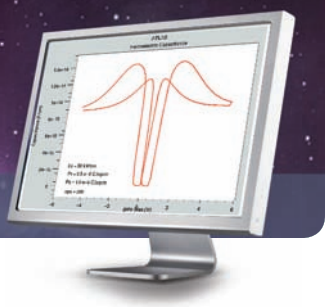
Ferro

Ferroelectric Field Dependent Permittivity Model

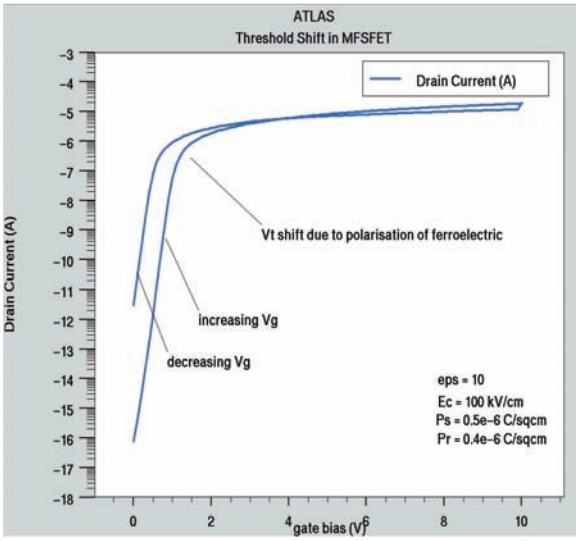


Ferro has been developed to combine the charge-sheet model of FET with Maxwell's first equation which describes the properties of the ferroelectric film. The model can accurately predict the static I-V behavior of these devices as well as the dynamic response in transient and small signal modes.

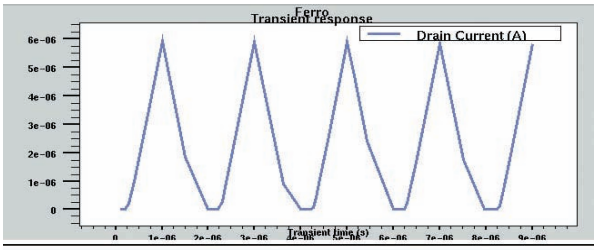
Ferro has been implemented as an optional module to both S-Pisces and Blaze device simulators. This seamless integration provides the user with all the capabilities of S-Pisces or Blaze resulting in a generalized application to different technologies.

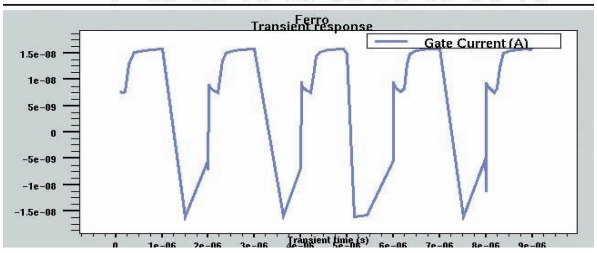
Simulation of the MFSFET Device

The Metal-Ferroelectric-Semiconductor FET (MFSFET) device is structurally similar to a regular MOSFET device except that the gate material is composed of a ferroelectric material (PZT) normally sandwiched between two layers of silicon dioxide. Ferro models the PZT material with a set of four material parameters; the saturation polarization Ps, the remanent polarization Pr, the coercive field Ec and the linear dielectric constant epsf.

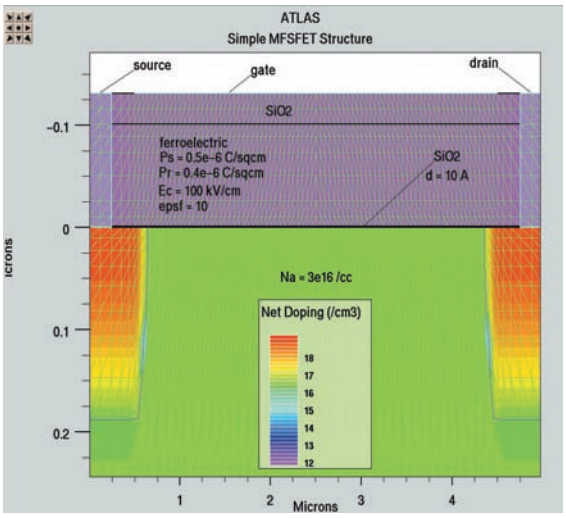


Ferro simulated a gate voltage sweep in both the positive and negative directions. The Ferro model accounts for the ferroelectric polarization hysteresis phenomena which results in a shift on the observed threshold voltage depending upon the sweep direction.

