

**FOR PIONEERING RESEARCH IN CHARACTERIZING
AND MODELING MOS DEVICES AND TECHNOLOGY,
AND FOR LEADERSHIP IN THE DEVELOPMENT OF
THE MODERN SEMICONDUCTOR INDUSTRY, GROVE
WILL RECEIVE THE 2000 IEEE MEDAL OF HONOR**

profile

andy grove

LINDA GEPPERT, Senior Editor

IN NO WAY COULD THE American Institute of Chemical Engineers have foreseen the consequences of its action. In bestowing a best student paper award on a young Hungarian student in 1959—coincidentally, the same year that saw the first integrated circuit unveiled to the public by Jack Kilby of Texas Instruments Inc.—it launched him on a career that has for decades shaped the course of the semiconductor industry.

"As a student, it was the first thing that I ever won," recalled Andrew S. Grove, today chairman of the board of Intel Corp., Santa Clara, Calif. "Needless to say, I remember it better than most subsequent awards."

The paper described heat transfer in fluidized beds and was written when Grove was studying chemical engineering at City College in New York City. "Fluidized beds are like a bunch of ping-pong balls in a container," he explained recently to *IEEE Spectrum*: "You start blowing air through them. The balls get lifted and separate from each other and start vibrating or bouncing around." The ping-pong balls could be any particulate, and when they become separated, they take on liquid-like characteristics. "You can tilt it, you can pour it, and because of all of the motion of the particles, the rate of heat transfer skyrockets," he said.

That project awoke Grove's interest in fluid dynamics—so much so that at the University of California, Berkeley, he picked a topic in the field for his Ph.D. thesis.

FROM BUDAPEST TO NEW YORK CITY

Chemical engineering had not been his first choice of a profession. As a teenager in Budapest in

the early 1950s, he wanted to become a journalist and wrote articles for a youth newspaper. But when some family members fell into disfavor with the Communist government, the paper stopped printing his material, even though his writing had nothing to do with politics.

"I was 13 and writing about things like 'what I did on my summer vacation'—which makes the fact that they stopped printing my little articles even more atrocious." He was so upset that he turned instead to chemistry. Nonetheless, his early zeal for writing did not evaporate. Throughout his career he has authored articles on management for magazines and newspapers and has published several books, including *Only the Paranoid Survive* (Currency Doubleday, New York, 1996).

In 1956, during his second year at the University of Budapest, the Hungarian revolution erupted. "After Stalin died, the Communist government became less repressive and people got encouraged" to demand more and more freedom, he recalled. Tensions built till there was a confrontation between the people and the USSR-backed Hungarian government. He took part in demonstrations "but no more than that," he said.

Deciding to leave his homeland, he picked a part of the country where the border with Austria runs through farmland, and simply walked across into foreign territory. Before the revolution, it would not have been so easy. The border had been heavily guarded and mined, he said. But the mines had recently been removed, and during the revolution, many of the border patrol troops were moved elsewhere. Within a couple of months, two hundred thousand Hungarians crossed the border.

PHOTOGRAPHS: ROBERT HOUSER

Grove left his mother and father behind in Hungary. They would join him in California in 1962. He found his way to the United States—where else than to New York City? "From a Hungarian perspective, as for most European immigrants, America and New York are almost synonymous at first," he said. Also, his uncle and aunt lived there.

When he arrived, Grove's grasp of English was a work in progress: "I could read relatively well. I could speak less well, but okay. I could understand nothing." He learned the language from other Hungarians, who also gave him their heavy accents. "On top of it, I was hard of hearing." (Grove's eardrums had been perforated by a bout with scarlet fever when he was a child. Several operations performed in the '70s restored his hearing.)

Language difficulties were only one of his problems with school in the United States. The teaching methods differed radically from university classes in Hungary, and he had to relearn how to attend classes and take tests. "We had oral exams at the University of Budapest," he said. "And here they had a closed book test where time was of the essence. I failed my first significant test—I had never failed anything in my life before."

FAIRCHILD DAYS

By 1963, however, Grove had earned his Ph.D. and was eager to tackle the U.S. job market. Newly minted chemical engineering Ph.D.s with specialties in fluid dynamics then either headed for professorships or went to the space and defense companies then flourishing in the wake of President John F. Kennedy's space program. Neither route appealed to Grove. Instead, he looked for a job in solid-state physics, which relies on some of the mathematics applicable to fluids.

