization and solving the Poisson equation. In order to allow simulation of rotational effects the one-dimensional Preisach hysteresis model had to be generalized. The remanent polarization components in non field directions are taken into account, respecting the fact that there is an upper limit to the number of dipoles as well. The generic implementation into our device simulator MINIMOS-NT can handle both isotropic and anisotropic materials respectively. Additionally, we introduced three transient terms with physical meaning into the basic material equation making the simulation of ferroelectric capacitors in a wide range of frequencies possible. The application of the new simulation tool to circuit simulation is most promising. It can immediately be used for the extraction of specifications for the read and write cycles or the geometry of ferroelectric memory cells.