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Lightwave Communications Technology. Part A: Material Growth Technologies

Edited by W.T. Tsang

(Series on Semiconductors and Semimetals, edited by R.K. Willardson and A.C. Beer, Academic Press Inc., 1985)

Lightwave communications systems are rapidly coming into a position of dominance for many different applications. Their use, however, has required the development of a large number of technologies over a wide range of conditions. *Volume 22: Lightwave Communications Technology* (part of the series *Semiconductors and Semimetals*) consists of a series of five volumes, Parts A through E, which treat the entire technology in depth in a way never before available. *Part A: Material Growth Technologies*—the subject of this review—deals with fundamental materials, growth, and processing problems which are both generic to and crucial for the fabrication of the light sources and detectors which, in turn, are indispensable for establishing lightwave communications systems. Parts B through E follow with a treatment of detailed characteristics of various light sources, such as light-emitting diodes, laser diodes operating at wavelengths between 0.7 and 1.7 μm, and detectors which are sensitive to wavelengths longer than 2 μm, such as photodetectors and avalanche photodiodes. Two additional volumes treating optical fiber communications systems will appear in the future.

Part A of this series focuses on modern crystallographic growth techniques for precisely controlled epitaxial layers of many III-V compounds, including GaAs, AlGaAs, AlGaAsSb, AlGaInAs, InGaAsP, and InAsPSb. This book details the state of the art of the epitaxial growth of these III-V compounds through 1982 and into 1983. The growth techniques discussed include molecular beam epitaxy, atmospheric and low-pressure vapor phase epitaxy (including techniques using the metal-organic compounds), halide and chloride chemical vapor phase epitaxy, and liquid phase epitaxy. The defects which result after growth, processing, and device operation, using the techniques discussed in this volume, are also described.

The book is composed of six chapters, which range through a broad spectrum of historical background, present and future problems involving the epitaxial growth of III-V compounds, and the application of these growth technologies to the design and fabrication of optoelectronic devices. Each chapter is independently written by an eminent specialist in the particular growth technique covered by that chapter, so the reader is free to start with whichever subject is of immediate interest. The authors are all very well chosen, although this reviewer notes a rather strong dependence on AT&T Bell Laboratories throughout the five parts of volume 22.

Chapter 1, written by K. Nakajima of Fujitsu, is concerned with liquid phase epitaxy (LPE), believed by some to be the "dinosaur" of epitaxial technology. However, despite its simplicity and lack of sophistication, LPE has many impressive attributes which must still be taken seriously, including low cost and high-radiative-efficiency material with a minimum of defects. This chapter deals particularly with LPE of the quaternary material most important for communications lasers, InGaAsP. Subjects such as phase equilibrium, growth rate, lattice matching, and high purity growth are handled with skill.

Chapter 2, on molecular beam epitaxy (MBE) of AlGaAs and InGaAsP, is written by the volume editor, W.T. Tsang of AT&T Bell Laboratories. With this technique, it is possible to grow thin epitaxial layers with unprecedented control (layers as thin as a single monolayer) and combine them into quantum wells and superlattices. This is done by sensitively controlling the composition of the layer in the growth direction. MBE therefore makes it possible to grow extremely complicated structures that are well suited to semiconductor lasers and detectors. The chapter is particularly useful because Tsang deals extensively not only with the MBE growth, but also with a large variety of the sophisticated devices which this technology makes possible, such as four-wavelength lasers and detectors, and the so-called GRINSCH (GRaded-INdex, Separate Confinement Heterostructure) lasers utilizing single or multiple quantum wells.