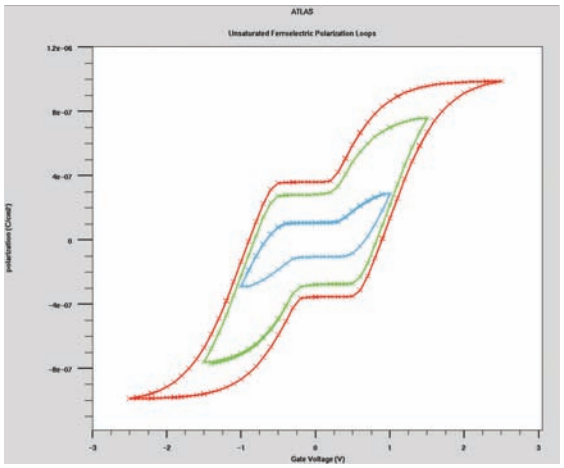




Nonlinearities in the transient response of the MFSFET to a 1 MHz 4 volt sawtooth on the gate are shown.



A standard MFSFET structure which could be used as single transistor memory cell. The gate stack is comprised of SiO2 and PZT ferroelectric materials.



Simulated unsaturated ferroelectric polarization curves for different drain bias values.

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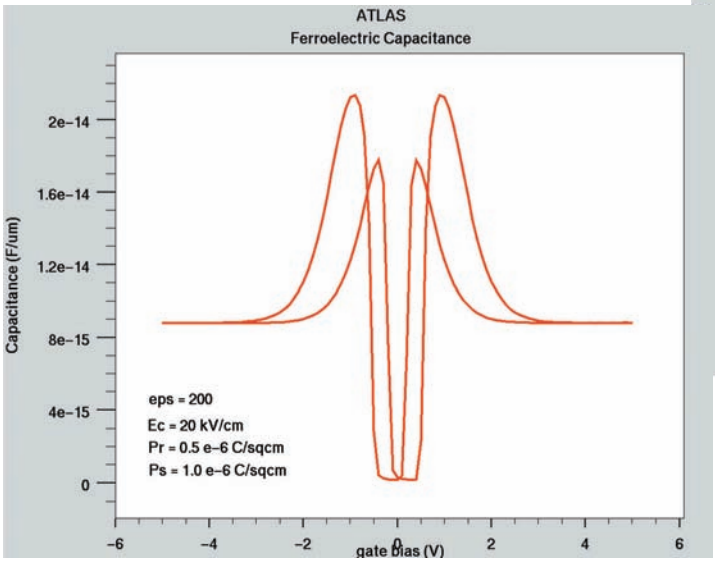
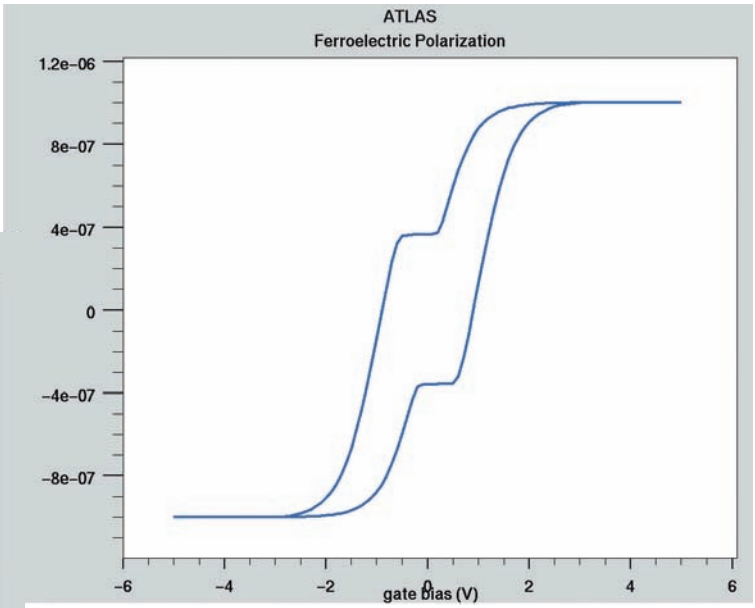
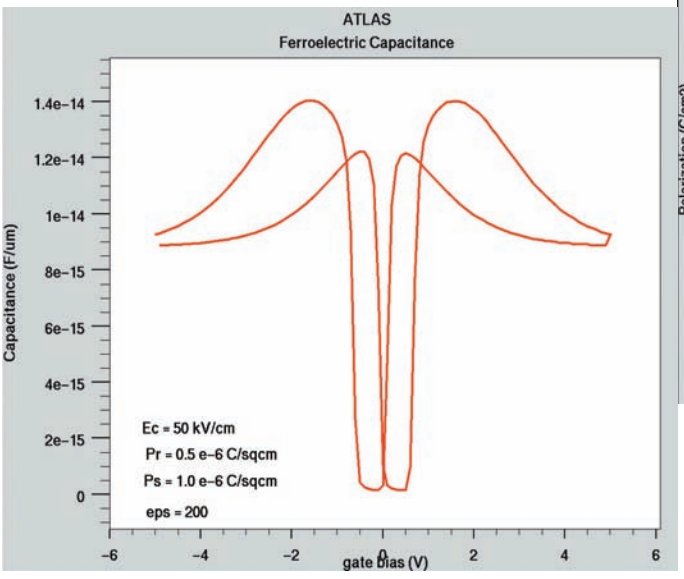
Simulation of Hysteresis

