Chapter 1

Introduction

In 1947, Bardeen, Brattain, and Shockly invent the first semiconductor transistor, a germanium transistor. Afterward, many kinds of semiconductor devices such as the integrated circuit (IC), the light-emitting diode (LED) and the solar cell have been invented. It goes without saying that the development of the ICs benefits a lot of industries. Therefore the ICs have been drastically developed over the past few decades. Nowadays the ICs consist of more than millions tiny transistors, most of which are metal-oxide semiconductor field effect transistors (MOSFET). MOSFETs are very important since each of them plays a role of a switch which represent a bit with the state "0" as current flow or the state "1" as no current flow.

For a successful design of the MOSFET, engineers are mainly concerned with the electron current, generated by the applied voltage, through the devices. Several mathematical models have been proposed to numerically simulate the current. These models, such as a hydrodynamic, an energy-transport and a drift-diffusion models, are often used for the device simulation with the suitable choice, depending on the purpose of the device usage. In fact, the hydrodynamic and the energy-transport models are especially important in analyzing the temperature change to study the hot carrier problem. The hydrodynamic model is more accurate in a physical point of view, and makes more detailed simulations possible than the energy-transport model. However, the hydrodynamic model contains hyperbolic equations, which may cause discontinuity of a solution. On the other hand, the energy-transport model consists of parabolic and elliptic equations only, which is easier to analyze numerically and theoretically. For example, engineers usually use the energy-transport model although they lose some accuracy. Furthermore, in cases in which the change of temperature is not significant, they may use the drift-diffusion model instead because it is obtained from the energy-transport model for the constant temperature. Hence, it is important not only in engineering but also in mathematics to study a model hierarchy, relations among these models, and to prove the validity of the use of simpler models rigorously.