The subject of Chapter 3 represents the principal competition for MBE: organometallic vapor-phase epitaxy (OMVPE), also called metal-organic chemical vapor deposition (MOCVD). The author, Prof. G.B. Stringfellow from the University of Utah, gives a very broad and useful review of the field, surveying the fundamentals of the growth process and including a great deal of specific information about many of the III-V compounds and devices made from them. Much of the emphasis in this chapter is on the chemistry of epitaxial growth, a much-needed emphasis in a field that tends to be populated by physicists and electrical engineers. Chapter 5, by M. Razeghi of Thomson-CSF, deals, on the other hand, with only one of the materials systems of interest, the InGaAsP system, for which she has done pioneering work in low-pressure MOCVD growth. Chapter 5 therefore presents much detail useful for the fabrication of light sources and detectors, and deals with up-to-date problems

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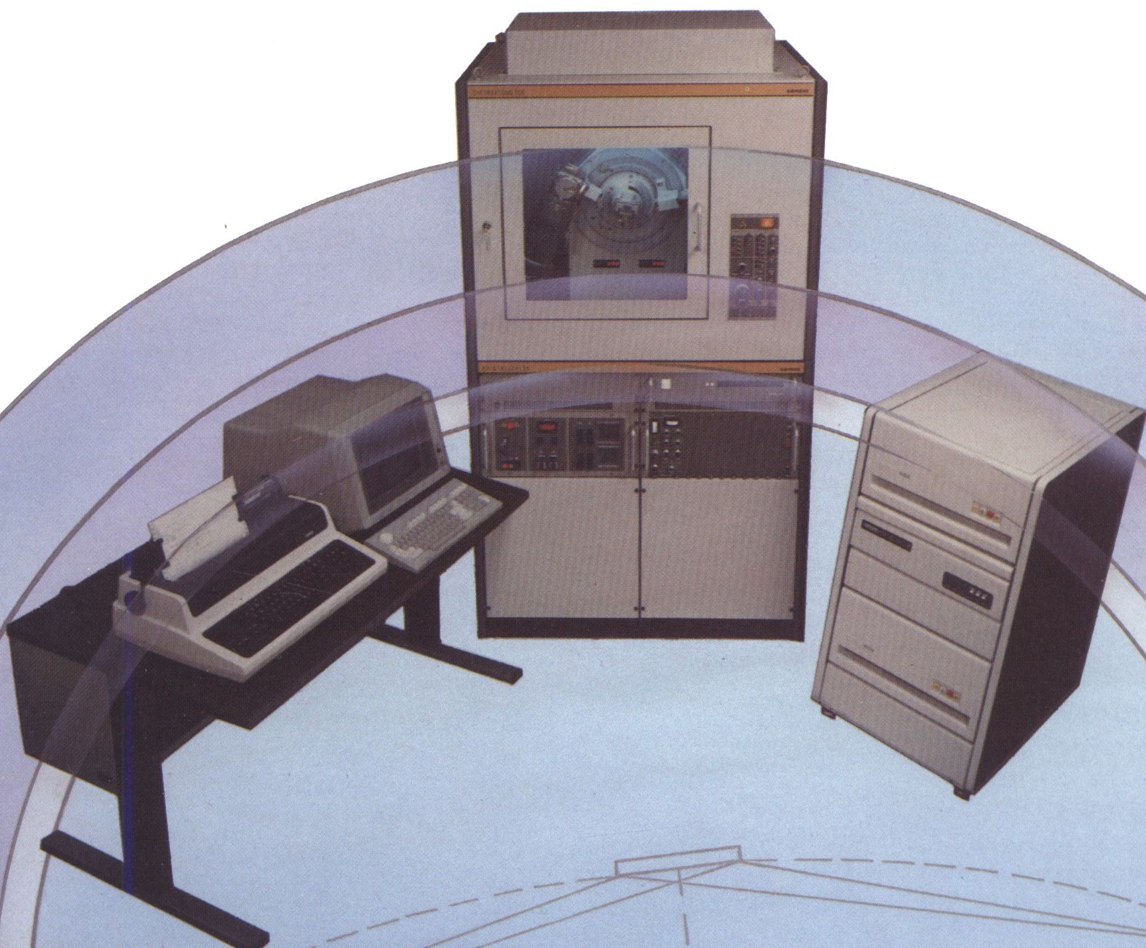

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as well, such as the fabrication of multi-quantum well structures. The emphasis in this chapter on InGaAsP/InP is a reasonable one, since this is the most important system for long-range optical communications.

