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ON SOME STRIKING EXAMPLE OF JAN CZOCHRALSKI, AND HIS SCIENTIFIC ACHIEVEMENTS, ALLOWING TO UNDERLINE HIS YEAR 2013 IN POLAND

INTRODUCTORY REMARKS

Jan Czochralski (1885-1953) was born in Kcynia (Pałuki, Poland), and died unexpectedly in Poznań, after former Polish secret service action while at home [2,8]. Both towns are located in Greater Poland—in this region a special *ethos* of well-done work is often seen as an added value. Czochralski was born in Kcynia in 1885 when the small but old town belonged to the German part of the occupied Polish territory. At about 1903/1904 he left Kcynia commencing this way his own and independent, though really difficult adventure of becoming internationally recognized and famous researcher.

Let us assume that by the present study, the whole life story of Professor Czochralski is explainable to an educated person by his record of the research performed since one hundred years ago, and then until 1940 [1], fairly synthetized by FIGURE provided, and juxtaposed more carefully in a formal form of TABLE included. The practical type of research performed insightfully by Czochralski [2] was an exceptional masterpiece of those times because it has actually been done by a "freshman", or as the German people used to say, an *Autodidakt*. That is to say, a gifted and dilligent person who was able, being formally not really well educated, to teach himself; he was then capable of taking direct practical profit from such self-experienced teaching [2].

It is fair to emphasize that Jan Czochralski was a person who achieved a formal success in research, and its applications, at least in three subdisciplines of

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physicochemical metallurgy with which he has to be identified. One of those subdisciplines is inevitably going to be metal crystallization, and the determination of pulling the selected metallic crystals from a melt [3]. This has been continuously judged as his greatest achievement so much influencing the modern high-technology, involving presently the integrated microelectronic circuits, microprocessors, memory circuits, *etc.* [2]. The second subdiscipline appears to be the phase-change, metallic-systems addressing research, adopting the three-dimensional recrystallization phase diagrams, depicted in terms of strain-temperature and grain size of a final polycrystalline material output [4]. The third field of Czochralski's intense activity concerns the metal-surface science original research, especially the one performed about 1925, see TABLE, with the aid of by himself invented radiomicroscope, the device itself prospectively uncovering future scanning-tunelling and atomic-force spectroscopy principal ideas [5]. It served originally to scan directly the metal-piece surface in terms of determining its roughness by means of detecting the changes in acoustic wave reception by the researcher just listening to the surface structural asperities and metal (or, composite) roughness's supra-atomic peculiarities [2,5].

The aim of the present study is to shed more light on the research achievements by the well-known and respected researcher, Jan Czochralski, the achievements juxtaposed in a concise way in TABLE, upon inserting them within an appropriate historical and geopolitical context of the time interval of 1913-1940, provided that Czochralski performed 15 of 24 active research years, thus more than 60 percent, under German research administration. The remaining 9 years were under its Polish counterpart, while 4 years of his research activity, witnessed by both FIGURE and TABLE included, were remaining as more or less inactive or "mute", when looking carefully at four *0*-values included in the middle column of TABLE, in accordance with the internet source [1] provided recently by the Warsaw University of Technology; cf. the insert of FIGURE. In addition, there remains a certain hope coming from [2, 6-8] that those research years (1919; 1933-34; 1939) were not necessarily totally empty in terms of some at least minor and historical-context addressing activity of Czochralski, especially when the time span of the world's economic crisis in the beginning of the 1930s has to be pointed out [2,8], and then rediscovered within the body of TABLE.

CONCISE DATA-BASED DESCRIPTION (WITH A DISCUSSION) OF MAIN CZOCHRALSKI'S ACHIEVEMENTS

Let us accept for the moment that we are in a position to disclose the main subject of Czochralski's research when embarking thoroughly on the data contained in TABLE, and complemented by FIGURE attached.

Of course, TABLE contains much more data than FIGURE because it is designed in order to reveal properly the basic historical, and even entirely personal context, associated with Jan Czochralski during the time span of 1913-1940 covered by the present study.

First, the time period under consideration was full of bold-faced facts and many breathtaking historical events, being full of huge repercussions on human-being destination of one's life. As can be inferred from TABLE, such a property can be assigned to Czochralski's life addressing history, with very complex impact on him, and his family, even until the present time [8,2,6,7], cf. TABLE.

