engineering and to speed up process optimisation. In this chapter we will report on those simulation tools, various thermal models and examples of numerical simulations of silicon crystallisation processes.

6.6.1 Simulation Tools

Numerical simulation tools can be distinguished in universal and special-purpose programs. Examples of commercial universal-purpose programs are ABAQUS [72], ANSYS [73] and MARC [74] with a wide range of applications in structural analysis, thermal and fluid-flow simulations or electromagnetic field simulations. The number of special-purpose programs cannot be estimated seriously. Many universities and companies are working with specially developed software tools to obtain solutions of their specific problems. Recently, the large commercial programs both compromise and enable the user to add their specific subroutines to a program run.

The main structure of most of the simulation tools is similar: A pre-processing is designed to define the initial and boundary conditions of a simulation run and includes the generation of the simulation domain (finite element mesh) as well as a set of physical data that describes the material properties. The main-processing is normally not interactive and contains the solver of the mathematical formulations. The post-processing visualises the simulation results.

The demand for simulation tools depends on the complexity of the physical problem or on the technical process that the user wants to simulate. In general, the description of all physical relationships is reachable only in relatively simple and well-known problems. The full description of an industrial production facility by numerical simulations is not possible today, and neither is it reachable in the near future because too many details are too complex to be described by the numerical models. Therefore, the development of useful simplifications is one of the important keys to a successful simulation. This demand requires an integrated teamwork between the user of a simulation tool and the operators at the production facility and other process specialists.

Not the another important requirement is the validation of simulation results by experimental data. At least two experiments are necessary to validate simulation results concerning the process behaviour of a production facility. This means that the simulation model should be validated by measurements during a standard process and in a worst-case scenario to ensure the correctness of the results in an enlarged area of validity. Normally, these experiments are expensive and difficult to realise during a running production, but otherwise, running a non-optimised production would be quite more expensive. Anyhow, the validation of simulation results is necessary to ensure the success of the simulation method.

6.6.2 Thermal Modelling of Silicon Crystallisation Techniques

The wafer material for crystalline silicon solar cells can be divided into those from ribbon and bulk crystals. For most of wafer production processes, numerical simulations are in use to describe the thermal conditions during the crystallisation. In the case of ribbon crystals, only the EFG [75, 76] and the STR process [77] have reached a market