Microtechnologies. With the floating zone method (below), Siemens researchers created the basis for making ultrapure silicon for computer chips. Today they're working on other chips, such as those used in DNA analysis of diseases (right).

THE SILICON PIONEERS

In 1945, Siemens researchers converted a manor house into a lab. There, they invented a new method for producing ultrapure monocrystalline silicon — a process that's still used for 80 percent of the world's production.

When most people hear the word "silicon," they think of "Silicon Valley." However, the story behind one of the information age's most important basic materials actually begins in Pretzfeld, an idyllic village not far from Nuremberg, Germany. It was here, and not in California, that researchers developed the method that's still used today to produce about 80 percent of the world's ultrapure silicon.

Back in the 1930s, renowned physicist Walter Schottky, one of Max Planck's students, investigated the fundamentals of semiconductor physics in Siemens' laboratories. Any commercial use was then still way beyond the horizon. Shortly before the end of World War II, Siemens relocated its semiconductor lab to a manor house in Pretzfeld. Initially, a small team led by Eberhard Spenke turned its attention to selenium, and produced its first rectifier components on three old kitchen tables.

A few years later, the company established a profitable manufacturing operation that would continue in Berlin until well into the 1970s. During the same era, researchers in the General Laboratories at the Siemens-Schuckert Works in Erlangen and in the Main Materials Laboratory of Siemens & Halske investigated the suitability of other crystal systems for use in semiconductor components. Silicon was one of those materials. While the Bell Telephone Laboratories, which developed the first transistor in 1948, relied entirely on germanium, Spenke made the bold decision to use silicon, and in 1952 persuaded Siemens management to support this approach.

The Americans had an insurmountable lead in germanium technology, but Spenke knew that germanium had serious drawbacks. Because its maximum operating temperature is 70 degrees Celsius, it was particularly unsuited for applications in power electronics. Silicon, on the other hand, can be used at temperatures of up to 200 degrees. The breakthrough in producing ultrapure silicon came with zonal heating of vertical rods in a high-frequency field. This method takes a perfect "seed crystal" and creates a larger, equally perfect monocrystal around it. The crystalline rod is then sliced into wafers and processed to make components.

The method developed by Spenke and his staff became a milestone in engineering history. At a conference in Garmisch-Partenkirchen in October 1956, Siemens presented the first silicon power rectifiers with the then unimaginable rating of 1,000 volts and 200 amps. Conventional selenium rectifiers were rated at a mere 30 volts and 80 amps. Spenke's "floating zone" method marked the beginning of the triumphant advance of silicon. Many companies in the US, Japan and Germany licensed the process.

Another breakthrough was achieved when communications engineer Karl-Ulrich Stein developed his single-transistor storage cell, complete with a special amplifier. In this device, a tiny capacitor has a small electrical charge or is uncharged. An interconnected transistor amplifies this charge so that a computer can read it. Today every PC contains storage cells and amplifiers based on that principle. They are sold by the millions as DRAMs (dynamic random access memory) and are based on power-saving CMOS technology. But Siemens patent specification number 2148896 of September 30, 1971, was far ahead of its time.

"In the 1960s and '70s we lost a lot of time. Due to certain physical instabilities, CMOS was considered a lame duck at Siemens in the early 1960s. But that was a mistake," recalls Walter Heywang, who later became director of Corporate Research and Development. Siemens ultimately lagged three years behind Japan, the leader in this field. That's an eternity in the fast-moving semiconductor business. Due in part to forceful advocacy by Karl-Heinz Beckurts, managing board member responsible for research, Siemens declared the pursuit of the megabit memory chip to be a strategic goal in 1983 and invested about DM 2.6 billion in that "megaproject." Under the aegis of Hermann R. Franz, Siemens caught up with the competition in 1988 with the 4-megabit chip. And the company has remained at the top ever since.

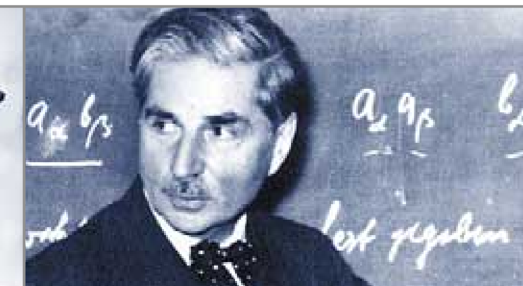
Though the semiconductor business was spun off as Infineon Technologies AG in 1999, silicon researchers at Siemens haven't run out of work. That's because silicon remains important as a basic industrial material. The hot products today are tiny, highly integrated MEMS (microelectromechanical systems). MEMS integrate basic automation elements into a single component. They can act as sensor, logic processor and actuator, all wrapped into one, and can communicate wirelessly with the outside world. When necessary, they can send warning messages to a higher-level computer, such as "Loss of tire pressure." They will also soon be widely used in buildings, where they can monitor the temperature on any floor or report a fire.

What's more, it is now possible to have chemical or biological substances react on a chip. The *quicklab* technology platform developed by Siemens is a complete DNA analysis laboratory the size of a credit card. The interaction of electronics and biochemistry in such a small space enables physicians to reach specific diagnoses quickly without sending a specimen to a lab. In *quicklab*, capillary forces propel a blood drop through micro pipes on the chip. In minuscule reaction chambers, genetic information is extracted from the blood cells, amplified and fed to an analytical unit. The result can be sent directly to a computer. In 2004, a team of Siemens scientists and colleagues at the Fraunhofer Institute in Itzehoe and at Infineon shared the German Future Prize (see *Pictures of the Future*, Fall 2004, p. 74).

Today's microfluidic systems are at the stage where silicon technology was at the beginning of the 1960s — still in the starting blocks but capable of changing our lives as profoundly as silicon technology has been doing for 40 years. ■ *Björn Schaffer*

HEINRICH WELKER

In 1951 Heinrich Welker, then director of Solid State Physics at Siemens Research in Erlangen, discovered the III-V compounds of elements in the 3rd and 5th groups of the periodic system. One of these is gallium arsenide — a key ingredient for high-frequency components and semiconductor lasers in optoelectronics. Welker's team advanced the fields of microwave semiconductor components, LEDs and laser diodes. Welker was director of the Corporate Research Laboratory from 1969 until 1977.



THE SPIRIT OF PRETZFELD

When they think of the past, the semiconductor researchers wistfully remember the idyllic little village and the "Spirit of Pretzfeld" (left). Never were the paths between top decision-makers shorter or the researchers' lives less complicated. Spenke (second from left) was a great motivator. He also translated the brilliant but highly complex reflections of Walter Schottky (third from left) into the language of experimental physicists. Spenke was a modest man who referred honors to "Dr. Pretz," the nickname he had given to his team. In the end, Pretzfeld regrettably became too small to serve as the semiconductor lab of a global company. In 1969, the different Siemens companies merged to form Siemens AG and, after a few detours, the Siemens researchers relocated to Munich, Erlangen and Berlin.

FACTORY ON A CHIP

The concept of the "laboratory on a chip" can also be extended to serve other purposes — for instance, for producing chemicals in tiny amounts. The inventory of such a "factory on a chip," which is currently a major focus of attention at Corporate Technology, includes sensors and an intricate system of capillary channels. Within these pathways — which are as thin as a human hair — chemicals can be efficiently transported, mixed and made to react with one another. This microreaction technology is extremely useful wherever it is necessary to produce minuscule amounts of a high-purity substance with high efficiency, for example in various areas of biotechnology, pharmaceuticals and fine chemistry (see *Pictures of the Future*, Fall 2002, p. 16).