Special Anniversary Issue: Professor Jan Czochralski Year 2013 — Invited Paper

Jan Czochralski and His Method of Crystal Growth

This year we celebrate the 60th anniversary of the death of Professor Jan Czochralski. Recently, the Polish Parliament has given him tribute and established 2013 the Year of Jan Czochralski. The present issue of *Acta Physica Polonica A* is a contribution to these celebrations.

Jan Czochralski was born on October 23rd, 1885 in Kcynia, a small town in central Poland, located about sixty kilometers north-east of Poznań. After finishing education at a local high school, he left Kcynia and started to work in Berlin and later in Frankfurt am Main. After 24 years of work in Germany he came to Poland where he spent the rest of his life working in Warsaw and, after Second World War, in Kcynia.

From his earliest years, Czochralski liked chemistry experiments. After moving to Berlin in 1904, he worked in several laboratories and companies. During this period, he studied chemistry in Königliche Technische Hochschule in Charlottenburg near Berlin. In 1910, he married Marguerite Hasse, a pianist of Dutch origin. They had one son and two daughters.

In his professional life, Czochralski specialised in metal chemistry and his most important achievement was the introduction of aluminium for a broad use, in particular a component of alloys.

In Berlin, he worked in the laboratory of Kunheim and Co. and later in Allgemeine Elektrizitats-Gesellschaft (AEG) where he headed the laboratory. From 1911 to 1914, he was an assistant of Wichard von Mollendorff, a well-known metallurgist, technologist, then a vice-director of AEG. At this time he published, together with Mollendorff, the first scientific work on metallographic investigations of aluminum, iron, lead and copper. Jan Czochralski worked in AEG in Berlin until September 1917. A year before leaving AEG, in 1916, he wrote a paper on the crystal growth method, later named the Czochralski method. A historical outline of the Czochralski method (Cz-method) is presented in Fig. 1 and 2. The paper was received by the editorial board on August 19, 1916 and was published in 1918, with a two year delay [J. Czochralski, "Ein neues Verfahren zur Messung des Kristallisationsgeschwindigkeit der Metalle", *Z. Phys. Chem.* **92**, 219 (1918)]. In the scientific literature, the year 1916 was adopted as the date of elaboration of the method. The idea of Czochralski method is based on pulling a crystal from the melt against gravity forces — this feature contitutes an important difference in respect to other known crystal growth methods. Czochralski has grown single crystals of tin, zinc and lead by this simple method and investigated their rate of crystallization. The paper provided a description of a device which contained a silk thread with a holder and was completed with a glass rod. It can be deduced that part of the glass immersed in the molten metal was covered with a metal layer, and then the growth was continued. The obtained wires were of about 1 mm diameter and had up to 150 cm in length. The Cz method was improved and cited by some authors from the very beginning. For example, in 1918 Wartenberg used a seed zinc wire to grow the crystals of zinc. Later, in 1922, Gompez called this method for the first time the Cz method. Later, works describing the method were written by Mark et al. in 1923, by Sachs in 1925 and by others. It is worth noting that up to the Second World War, scientists were mainly interested in the properties of metals and their alloys, so mainly such crystals were grown at that time. After invention of germanium-based transistor in 1947, Gordon K. Teal from Bell Laboratory used the Czochralski method to obtain germanium single crystals. The first single crystal of germanium was obtained in 1948 and the

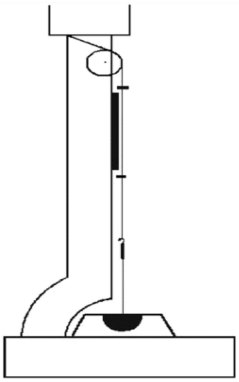

Fig. 1. From the paper: J. Czochralski, "Ein neues Verfahren zur Messung des Kristallisationsgeschwindigkeit der Metalle", *Z. Phys. Chem.* **92**, 219 (1918).

