Handbook of Thin-Film Deposition Processes and Techniques. Edited by *K. K. Schuegraf.* Noyes Publications, Park Ridge, N.J., USA 1988. xvii, 413 pp., bound, US $ 72.—ISBN 0-8155-1153-1

The book gives a thorough account of a large number of thin film deposition processes. Emphasis lies on the techniques which are either already in extensive use in high technology areas, especially in the microelectronics industry, or may be expected to become competitive in the future. Apart from the introduction, which gives a somewhat broader overview, the treatise has been confined to processes in which the films are deposited from the gas phase at pressures ranging from atmospheric to ultra-high vacuum. The techniques treated in this volume can be classified into the following three categories:

1) Chemical methods: They entail chemical vapor deposition (CVD) and its variants, like low pressure chemical vapor deposition (LPCVD) or metal-organic CVD (MOCVD). In these techniques one or several gaseous species react in the vicinity of, or on, the substrate and condense to form a solid film. Apart from the supply of purely thermal energy for reaction initiation a number of additional means are used, leading to higher reaction rates at lower temperatures, such as photochemical vapor deposition (PHCVD) and laser assisted CVD (LCVD). In the former, UV-photons are used to dissociate or excite molecules in the gas phase or on the substrate surface to form a thin film. The latter method either uses a laser beam for the same purpose or for highly localized substrate heating. In electron beam assisted CVD (EBCVD) a high energy electron beam is used instead to dissociate the gas molecules by impact ionization.

2) Physical methods: These include plasma techniques, such as RF and DC sputtering and ion beam deposition, the latter being applied in either of two modes: a) Sputtering mode allowing for a better control over the sputter parameters and a lower operating pressure in the deposition chamber than conventional techniques and b) ion assisted deposition (IAD) in which a beam of ions is directed towards the substrate during the deposition from another source. Conventional vacuum evaporation and electron beam evaporation are not treated in this text, apart from their most advanced application, i.e. in molecular beam epitaxy (MBE). This method offers probably the best control of single crystal growth on a monolayer scale of all deposition techniques in current use. As a result, a number of devices relying on superlattices or quantum well structures have been fabricated, some of which are described in the text. Equally promising is one of the latest developments, namely ionized cluster beam deposition (ICB), in which ionized particles containing typically 100–2000 atoms impinge on a substrate where they spread and eventually condense into a thin film.

3) Physico-chemical methods. They are in essence a combination of the physical and chemical methods mentioned above, the chemical reactions taking place in a plasma generated in a number of ways. Plasma-enhanced or plasma-assisted chemical vapor deposition (PECVD, PACVD) use a plasma generated in a glow discharge. Ions and free radicals produced in the discharge greatly accelerate reaction rates, allowing film deposition at lower substrate temperatures than in purely thermal CVD. Much higher ionizing efficiencies, yielding high deposition rates at still lower substrate temperatures, are offered by electron cyclotron resonance deposition (ECR), in which electrons orbiting in a magnetic field absorb microwave radiation under resonance conditions.

Reactive sputtering, in which a reactive gas is mixed with the inert sputter gas, also belongs to this category.

A special chapter is devoted to plasma and high pressure oxidation of silicon for very large and ultra large scale integration.

Apart from the deposition processes, the book covers a number of other equipment-related topics, such as etching techniques (sputter etching, reactive ion etching, ion beam etching, etc.), resist patterning, including self-development and beam-induced thermal processes.

The book gives a short overview of the physical principles, underlying the various deposition techniques. The basic design and the performance of the deposition equipment are thoroughly outlined. Numerous tables and figures describing the properties and the uniformity of the deposited films are given, enabling the reader to compare the advantages and the limitations of each method. A considerable part of the applications in many chapters has been devoted to silicon technology, in particular to silicon epitaxy, polysilicon, silicides and dielectrics, like silicon oxide, silicon nitride and -oxynitride. The increasing importance of low temperature processing, especially in future ULSI is becoming apparent in view of the many techniques capable of low temperature deposition. III/V-epitaxy and its applications are the leading topics in the chapters on MOCVD and MBE. Other applications include metal films and especially metal-insulator-semiconductor heterostructures, where important advances have been made, particularly by ICB.

The extensive bibliography will be valuable help, especially for newcomers in any of the fields, the references covering the period up to 1986.

In general the book can be recommended to all engineers and scientists wishing to become acquainted with current trends and future outlooks in thin film technology. Since prime importance has been laid on the practical aspects, the production capabilities of the various techniques and their limitations with respect to large scale applications can easily be assessed by the practically minded reader.

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