The Man Who Mistook Molten Tin for an Inkwell

KINGA MAŁECKA
ACADEMIA magazine
kinga.malecka@pgi.gov.pl
Dr Kinga Małecka is interested in environmental geochemistry, including the distribution of rare earth elements in surface sediments and their applications in modern industrial technologies.

What would today's world be like without telephones, MP3 players, GPS navigation, television, digital cameras, microwaves, washing machines, fridges, television decoders, game consoles, and credit cards? Fortunately we do not even have to imagine it, thanks to Jan Czochralski and his pioneering method of growing single crystals

Jan Czochralski was born in Kcynia near Bydgoszcz in 1885 and raised in a multi-child family, of simple ancestry yet well-respected. Czochralski's father did not approve of his passion for risky chemical experiments. At the age of 16, Jan moved to Krotoszyn and started working at a pharmacy. But his adventure with chemistry did not start for good until 1904, when he moved to Berlin and took up a job in the laboratories of Allgemeine Elektrizitäts Gesellschaft (AEG). While working there, he continued his education and graduated as a chemical engineer from the Charlottenburg Polytechnic in Berlin in 1910. After coming back to Kcynia, he set up a chemical plant, Zakłady Chemiczne BION. It produced various cosmetics and household chemicals such as shoe polish, curing salt, and perming solutions. But what led Jan Czochralski to be named alongside such prominent Poles as the Nobel prize winner Maria Skłodowska-Curie and Nicolaus Copernicus were his scientific accomplishments in chemistry and metallurgy.

It all started with rails

One of Jan Czochralski's major inventions was bahnmetal or metal B, an alloy perfectly suited for the production of railway bearings. It differed from other materials in that it did not include tin, an expensive metal difficult to obtain, and made it possible to increase the speed of trains. German railways were quick to buy the patent, but bahnmetal ultimately spurred marked growth in the rail sector also in Poland, the US, the UK, and the USSR.

Nonetheless, no one has any doubt that Prof. Czochralski's greatest discovery was the development of a method of measuring the crystallization rates of metals. It was 1916. As the anecdote goes, the professor absentmindedly dipped his pen in a crucible containing molten tin instead of an inkwell. When he withdrew it, he saw a thin thread of metal hanging from the pen. That led him to a discovery that changed the face of the world.

From furnace to phone

Czochralski's method involves carefully pulling single crystals from a molten substance, using a thin rod that touches its surface. It can be used for any materials whose molecules do not break apart when heated and melted. Single crystals obtained in this way are characterized by high purity and homogeneity.

Single crystals are grown in a special furnace filled with argon to ensure an inert atmosphere. Inside the furnace, there is a crucible made of silica, or silicon dioxide (to prevent melted silicon inside the crucible from absorbing foreign elements at high temperatures). When the temperature inside the furnace exceeds 1,400°C and the silica turns into liquid, a thin rod made of monocrystalline silicon is brought into contact with its surface, assuming the role of a seed around which the atoms of liquid silica are gradually deposited. Controlling crystal growth requires strict procedures that determine the rate at which the seed rod is pulled out of the crucible, the speed of rotation, temperature, even the composition and pressure of the atmosphere inside the furnace. As the crystal grows, its weight is constantly monitored by sensitive electronic scales. If special software finds that the crystal is growing too fast, the temperature inside the furnace drops, thus reducing the viscosity of the liquid and the rate of crystal growth. Computer-controlled stepper motors are used to ensure the proper rate of pulling the rod out of the crucible, which affects the diameter of the crystal. Atoms in the crucible must be properly arranged in the crystal structure of the growing seed. If the rod is pulled to quickly, the crystal structure will have defects or, in extreme situations, may not even form. Importantly, silicon crystals can be grown within


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Jan Czochralski (1885 - 1953)
A professor at the Warsaw University of Technology and head of the Institute and Department of Metallurgy.

a very short period of time: it takes only 30 hours to grow one meter of crystal. Other semiconductors form crystals at a slower rate, usually 10 cm a day, whereas single crystals of oxides grow at a rate of slightly over 10 cm a week.

Crystals of especially rare materials and/or materials that are especially difficult to process need to be grown in specially modified furnaces: they are pulled out of single drops levitating in a magnetic field.

Prof. Jan Czochralski's first crystals resembled metal wires up to 1.5 m in length and 1 mm in diameter. The silicon crystals grown nowadays can be even more than 2 m in length, almost 0.5 m in diameter, and can weigh several hundred kilograms. Other crystals obtained from semiconductor compounds are usually much smaller (single crystals of oxides, for example, are up to 10 cm long and their diameter does not exceed 5 cm).

Silicon crystals are further processed to form cylindrical ingots of manufacturing-grade diameter and cut into wafers. Once polished, these wafers become a perfect material for the construction of various electronic components. Some crystal fragments characterized by a perfect structure and top chemical purity are cut out and used as seeds in growing new crystals.

Better than Copernicus

Initially, Czochralski's method only attracted the interest of metallurgists, but nowadays it is commonly used to grow crystals, especially semiconductor crystals used to build transistors used in electronics. It is estimated that as much as 90% of semiconductor devices are built using the method the Polish scientist developed. In Poland, it is most widely used by the Institute of Electronic Materials Technology in Warsaw.

The importance of Jan Czochralski's invention can hardly be overestimated, as demonstrated by the fact that the number of scientific papers citing him has nearly doubled over the last decade. Czochralski himself authored and coauthored over 120 scientific publications as well as numerous inventions and patents. He is the most frequently cited Polish scientist, having outpaced even Nicolaus Copernicus and Maria Skłodowska-Curie. He is the most frequently mentioned Polish scientist in scientific and technical literature around the world.

If Prof. Czochralski had lived long enough to witness rapid growth in semiconductor electronics, chances are that he would have been the second Polish Nobel prize winner in the most prestigious field of exact sciences. Alas, the professor did not live to enjoy the splendors related to his invention. But we know that if it had not been for his method of growing single crystals, our lives would be indeed very different. ■