In Chapter 4, G. Beuchet, also of Thomson-CSF, treats both halide and chloride transport vapor phase epitaxy (VPE) of GaAs and InGaAsP. The thermodynamic analysis, and details of the growth mechanism, are described in this chapter. Finally, Chapter 6 is devoted to defects in the III-V compounds. Written by P. Petroff, who is currently moving from AT&T Bell Laboratories to the University of California-Santa Barbara, the chapter deals with a number of important subjects: the quality of the material resulting from these various crystal growth techniques, native and process-induced defects in optoelectronic materials, and other defects that influence the performance of these devices. Unfortunately, however, this chapter is extremely short and concise: for sufficient detail to understand this most important subject it may be necessary for the reader to consult other, more detailed treatises.

In summary, this book is unique. It should assist researchers and engineers in the preparation of complicated structures of high quality material needed for fabricating the light sources, detectors, and other devices which will form the basis of future lightwave comunications systems.

Reviewer: Dr. Makoto Ishii is head of the Epitaxial Growth Group at the Optoelectronics Joint Research Laboratory in Kawasaki, Japan. In preparing this review, he was assisted by Prof. James L. Merz of the University of California-Santa Barbara.

Microcircuit Engineering '84
Edited by: A. Heuberger and H. Beneking
(*Academic Press Inc., 1985*)

This book contains the proceedings of the International Conference on Microcircuit Engineering 1984, held in West Berlin, September 25-29. The conference was the tenth in the series of such meetings and it was attended by 300 participants. The book contains 42 papers on lithography (optical, electron beam, x-ray, and ion beam), 10 papers on resists and processing, and 7 papers on electron beam testing.

An overview paper on submicron lithography by A.N. Broers summarizes the types of cameras in use in addition to lithography requirements until 1992. Operating parameters for electron beam fabrication systems and throughput versus resist sensitivity are described. Overall, this paper does a good job of summarizing the lithography needs of high volume and custom logic chips.

Other papers on optical lithography include deep UV contact printing, single-layer resist technology, contrast enhancement processes, and new optical lenses for GCA equipment.

Papers discussing electron beam lithography cover a broad range of topics including device fabrication and electron beam system design and software. The shaped beam approach of IBM's system is also used in photomask pattern inspection. Mask repair for silicon transmission masks is described by Behringer et al. Colbran et al. present a sobering discussion of the data processing needs of high throughput systems, and point out the importance of integrating software development with electron beam design and manufacture. Ehrhardt et al. describe a new method for proximity compensation using an additional exposure to substitute the missing background dose in the unexposed regions. Also described is the use of electron beam lithography in fabricating submicron GaAs devices, magneto-resistive devices, accurate grids, and NMOS ICs.

The section on x-ray lithography begins with an overview by K. Hoh on the state of research on synchrotron radiation lithography. This technology has potential, but its usefulness depends on advances in mask fabrication, resists alignment methods, etc. As a result, most of the other papers in this section deal with masks and resists.

Ion-lithography research for proximity printing and direct writing is described next. Ion source work and efforts in focused ion beam processes are described.

Electron beam testing is a method of charging pads and reading associated potentials by the electron probe. An overview of crucial parameters in this technology is given by M. Brunner et al. Other papers discuss frequency tracing and mapping, voltage contrast detectors, and measurement.

The last part of this book describes resists and processes. Single and multiple-layer technologies are covered as are limitations of single-level lift-off processing. New resists are described, including a high resolution plasma developable resist and a positive optical resist for bilayer systems.

Overall, *Microcircuit Engineering '84* represents a "snapshop" of technology in lithography and resists which any active worker in the field would need.

Reviewer: Richard B. Fair is vice president of research, Microelectronics Center of North Carolina, and professor of electrical engineering at Duke University.

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