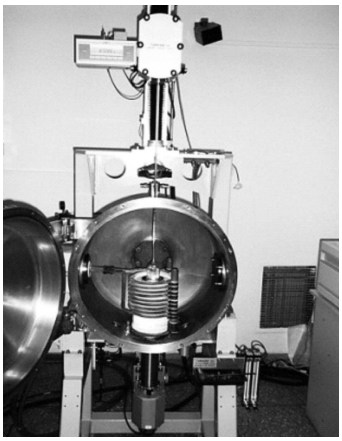

Fig. 2. Modern apparatus for the Czochralski method.

results were presented at the Oak Ridge Meeting of the American Physical Society in 1950, and were reported in G.K. Teal, *Phys. Rev.* **78**, 647 (1950). One of the sentences confirms the used method: "germanium single crystals of a variety of shapes, sizes and electrical properties have been produced by means of a pulling technique distinguished from that of Czochralski and others in improvement".

It should be noted that the Cz method of crystal growth is continuously improved and developed with regard to the technical level of process automation and including thermodynamic considerations of growth processes even today. It permits to prepare a high quality bulk single crystals, among them silicon, as well as a multitude of oxides, fluorides, metals and alloys, multicomponent compounds and solid solutions.

Now, the main advantages of the Cz method are growing single crystals in defined crystallographic orientations with different sizes, shapes which are mainly limited by a design of crystal puller.

After his stay in Berlin, in 1917 Czochralski moved to Frankfurt am Main. There, he continued his scientific work and organized the Laboratory of Metal Science of the Metal Gesellschaft A.G. This period is marked out by numerous achievements, such as a patent on "metal B", a tin-free bearing alloy in 1924, used in railway industry.

In 1919, Czochralski was one of the founders of the Deutsche Gesellschaft für Metallkunde. (German Metallurgical Society) and in the period of 1924-1929 he was its President. He was also a honorary member of the Institute of Metals in London.

In 1928, prof. Ignacy Mościcki, then President of the Polish Republic, chemist, professor at Warsaw University of Technology, convinced Jan Czochralski to return to his country of origin. In 1929, Czochralski received the title of doctor honoris causa of the Warsaw University of Technology. Soon, he was appointed the title and position of professor of Metallurgy and Metal Science Department at the Faculty of Chemistry at Warsaw University of Technology and then of the Institute of Metallurgy and Metal Science. He also founded the Metallurgical Section in the Chemical Research Institute. In Poland, he continued the studies of the rate of crystallization of metals, elastic properties, corrosion of metals and alloys.

Jan Czochralski collaborated with many companies and worked in a number of scientific societies. He was an active member of the Chemical Society and the Society of Polish Mechanic Engineers.

During his stay in Germany and in Poland, he obtained a number of valuable research results. He conducted structural investigations, his metallographic investigations required a development of new methods of etching. He constructed a radiomicroscope and optical apparatus for orientation of crystalline samples and for investigation of defects and detection of phases in polycrystalline samples.

The Second World War interrupted his scientific activities. He headed a workshop on-site of the (closed) University of Technology. After the war, the Senate of Warsaw University of Technology accused him of collaboration with nazis. Despite lack of evidence, in 1945 the Senate excluded him from scientific life of the country. Then, he moved to his native town Kcynia and together with his family founded a small enterprise, BION, which produced cosmetics and household chemicals. On 22 April, 1953, he died of a heart attack and was buried in his family grave in Kcynia.

In June 2011, the Senate of the Warsaw University of Technology adopted a resolution to restore the dignity of Professor Jan Czochralski and on December 7, 2012, the Polish Parliament adopted a resolution declaring 2013 as the Year of Jan Czochralski.

An important event connected with Professor Jan Czochralski is the International Conference for Crystal Growth, ICCGE-17, organized this year in Warsaw.

The Readers can find detailed description of Czochralski life and achievements on the PTWK Web Site: www.ptwk.org.pl and also in the new biography by P. Tomaszewski (English translation will appear in 2013).

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