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Electronics Process Technology

Production Modelling, Simulation and Optimisation

Springer

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Translated by Anthony Rudd

With 281 Figures

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Preface

Process Technology Scientific Discipline

Manufacturing of electronic products places ever-increasing demands on technological procedures and processes.

The increasing range of products, coupled with the reduction of the production interval, has led to the creation of flexible manufacturing processes. Furthermore, quality assurance assumes an ever-increasing importance in production, in particular, also because the functional scope of electronic products is increasing permanently. The integration level of electronic components will also further increase in the future, and finally, in the meantime, the miniaturisation of the components and modules has made the transition from the precision technology to microtechnology and, in a few years, to nanotechnology.

All these developments affect manufacturing and cause the manufacturing process itself to become a complex and often also fault-susceptible system that normally can only be maintained stable using process control. Consequently, for new products that have not yet achieved a fully perfected technology, the so-called process window proved to be very small, and, in many cases, the technological know-how has a high strategic significance for a company with regard to process mastering.

With regard to this development, the new discipline of electronics process technology was established in recent decades in research and education. In the meantime, many individual questionnaires and tasks can be combined to form a unit. Similarly, the range of methods for successful solutions has led to a theoretical basis that makes it desirable to present it in a closed form, especially since practical results have proved the usefulness of these methods and this discipline. Although this book pays particular attention to the specific characteristics of electronics manufacturing, transfer to other disciplines is possible.

A special characteristic of electronics manufacturing is the large number of inspection processes and test steps needed to determine faults in products immediately after their occurrence. This raises the question: should the faults be detected and corrected “immediately” after their occurrence or the faulty products separated out as reject, or should this decision be made “later”, namely after one or more additional technological steps. This is a typical problem from electronics manufacturing. Figure 0.1 shows symbolically an SMT manufacturing line for the assembly of electronic modules with an inspection process and a repair process immediately after the solder paste printing.

A further problem situation concerns system theory. System theory has been used in electrotechnology for around 80 years. Operational calculus through to the so-called “symbolic methods” have proved themselves to be powerful tools for the calculation of electrical networks and circuits. It is now possible to show that the same methods can generally also be used for the analysis of manufacturing processes, where this produces a very interesting connection to reliability theory.

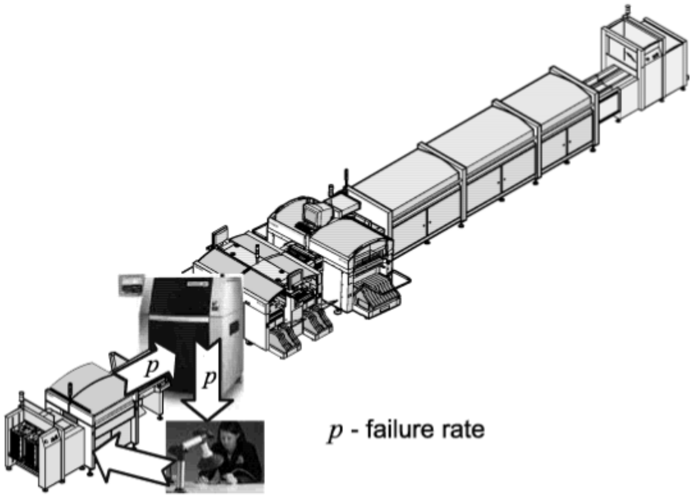

Figure 0.1. Typical SMT assembly line with included inspection process

Structure analysis, the separation of systems into their elements, flow graph theory and operational calculus give process technology new procedures that can be used for analysis and synthesis. If must also be mentioned that most of the models not only require probability theory and the methods of mathematical statistics, but also can only be interpreted on the basis of the mathematical term of the random quantity and the resulting mathematical methods.

Contents of this Book

The first chapter discusses the modelling of manufacturing processes. Based on the system term and the definition of the process technology parameters, the process characteristic and the test characteristic are presented as generalised descriptions of the technological processes, with operational calculus methods developed as a basis for a theory of product-flow graphs. Some examples show how the presented methods can be used not only for the modelling of manufacturing processes but also for quantitative analysis and synthesis.

The second chapter prepares special methods of graphical theory for the electronics process technology, and presents examples that show their capabilities and limits. The transition from product design to the quantity balance of the manufacturing process and to its structure produces an interlacing graph. The simplest network planning model, CPM, the critical-path method, is described and this augmented and extended with flow graph theory. Similarly to the theory of the signal flow graphs, product-flow graphs developed in this way provide a tool that can be used to represent and compute manufacturing structures in closed form. Figure 0.2 outlines the product flow graph for the SMT manufacturing line shown before. Queue models and Petri nets complete this chapter.

