THE FUTURE OF SUPERCONDUCTIVITY

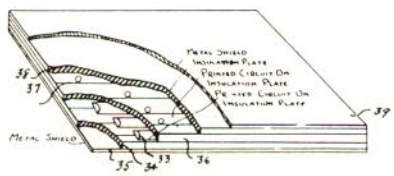
Michael Ebert
Albert Nerken School of Engineering, The Cooper Union

An idea ceases to be a secret when it is patented and thus goes public. The literal meaning of the word "patent" is "open letter," but putting the public on notice of an idea by no means signifies that its time has come.

The discovery of so-called "high-temperature" superconductors is regarded by many as the greatest technological advance since the transistor. The public has been bombarded with futuristic projections on superconductivity, whose launching pad is the 1986 Nobel Prize-winning discovery by Bednorz and Muller, two Swiss scientists working in Zurich for IBM. They found that the phenomenon of *zero electrical resistance* is attainable in certain exotic ceramics when cooled to about 40 degrees Kelvin above absolute zero. Not long after, Chu and Wu, researchers at the University of Houston, made a ceramic superconductor that works at 95 degrees Kelvin. This dramatic step forward ignited the scientific community, for now liquid nitrogen could serve as the cryogenic agent. Since liquid nitrogen is no more expensive than milk (at New York City prices), Chu and Wu's discovery appeared to open the door to practical applications that were unfeasible with the more intensely cold and costly liquid helium.

Whether substances ever will be found which superconduct at close to *room temperature* appears to lie in the lap of the Gods, yet the real payoff in superconductivity may have to await this breakthrough. The fact that the Japanese Patent Office is flooded with thousands of applications relating to superconductivity, and the U.S. Commissioner of Patents has set up a special superconductivity section, is no assurance that any one of those seeking patent protection has come up with a room-temperature superconductor. The much touted rivalry between Japanese and U.S. industrial giants to gain dominance over this promising new field does not mean that either side will prevail, for at the present state of the art, commercial applications are not earthshaking.

In 1962 I obtained, on behalf of IBM, a patent (No. 3,043,512) on a superconductive computer conceived by two young Duke University physics professors. The brain of this computer is composed of microscopic superconductive memory cells packed on a common substrate (if a computer can't remember, it can't think). The inventors and I then thought their scheme would revolutionize computer technology, but we failed to consider the inconveniences imposed by needing to maintain the computer's logic at the temperature of liquid helium.



Patent No. 3,043,512
M. J. Buckingham et. al., inventors 1962
Superconductive persistatrons and computer systems formed thereby

Now, more than a quarter-century later, after IBM had apparently abandoned ship on superconductivity, I find that two of its researchers in Zurich were working in this field, but under wraps and without official authorization. Their discovery overcame a barrier that for generations appeared unsurmountable.

A fair number of significant inventions were conceived ahead of their time. The familiar maxim "Nothing is so powerful as an idea whose time has come" offers scant comfort to the idea's creator, who may not be around when its time has come. For every inventor who lives to enjoy a handsome royalty under a patent, there are many others less fortunate. Some gifted inventors never reap a just reward for their contributions, for by the time the market recognizes the merit of the invention, their patent has already run out.

In the late 50s I patented for the Bulova Watch Company the very first electronic watch—the Accutron. In this extraordinary watch, a single transistor (then recently invented) controls the magnetically-induced vibrations of a tiny tuning fork. Impulses taken from the tuning fork drive gear works turning the watch hands. The Accutron created a sensation, for it was far more precise than the very finest spring-powered watch. However, the accuracy of an Accutron depends on a miniature battery whose voltage must remain constant for at least a year while its energy is being continuously drained—a most difficult requirement. No such power cell existed when Max Hetzel of Switzerland conceived the Accutron, but luckily for Hetzel, such a battery was later invented (not at Bulova), and the Accutron became a commercial reality.

While I knew at the time that it was within the realm of technical possibility to create an even *more* precise timepiece by using a quartz crystal as the time base, the electronic circuits that had to be linked to this highly stable oscillator entailed dozens of transistors. There was no way to crowd these transistors into a watch case. What I could not then anticipate was the much later follow-through invention of the integrated circuit, which incorporates a multitude of transistors into a tiny chip. The integrated circuit rendered the Accutron obsolete and laid the foundation for the quartz watch, that now dominates the market and has shifted the centers of watch-making from Switzerland and the U.S. to Japan and Hong Kong.