Second, when inspecting both graphical sources involved, one may read out from them that there is a publishing-irregularity (and, a slight repetition-bearing) matter almost biasing the TABLE contents, so well graphically uncovered by FIGURE, wherein the peak of Czochralski's research activity goes toward the really narrow two-year interval of 1936-37. It remains an interesting but separate topic to be debated why mostly other than those of that period research achievements, thus out of the span of 1936-37, are the ones of the greatest reception by the scientific community of interest? In other words, did Czochralski perform his research while in Germany more significantly in terms of its value than that performed after coming to Warsaw in 1929? Honestly speaking, it seems to the present author that while in Germany Czochralski succeeded more in terms of research value but he worked then really successfully as to plant the former success into Polish ground, the latter being actually substantiated by the greatest publishing achievements (1936-37), i.e. while working in Poland. There remained a legitimate though hardly answered question about the subsequent continuation of research by Czochralski (cf., WWII in TABLE) presumed that there would be no interruption of it by WWII [2,6-8] .

Next, there remains, however, a principal question of the present study to be answered, as to which main topic (or, a recent classification subject) did the Czochralski's research actually belong? The question is addressed reasonably since many people rediscover Jan Czochralski as chemist while others describe him as a metal-science (or, materials science) researcher, whereas some tell about him as a crystallographer. A certain minority of the present researchers, describe

him even as a technical physicist, and they also do not seem to be devoid of some justification at the point. (There are some that try to classify Czochralski as a member of pharmaceutical community—they may be right but from very early historical point of view, also indicating a before-dying episode of him when a pharmacy enterprise has been created by himself in his birth town Kcynia at the turn of the 1940s and the 1950s [2,7] after treating him very severely by the former Polish secret police [8].)

Summing up partly, when looking at TABLE one can see that all invoking properly Czochralski's research interest and activity may at least in part be right when answering the question. This view is justified by the column headed as 'Basic Subject/Area of Research'. When inspecting its contents it turns out that Czochralski's research can be most appropriately, according to the present author's best knowledge, assigned to the physicochemical metallurgy, provided that mechanical properties of metals and their alloys (and/or, the corresponding composites) belong to specific, though well-established, physical properties of the system under discussion [6]. By the way, the most fruitful time period (1936-37) of his research activity when he worked in Poland, confirms to a greatest extent such quite interdisciplinary-in-nature descriptive statement. According to our view, the contents of TABLE, being, in fact, a collection of Czochralski's life milestones, also corroborated at length by FIGURE in terms of its adequate graphical representation, immersed within those colorful and plenty-of-consequences (thus, really complex) historical-geopolitical contexts, fully approves for arguing the overall matter in such way proposed here.

It is, however, worth noting carefully that the most informative part of this section is built in the TABLE, and its contents (thus, to be analyzed by the reader on her/his own), also graphically accompanied by FIGURE, as far as the publication record analysis of Czochralski's achievements is concerned. Then, the reader should be able to uncover on her/his own the answer on the basic question raised herein. Anyway, an author's answer has been provided for fairly comparative reasons. The answer is included in the following, and it might be taken as not really univocal, though being of more interdisciplinary nature (thus, complex enough, with many so-called interfaces emerging between such subdisciplines involved [4]), which is the case advocated by the present author. In brief, none of the subdisciplines mentioned in the TABLE wins readily over the other but rather all (or both, meaning here applied physics and metal chemistry), as an entirely interdisciplinary research context, are actually the winners, supporting to a large degree the main Czochralski's achievements [3-5].

RESUME

By addressing an interdisciplinary rationale of the type proposed by the present study, it has been shown that Jan Czochralski, a very gifted but also severely touched by twentieth-century historical context personality, cf. the column headed by 'Juxtaposition of Relevant and Other Events Associated to Czochralski's Life' (TABLE), performed mostly his (sub)disciplines' synergy involving research as an overall activity being extremely well-immersed within physicochemical, and specifically, mechanochemical metallurgy, an (inter)discipline of very complex as well as truly practical systems that he was able to address, and then to comprehend, by his successful and rich-in-results, also very insightful investigations [1-7].

