# Current state of semiconductor silicon technology and material science.

V. B. Timofeev
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*Semiconductor Silicon: Materials Science and Technology: Proceedings of the Summer School, Erice, Trapani, Sicily, July 3–15, 1988.* Eds. G. Harbeke and M. J. Schulz. Springer-Verlag, Berlin; Heidelberg; New York; London; Paris; Tokyo; Hong-Kong, 1988 (Springer Series in Material Science, Vol. 13). 360 pp.

In recent years the Springer-Verlag publishing house has published systematically the proceedings of conferences, symposia and schools as separate books. Typically these materials are prepared with astonishing dispatch and thus become important sources of up-to-date scientific and technological information alongside traditional publications in scientific journals. Among such publications the series devoted to material science and thin film technology has gained particular acceptance. It is worth noting that the editor of this series is Dr. K. Alex Müller, who received the 1987 Nobel Prize in physics for his discovery of a new class of high-temperature superconductors.

The book under review is the thirteenth volume of this series and is devoted to semiconductor silicon. It is well known that silicon is the workhorse material of modern semiconductor technology, including microelectronics. The applications of silicon in this rapidly evolving technological field are numerous and wide-ranging: from powerful supercomputers to consumer radioelectronics, calculators, and solar cells. Suffice it to say that the highly developed electronics industry of the West consumes and processes into products over 5000 tonnes of high-purity single crystal silicon.

The book under review has been assembled from the materials presented at a summer school devoted to the problems of silicon materials science and thin film technology that took place in Sicily during July of 1988. It addresses a wide range of current problems in silicon–from fundamental scientific questions to technological and purely applied problems related to the manufacture of concrete devices, particularly integrated circuits. The book contains both review articles and new communications by leading specialists in silicon technology representing such world-famous companies as IBM (U.S.), AT&T Bell Labs (U.S.), Wacker-Chemitronic (West Germany), Siemens AG (West Germany), and others. The book is divided into seven chapters.

Chapter 1 is devoted to the growth of silicon single crystals. A specialist from the Wacker-Chemitronic company (West Germany), which is the world leader in the growth of large silicon crystals using the Czochralski method, contributes a detailed review of the state of the art in this area. Modern crucible materials and their influence on the chemical composition of the vapor phase and crystal purity are discussed.

Also, this chapter examines the techniques of silicon homoepitaxy at atmospheric pressure. It is demonstrated that the self-doping of grown films has led to the evolution of a new field: low-temperature epitaxy in ultra-high vacuum. The chapter concludes by describing the technology and apparatus of silicon molecular beam epitaxy (MBE). Various MBE systems designed by different companies are characterized, including Anelva (Japan), Atomica (West Germany), Perkin Elmer (U.S.), Riber (France), Varian (U.S.) and VG (England).

Chapter 2 examines new techiques in silicon processing that are aimed at controlled doping of the lattice with impurity atoms and the formation of various surfaces made of different materials. This technology is motivated by integrated circuits.

Etching, deposition, lithography, ion implantation, and oxidation processes are discussed on an atomic level.

A general theoretical model of silicon doping using lasers as the heat source (laser sputtering, laser annealing) is presented.

An exhaustive paper by a Bell Labs specialist examines ion implantation. The feasibility of forming pure $\alpha$-Si layers by ion implantation is demonstrated and new results on the enthalpy of melting are presented. It has been established that $\alpha$-Si becomes a metallic melt at 225 K. Therefore it follows that $\alpha$-Si can be obtained by quenching a melt that is supercooled below this temperature, with the rate of cooling exceeding $10^{12}$ K/s.

Chapter 3 contains a detailed description of defects in silicon crystals grown by various techniques. Particular attention is devoted to point defects (above all, interstitial oxygen) and the little-studied needle-shaped defects that have been attributed to a modification of $SiO_2$ that can appear at high pressures and $T < 800$ °C.

Chapter 4 addresses modern methods of silicon characterization. Among the discussed topics are high-resolution electron microscopy, including the contrast method using lattice defects, tunnel microscopy, deep level spectroscopy (DLTS), and special spectroscopic methods developed for silicon–insulator structures.

Especially interesting are the new methods of determining the oxygen content in polycrystalline profiled silicon by means of infrared spectroscopy.

Chapter 5 is devoted to the formation and analysis of insulating films on silicon. Silicon oxide and the problem of remnant charged impurities in thin insulating films receive particular consideration.

Chapter 6 discusses the formation of transition metal silicides, widely used in integrated circuits. There is also a description of a new tunneling experiment that yields information on the properties of the metal–semiconductor interface (Schottky contacts).

Chapter VII, the final chapter in the book, addresses the development of new silicon devices. The production of 4 megabit DRAM chips (Siemens AG) is described. Several means of improving the efficiency of crystalline silicon solar cells to 30% are discussed, including the utilization of sharp isotropic $p^+$–$p^-$ barriers, corrugation of the surface, deposition of double interference antireflection coatings, epitaxial growth of high-purity surface layers of silicon, etc.

There is no doubt that this collection will find a large and receptive audience among specialists interested in the current problems of semiconductor physics and technology. Furthermore, this collection will be of great help to those who are just entering this field–students, graduate students, and research associates–because semiconductor technology really should be studied by considering its latest and most significant advances.

Translated by A. Zaslavsky