It was the bright dawn of the semiconductor industry, and its most brilliant herald was Fairchild Semiconductor, then a leading manufacturer of bipolar ICs in Palo Alto, Calif. There the young man was interviewed by Gordon Moore, one of the company's founders and its director of research. He would soon become a household name after the eponymous Moore's Law, which he wrote in 1965 to describe the exponential growth of chip capacity, and it has held true for more than three decades.

"Grove was a memorable interview," Moore told *Spectrum*. "It was rather unusual for chemical engineers to apply for jobs in the semiconductor industry."

While other companies in the field had interviewed the young man, Moore recalled, he had received few offers because his thesis had no direct bearing on the industry. But having been trained as a chemist and physicist himself, the Fairchild manager was more receptive than most recruiters to people coming in from other disciplines. Grove's explanation of his Ph.D. research was a further point in his favor.

Moore also wrote to Grove's thesis professor, Andreas Acrivos, asking for a recommendation. "I got back the letter I had written with a note on the bottom which said simply, 'This is truly an unusual individual. Whoever hires him will be very lucky.'"

He got the job.

FIRST STEPS

Grove joined Fairchild Semiconductor as a member of the technical staff, and at first did not report to the director of research directly. He was put to work studying the silicon/silicon-oxide interface of the metal-oxide-semiconductor (MOS) devices being developed by the laboratory.

"At that time, MOS devices were behaving in peculiar ways we didn't understand," said Moore. They were just beginning to be studied, in a nascent semiconductor industry still rooted in bipolar devices.

"A big issue with MOS technology was reliability," explained Les Vadasz, a fellow Hungarian, one of Grove's colleagues at Fairchild, and now executive vice president of Intel and president of Intel Capital. (Though both Vadasz and Grove had lived in Budapest and left Hungary in the same year, they first met at Fairchild.) "You made the devices and under the most benign conditions their characteristics drifted, even over short periods of time."

Grove and several team members discovered that sodium impurities from the filaments used to evaporate aluminum were being inadvertently introduced into the device during manufacture, shifting its threshold voltage and altering the conduction. "The effect could not be seen in bipolar devices, but it was devastating for MOS devices. Andy [Grove] and his group figured this out and then changed the manufacturing process in order to eliminate the sodium," said Vadasz.

His hard work paid off. A steady stream of more than 35 seminal papers on the properties of silicon and silicon oxide flowed from the work Grove did in the short five years he was at Fairchild. He and Bruce Deal, also on the technical staff, developed a model of silicon oxidation—the Deal-Grove model—still used today in studies of how oxide growth is affected by substrate orientation, dopant concentration, and other parameters. He was the first to fully explain the characteristics of capacitance-voltage curves of MOS capacitors, and he studied the breakdown voltages of planar p-n junctions.

Meanwhile, the young researcher developed an enjoyment of teaching that he retains to this day. While at Fairchild, he taught a variety of courses, which culminated in his first book, titled *Physics and Technology of Semiconductor Devices* (John Wiley & Sons, 1967).

The book explained the technology at a very practical level, according to Ron

Whittier, now senior vice president and general manager of Intel's Interactive Media Services Division, who also worked at Fairchild. "It was a working-level description of the technology and physics of devices at that point in time," said Whittier. "Any farther than that, you were over the top. Any less deep, you really couldn't understand what you were doing."

"He's an excellent teacher," said Moore. "He has not gone on any outside corporate boards, but has for years taught a class"—at Berkeley for several years and currently a course on business strategy at Stanford University.

Soon Grove's managerial talent also shone forth. In 1967 he was promoted to assistant research director, under Moore. "Not bad for someone four years out of school," the then research director observed. "But he was the best. Not only was he outstanding technically, he was extremely well organized. Very direct. Willing to dig in and get results."

'A VERY STRONG INTELLECT'

In fact, "well-organized" and "direct" are words often applied to him by his colleagues. So also are adjectives like "logical," "bright," and "prophetic."

Of all his Intel colleagues, Ron Whittier has known Grove the longest. They met at Stauffer Chemical Co. in Richmond, Calif., a manufacturer of heavy industrial chemicals, especially phosphorus. Whittier and Grove were lab mates. Grove was there for the summer before going on to graduate school at Berkeley. Whittier had a full-time position at Stauffer.

The two talked about the future of the chemical industry and reasons why electrical engineers earned more than chemical engineers. "Even then he had an enormous curiosity about something that was above the straight engineering level," Whittier told *Spectrum*. He remembers Grove as being "extremely organized as an engineer. My lab notes were not as good as his and I knew it immediately. It was pretty obvious that he had a very strong intellect."