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NA TEMAT UDERZAJĄCEGO PRZYPADKU JANA CZOCHRALSKIEGO I JEGO OSIĄGNIĘĆ NAUKOWYCH POZWALAJĄCYCH PODKREŚLIĆ WAŻNOŚĆ ROKU 2013 DLA UPAMIĘTNIENIA TEJ POSTACI

S t r e s z c z e n i e

W pracy tej postawiono sobie pytanie, na które udzielono częściowej odpowiedzi, a mianowicie: do jakiego stopnia należałoby uważać postać Jana Czochralskiego, wybitnego i powszechnie znanego polskiego krystalografa, chemika oraz metaloznawcę, a także materiałoznawcę – jeśli posiłkować się jego dokonaniami naukowo-badawczymi – jako przedstawiciela metalurgii fizycznej (fizykochemicznej) lub traktować go jako („czystego") chemika, pracującego zgodnie z arkanami tej dyscypliny z metalami i ich zawierającymi domieszki i/lub zanieczyszczenia stopami? Rzeczywista podstawa do sformułowania odpowiedzi na tak zadane intrygujące pytanie polega na tym, że badacz wykonywał z sukcesem swoje badania naukowe głównie na styku obszarów metaloznawstwa, gdzie kontekst fizykochemiczny przenika się z jego mechanicznym, ale również chemicznym odpowiednikiem, co

podkreśla złożoność badanych przez niego układów, mających bardzo duże znaczenie praktyczne. Dokonano próby pokazania, że tak zaprojektowany typ badań powinien zostać opisany jako typ badań interdyscyplinarnych, w których manifestuje się synergizm poszczególnych (sub)dyscyplin, kształtujących te badania. Co zadziwiające, życie tego badacza w ówczesnym kontekście historycznym może stanowić gotowy zapis złożonego w swej naturze scenariusza, zawierającego sieć skomplikowanych wzajemnych połączeń jego indywidualnych aktywności życiowych, wskazujących na przyjmowanie przez niego wielu życiowych ról, jak choćby roli wynalazcy, profesora uniwersytetu, właściciela dóbr materialnych, inwestora, mecenasa sztuki, filantropa, jak również prawdziwie skromnego autora poezji czy też wreszcie męża i ojca trójki dzieci.

Streścił Adam Gadomski

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S u m m a r y

A question has been addressed, and then partly answered, namely, to what degree Jan Czochralski, an eminent and well-recognized abroad Polish crystallographer, chemist, and metallurgist, also a material (metal) scientist, should, when based on his achievements in research, belong to (physicochemical) metallurgy, or ought to be recognized rather as a ("pure") chemist, working in a chemical fashion with metals and their impurities-containing alloys. The actual ground for trying to answer the intriguing question, relies on the fact that he performed his research entirely within physicochemical, or specifically, mechanochemical metallurgy of complex as well as very practical material systems that he was able to resolve successfully by his treatments. Its has been attempted to show that his type of research should be described as interdisciplinary, thus, being synergistically intermingled amongst a few cross-disciplines of technological and basic research. Astonishingly, his historical-context sensitive life, can also be viewed as the one being well networked amongst many areas of his activity, drawing him as inventor, university professor, owner, investor, art supporter, philanthropist, as well as some truly modest poetry author, or finally, husband and father of three children.

Summarised by Adam Gadomski

Słowa kluczowe: interdyscyplinarne badania naukowe, synergizm badań naukowych, metalurgia fizyczna z krystalografią i chemią metali, sylwetka i biografia badacza, kontekst historyczny.

Key words: interdisciplinary scientific research, synergy of scientific research, physical metallurgy with metal crystallography and chemistry; researcher's profile and biography, historical context.