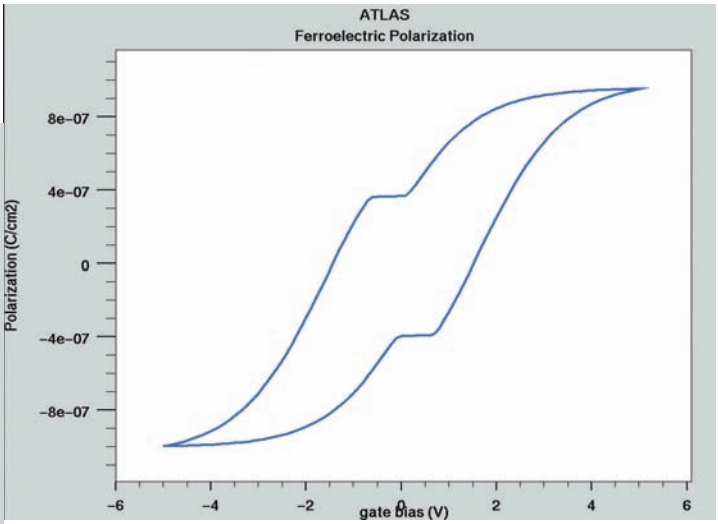
The shape of the ferroelectric polarization curve is determined by the material parameter set (Ps, Pr, Ec and eps). To illustrate this we have simulated the MFSFET device with two parameter sets. The simulation was done in the small signal ac domain so that the C-V characteristics and polarization curves could both be shown.





These two figures show the polarization curve and resultant small signal C-V results for the parameter set (1e-6 C/cm^2, 0.5e-6 C/cm^2, 20 kV/cm, 200). The gate bias was swept in both the positive and negative directions.





The Ferro parameter set was then changed to (1e-6 C/cm^2, 0.5e-6 C/cm^2, 50 kV/cm, 200) which has a higher coercive field. This higher coercive field results in a broadening of the ferroelectric polarization curve as shown in the polarization curve above. The resultant ferroelectric capacitance is shown beside it where we see lower values of capacitance and a broadened C-V characteristic.

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