Ted Jenkins, who retired from Intel last year after 31 years with the company, had also been at Fairchild and had been interviewed by Grove in 1966 when he applied for a job there. He recalled his interrogator's appreciation of silicon and how prophetic it had proved.

"During the interview, I said 'Well, this silicon is nice, but, what about getting into some new, more exotic and modern materials?' And he said, 'Silicon has worked pretty well. You can heat it in an oxidizing atmosphere and get a good oxide. Yes, there are some applications where the higher mobility [of the more exotic materials] is nice, but we think silicon is going to last for quite awhile.'"

Jenkins was also struck by Grove's ability to organize his thoughts logically, and in particular how his technical papers explained precisely what the researcher-authors knew and what they did not know. "He was very deliberate about that. And he was also very direct in his conversation with you or his interrogation of you."

That directness and intensity might have intimidated some people, observed Jenkins, recalling a hallway conversation with Whittier and Grove in the '60s, while the three were still at Fairchild. They were talking about some results having to do with gettering, a method of improving device performance by reducing electrical leakage due to impurities, and Jenkins was throwing out some numbers. "Andy got very aggressive with his line of questioning. And I thought that I could just get run over if I didn't stick with my story and make sure he understood what I did," he recalled.

To long-time colleague Vadasz, Grove's greatest strength is his logical mind. "He has an uncanny ability to go out and reduce a large set of confused facts into some logical basic truth," he observed. But his reasoning powers make it difficult for others to win debates against him, even if he is wrong, "because of the logical way that he can weave the argument," said Vadasz.

THE INTEL START-UP

A year after Grove became assistant lab director at Fairchild, Gordon Moore and Robert Noyce, two of the eight Fairchild founders, decided to leave and start a new company to manufacture semiconductor memories. At that time, nearly all computer memories were based on magnetic cores which were ten times cheaper than equivalent semiconductor devices.

Moore disliked the way Fairchild was being run, and Robert Noyce, the co-inventor of the planar process for connecting components on an IC and at that time general manager at Fairchild, was displeased that Fairchild's board of directors was looking for a chief executive officer (CEO) outside the company. He felt that he was the likely internal candidate for the position.

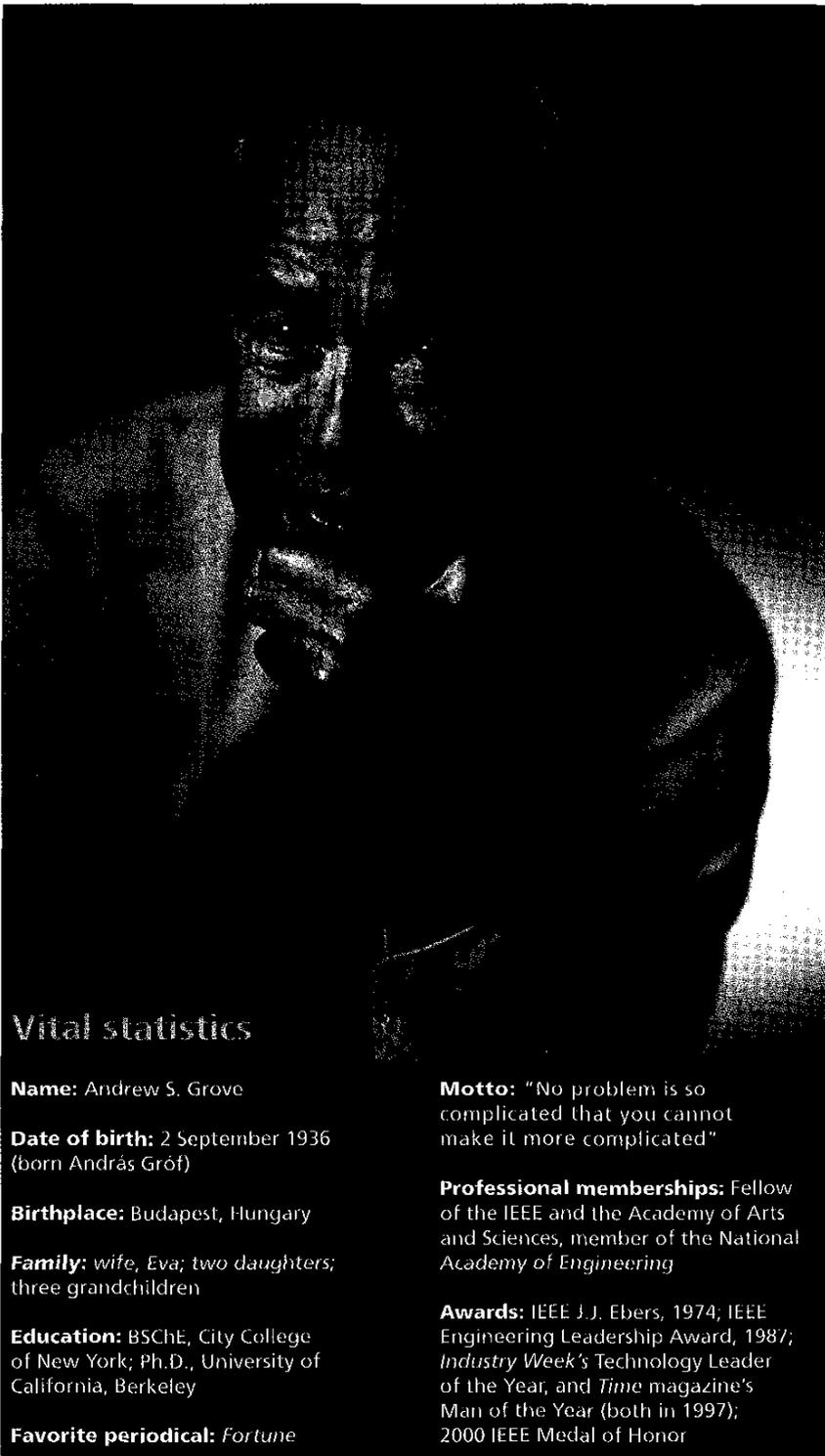
When told by Moore that the two were leaving Fairchild, Grove's immediate reaction was that he wanted to go, too. "I didn't discourage him," his mentor recalled.