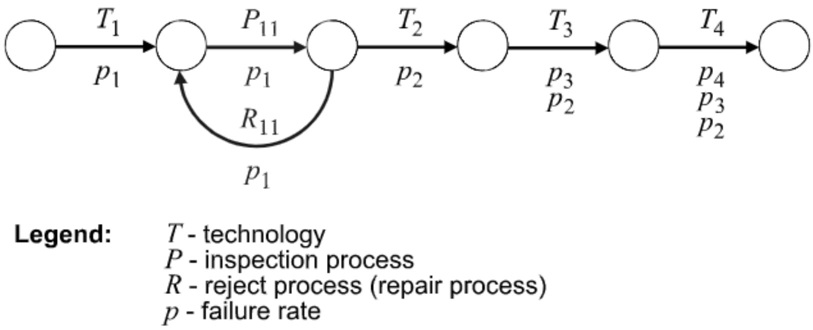

Figure 0.2. Product flow graph of the SMT assembly line

A chapter for the simulation of manufacturing processes follows. Simulation is often the only method that produces a solution when analytical solution procedures either do not exist or do not produce a result in an acceptable time. In recent years, simulation has been used in new application areas and has proved its efficiency, not only in planning and configuring, but also for direct manufacturing control under real-time conditions. For such tasks, in particular for process-accompanying execution simulation, new methods are shown, original tools presented and electronics manufacturing examples presented to show the effectiveness.

Optimisation is part of the fourth chapter. Starting with the classical extreme-value problems with examples from the yield optimisation and the problem area of the economical lot size, linear optimisation and dynamic optimisation is prepared for electronics process technology. The following section discusses new developments, such as heuristical procedures, and then makes the transition to simulation-based optimisation. Process simulation shows its full effectiveness only in conjunction with the optimisation of these processes. The optimisation always assumes a target function. Examples are provided to show that not only the costs, but also quality, quantity and time duration can be used as operational target parameters.

The fifth chapter, quality assurance, introduces the quality parameters on the basis of probability theory. Much importance is placed here on a clear and exact description, calculation and interpretation, because, especially in quality assurance, inadequate knowledge of the relationships can very easily lead to incorrect conclusions. As major tools of statistical process control (SPC), quality rule cards and sampling test schedules are described in detail, tailored to the requirements of electronics manufacturing, and using many examples. A section for the process and machine capability with new theoretical principles and many practical results completes the chapter.

The sixth chapter, process cost optimisation, illustrates the methods that lead to a low-cost creation of inspection processes during manufacturing. The actual manufacturing process that caused the fault is compared with a so-called quality process that detects and rectifies this fault, and then returns the fault-free products to the manufacturing process or alternatively declares the faulty products as rejects and separates them from the process. Because a quality process can be positioned either immediately after the cause of the fault or after some later process, an optimisation problem results that can be easily solved and leads to dynamic optimisation for large processes.

Statistical test designing has proved to be very effective for process analysis. The methods and examples introduced in Chapter 7 are directly tailored to electronics manufacturing. Because test designing produces regression equations for measurable characteristics, this method has also gained high importance for producing models from statistical data and thus forms a basis for process planning and optimisation.

Chapter 8 summarises the important reliability factors and models for electronics technological processes. The chapter describes the new procedures for determining test uncertainties and for the effect of the test characteristic on the quality factors and process equations. Concepts for a linear systems theory for manufacturing processes can be obtained by generalising the process equation.

The last chapter introduces the principles of a theory of assembly accuracy. The inaccuracies of the positioning action for electronic modules for the placement coupled with tolerance ranges leads to quality models that permit the calculation of the machine capability. Both rectangular and circular connection geometries of electronic components and circuit boards are significant. The theory proved to be usable for determining the operational limits for assembly robots while considering the achievable quality parameters.

The individual chapters introduce many matched methods for an optimum creation of electronics manufacturing processes that can be used both for the planning and preparation of the manufacturing process and also can lead to a high transparency and stabile mastering during the execution phase. The overall aim is always to achieve robust manufacturing processes that are resilient to fluctuations and malfunctions and that realise the optimum quantity, cost and quality for the manufactured products.

The figure summarises the major tasks of process-technology of electronics.

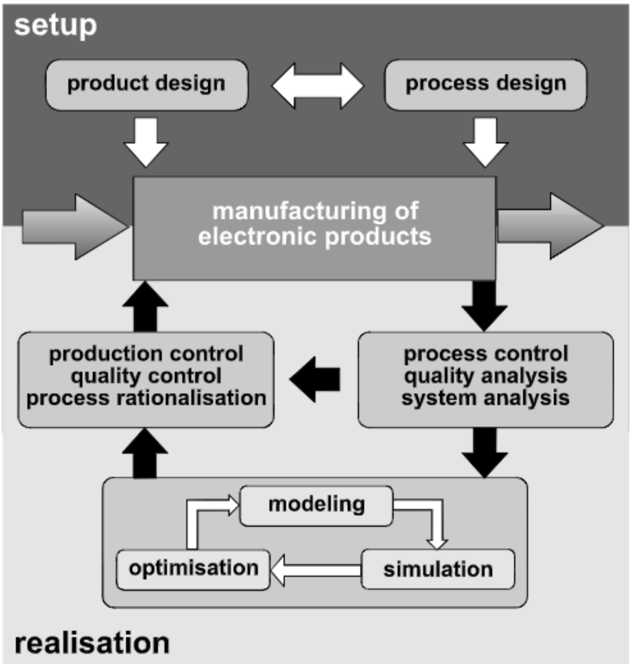

Figure 0.3. Process-technology tasks

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