It was the integrated circuit, not the original transistor, that ushered in an industrial revolution predicated on microcomputers—hand-held and desk top calculators, the word processor, and an endless series of computer-controlled systems and mechanisms. But at the time the transistor was invented, who could have predicted the invention of the integrated circuit? When I was embroiled on behalf of N. V. Philips, the Dutch-based electronics giant, on an interference in the U.S. Patent Office with Bell Laboratories to determine who was entitled to a U.S. patent on the first transistor, none of us appreciated the future value of this solid state device.

A climate conducive to pioneering in technology generally pervades a free enterprise system, but it is not usually found within highly structured government or corporate research facilities. These do not tolerate defiance of authority, disrespect for conventional wisdom, and free-wheeling behavior—the playful and at times chaotic spirit the real innovator. Thus while tightly organized R & D labs often yield refinements and important incremental advances, and thereby justify the heavy cost of running them, many if not most of the significant inventions of the last fifty years have originated with independent inventor-entrepreneurs.

The question before us, now that it has been proven possible to operate a superconductor at the temperature of liquid nitrogen, is whether we have reached an impassable dead end. By way of example, let's consider the impact of Thomas Alva Edison's contribution to the electric light bulb, and the problem he faced in conceiving his invention. When a voltage from a power station is supplied to a transmission line leading to a light bulb, say, a mile away from the station, the voltage may never get there because of the resistance of the line and the resultant voltage drop.

The history of invention is a chronicle of surprises, and some pioneering discoveries remain just that, without any follow-through innovations to render them commercially viable. The feasibility of a pioneering invention may depend on a follow-through innovation not yet in place, and there is no guarantee that it will ever surface.

Thomas Edison, strictly speaking, did not invent the light bulb. His patent on a practical incandescent bulb is based on a seemingly trivial change in the filament: all he did was reduce its diameter.

Let us now turn the clock back to Edison in 1878, when he was only thirty-one. Twenty years before, Joseph Swan in England had devised an incandescent bulb with a carbon filament. But Swan's lamp, which operated on a low voltage and drew a high current, could not be powered over a long transmission line. By changing the filament, Edison created a high-voltage, low-current bulb: power could be conveyed to this bulb over a transmission line with only a small voltage loss—as long as the line was not too long. Edison's first Pearl Street Station in lower Manhattan signalled in 1882 the start of the electric utility industry. The station generated 100 volts direct-current, which it supplied to roughly 200 customers, all located within a mile from the station. Because of voltage losses on the line, he could not service customers beyond this range.

Yet Edison's basic invention inspired a major breakthrough by his young assistant, the brilliant and neurotic Nicola Tesla, who began his inventing career in Hungary. Edison taught Tesla the advantages to be gained by operating at high voltage. Tesla, however, recognized that with DC, the voltage level was limited to what the operator could produce, whereas if one generated 100 volts alternating current (AC) at the power station, it was then feasible by means of a Tesla-invented transformer to step up this voltage and transmit it over a line and thereby sharply reduce the voltage drop. At the customer's site, the line voltage would be stepped down by another transformer to a level appropriate to light bulbs. This made it possible to supply power over much longer distances.

What, you may now ask, has the Edison-Tesla saga got to do with superconductivity? The answer is simple: these great inventors struggled to minimize voltage losses in conductors, while the superconductor promises zero resistance. In the age of superconductivity, it will be no longer necessary to manipulate voltages as Edison and Tesla did to minimize voltage losses, or to worry about the hazards of high voltages. However, this new dawn of superconductivity is not quite on the horizon, for zero-resistance superconductive wires operating at ambient temperature and capable of replacing conventional lossy transmission lines have yet to be consummated. They do not and may never exist.

"Whenever a fellow gets bad lost, the way home is just the way he didn't think it is." Davy Crockett

Thus we have reached a familiar impasse, for though we now know of certain materials that superconduct at cold temperatures well above that of liquid helium—and this discovery may enable levitating trains and other important practical applications—something vital is still missing: the follow-through advance like Tesla's giant step forward beyond Edison. Can we expect the follow-through advance of an ambient temperature superconductor inevitably to appear just because thousands of engineers and scientists are deeply engrossed in this problem and are spurred on by the promise of fabulous rewards? Or does the history of invention tell sus that this discovery awaits the second coming of an inventive genius, and, like Godot, he may never show up?