From Grove's point of view, without Moore, there was no reason to stay at Fair-

child. "I really liked working for Gordon. He was like another Ph.D. adviser and a very important part of the positives that I had at Fairchild. So, it was pretty clear to me that I wanted to go wherever he went."

Although Grove enjoyed his work at Fairchild, he was less than happy with the

company's utter disinterest in taking the good research and putting it to use in manufacturing. "In particular, we had developed the knowledge and understanding of MOS transistors from which the digital electronics industry as we know it today flowed," he told *Spectrum*. "It was a business opportunity



Vital statistics

Name: Andrew S. Grove

Date of birth: 2 September 1936 (born András Gróf)

Birthplace: Budapest, Hungary

Family: wife, Eva; two daughters; three grandchildren

Education: BSChE, City College of New York; Ph.D., University of California, Berkeley

Favorite periodical: *Fortune*

Motto: "No problem is so complicated that you cannot make it more complicated"

Professional memberships: Fellow of the IEEE and the Academy of Arts and Sciences, member of the National Academy of Engineering

Awards: IEEE J.J. Ebers, 1974; IEEE Engineering Leadership Award, 1987; *Industry Week's* Technology Leader of the Year, and *Time* magazine's Man of the Year (both in 1997); 2000 IEEE Medal of Honor

that some other companies managed to take advantage of and Fairchild never did."

But he did have qualms about leaving Fairchild. The company was relatively stable, while start-ups were a strange kind of existence. "I had never been to one, there weren't that many of them, and it was not a socially accepted thing to do," he explained.

Moore left Fairchild on 3 July 1968. Within three weeks, Grove was on the payroll at Noyce and Moore's new enterprise. The company was incorporated as N M Electronics, but within a month, the name

'We developed the knowledge of MOS transistors from which the digital electronics industry flowed'

was changed to Intel, short for integrated electronics.

Grove was the company's third employee, after Noyce and Moore, although officially, through some mixup, the No. 3 employee status went to Les Vadasz, who came over from Fairchild about the same time as Grove.

N M Electronics started out in Noyce's study. The third man's first assignment was to get a post-office box so the four could write away for literature. Then they made a list of all the things they might need, divided it four ways and started calling equipment vendors. One item assigned to Grove was a wire bonder. "I had never seen one before, but that was on my list. So, I had to decide what kind to buy," he said.

