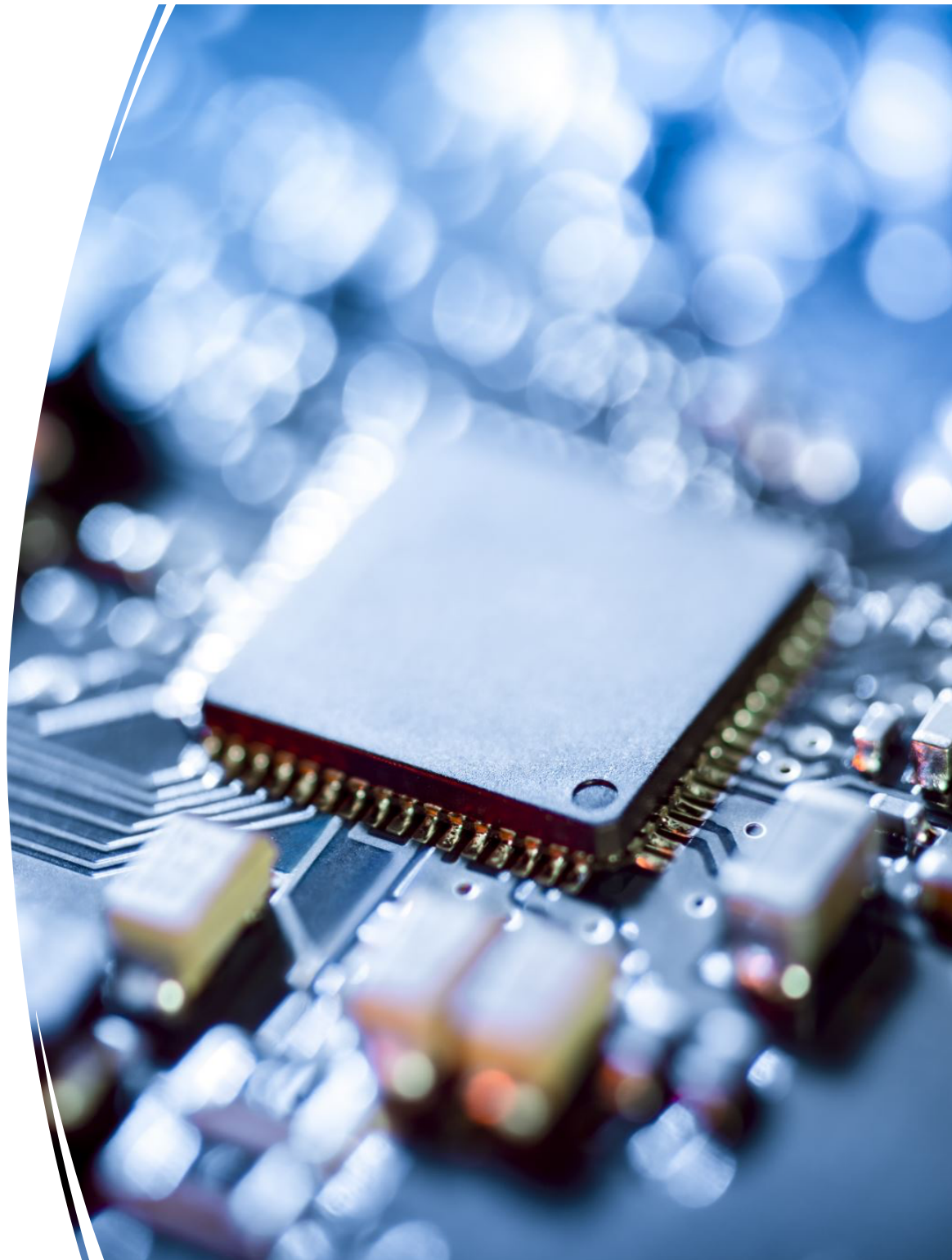# Semiconductor Device Modeling and Simulation

L4.05 Silvaco Atlas – Hydrodynamic and Energy Balance Models Syntax

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Energy Balance and Hydrodynamic Models

- The conventional drift-diffusion model of charge transport neglects non-local transport effects such as:
    - Velocity overshoot,
    - Diffusion associated with the carrier temperature, and
    - The dependence of impact ionization rates on carrier energy distributions.

- Energy balance (Stratton) and hydrodynamic models can be used within Atlas to account for these effects.

- The Energy Balance Transport Model adds continuity equations for the carrier temperatures and treats mobilities and impact ionization coefficients as functions of the carrier temperatures rather than functions of the local electric field.

Invoking Hot Carrier Model

- The **MATERIAL** statement is used to assign the energy relaxation times **(taurel.el, taumob.el, …)**

- The **MODELS** statement is used to select the physical models used **(hcte)**

HCTE.EL specifies that *electron temperature* will be solved.

HCTE.HO specifies that *hole temperature* will be solved.

KSN specifies which hot carrier transport model will be used for electrons. KSN=0 selects the hydrodynamic model and KSN=-1 selects the energy balance model.

KSP specifies which hot carrier transport model will be used for holes. KSP=0 selects the hydrodynamic model and KSP=-1 selects the energy balance model.

Relaxation Times

- The relaxation times are extremely important as they determine the time constant for the rate of energy exchange and therefore precise values are required if the model is to be accurate.

- **TAUREL.EL** and **TAUREL.HO** are the electron and hole energy relaxation times. The relaxation parameters are user-definable on the MATERIAL statement.

  - Monte Carlo analysis is the favored method through which values can be extracted for the relaxation times.

- The energy relaxation time can be modeled as a variable quantity. Atlas provides two ways of doing this:

  - Built-in model in which the energy relaxation time is a function of carrier temperature only.

  - Advanced built-in model in which the energy relaxation time is a function of both carrier and lattice temperatures.

Energy Dependent Mobilities

- The Energy Balance Transport Model requires the carrier mobility to be related to the carrier energy.

  - This is achieved through the homogeneous steady state energy balance relationship that pertains in the saturated velocity limit.

  - It allows an effective electric field to be calculated for a homogeneous sample, using:

$$q\mu_n(E_{eff,n})E_{eff,n}^2 = \frac{3}{2}\frac{k(T_n - T_L)}{\texttt{TAUMOB.EL}}$$

$$q\mu_p(E_{eff,p})E_{eff,p}^2 = \frac{3}{2}\frac{k(T_p - T_L)}{\texttt{TAUMOB.HO}}$$

  - For electron mobility, the parameter is **F.ENMUN**, which can be set in either the **MATERIAL** or **MOBILITY** statement. The corresponding parameter for hole mobility is **F.ENMUP**, which can be set in either the **MATERIAL** or **MOBILITY** statement.