By September, the company was getting down to the business of developing the technology for producing ICs, and Grove became director of operations. In 1969, the year the first men set foot on the moon, the company had grown to more than 800 employees and its first product, a 64-bit bipolar memory chip, was on the market. Today the company is first in revenues among semiconductor vendors with more than US \$26 billion, according to Dataquest Inc., San Jose, Calif. It has expanded beyond ICs and now supplies boards, systems, software, networking and communications equipment, and services for computers and Internet applications.

As Intel grew, so did Grove's responsibilities. In 1979 he was named president, in 1987 he became CEO, and in 1997, CEO and chairman of the board. He is reported to have been a tough taskmaster, demanding the same discipline from others that he applied to himself.

It was not all clear sailing. In the mid '80s, the company was in dire straits. The most serious setback occurred when the company lost the dynamic RAM business due to

falling prices and glut in the market. "Our head was handed to us on a silver platter—primarily by the Japanese semiconductor companies," recalled Vadasz.

Fortunately, Intel had just announced the 80386 microprocessor and its microprocessor business was gathering momentum. Grove's position was that the company should get out of the dynamic-RAM business and concentrate on microprocessors, a market that was growing rapidly. The company's microprocessor business had got its biggest boost in 1981 when IBM selected

the Intel 80286 processor to run the first PCs, which also featured Microsoft's first operating system.

"The notion that a company would get out of the business that was the seed of its formation was emotionally very hard to accept," said Vadasz. "We had all kinds of escapist arguments about why it shouldn't be done." But Grove's view prevailed, and history proved him right. "That was a fundamental turning point in Intel's history and fortunately Andy had the strength and the stubbornness to override our escapist discussions."

It was the right decision. The company has dominated the PC microprocessor market ever since.

LIFE AFTER INTEL

In 1998 Grove turned over Intel's helm to Craig Barrett, who had joined Intel in 1974 after spending 10 years as a professor in the materials science and engineering department of nearby Stanford University. He became Intel president in 1997 and CEO in March 1998.

Grove remains board chairman and a participant in discussions of the company's internal strategies. "I try to do that in such a way that Craig calls all the shots and I offer comments and questions," he said. "And I think I can do it right because there's a good relationship between us, just as there was between Gordon and myself."

He is also trying to work less. Characteristically organized, he keeps track of how many hours he puts in and told *Spectrum* he has gone from 55–60 hours a week to 40 or so. "If you want something to happen, you have to measure it," he explained.

Besides those 40 hours spent on Intel-related business, he also devotes time to promoting research into prostate cancer. His own bout with the disease started in 1994. Once he knew the diagnosis, he dived into

the medical literature to determine which of several alternative courses of treatment to take. Since his treatment in 1995, the cancer has not returned, which was not a foregone conclusion.

"One thing that got me interested in this research was the secret that the cancer recurs in about one-third of all patients treated for it," he said. "But it is very difficult to get that information—people highlight the positive."

As a patient, he had visited the Cancer Center of the University of California, San Francisco (UCSF), and was impressed with the multidisciplinary nature of the organization. Its approach reminded him of the R&D efforts at Intel and Fairchild. He and several others who have been treated there have become friends of UCSF—the center calls them patient advocates—and raise money to fund prostate cancer research.

Grove also serves the Cancer Center in an advisory capacity, developing recommendations on ways to spend research funds.

RIDING THE WHIRLWIND

The dizzying pace of change in the industry has spun off another of Grove's present activities at Intel. To ensure that the company keeps up, he is visiting the new Dot.coms and getting to know the people who run them. He thinks that the most important current trend in the industry is the development of Internet-based computing. "If that development took place at an ordinary pace, we could probably adjust to it internally," he said. "But since it is coming on us at such blinding speed, we have to go to the outside to acquire companies to acquire the capabilities to adapt. And that brings a whole different style of operation."

Intel will respond to this new force by building a mix of microprocessors and microprocessor-like devices for Internet applications, which "require personal computers but also communication chips, low-power chips, control chips and ICs for cell phones," said Intel's chairman. "We have to understand where the market is and the kinds of designs and design techniques that apply to these new markets."

In Whittier's opinion, the realities of the Internet economy and the need to diversify Intel's product line have broadened Grove's outlook. "I think Andy has adjusted to that and actually embraced some new areas that he wouldn't have touched five years ago," he commented to *Spectrum*.

In essence, though, the man has not changed. The intensity is still there, according to Whittier. "You could argue that it's buried a bit and so you don't see it. But if you get into any discussion that ranges from the direction of Intel to the political system in this country or the Internet, the intensity that has been characteristic of Andy for 40 years is still there." ◆