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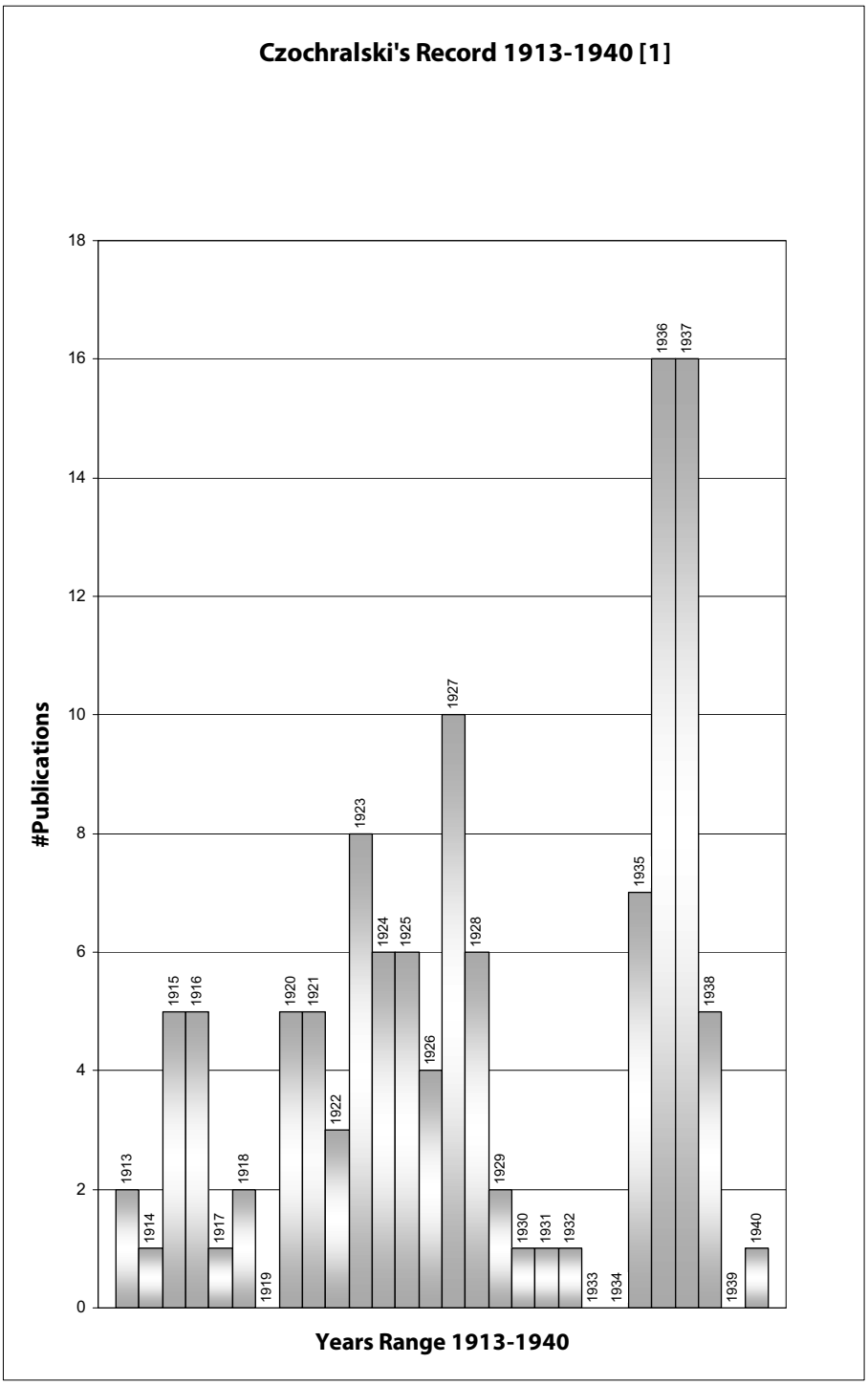
FIGURE: With historical and private events correlated research activity by the "freshman" Jan Czochralski, the very pioneer of crystal research [6,7], with his activity being lasted over ca. 28 years, and suffering from certain really small gaps in his publication record (see, TABLE; years 1933-34). The latter has been tightly related with the corresponding events, listed consecutively in TABLE, [1-8]. The total record of publications (co)authored by Jan Czochralski, while based on [1], amounts to a distinct number of 119. It could, however, be either slightly less or above [2] the value scored, cf. TABLE. The graph includes on its vertical axis the number of publications per year (co)authored by Czochralski [1], whereas on the horizontal axis the corresponding years within the span of 1913-1940 are marked by suitable colors, see the right-hand side legend's vertical bar as the insert to FIGURE.

The insert also shows four years of apparent Czochralski's research inactivity (years 1919;1933-34 and 1939) marked by letter "n" placed at the rear of each "mute" year; then, colors in the insert should be disregarded, or equivalently, taken as the background color. On the years horizontal axis the year 1929, marked by a light blue vertical bar has to be mentioned, pointing to the fact that with that year Czochralski started readily his research activity in Poland while finishing it in 1940, marked by an intense yellow vertical bar on the right-hand side far end of the years axis. Note that both years 1936 and 1937 were the years of a very distinct publication activity by Czochralski (mind the value of 16 items per year), likely associated with what has been offered to him by the Polish state of that time period, cf. TABLE. From 1928, and back to 1913, one anticipates very successful and by a few years longer than in Poland time span of Jan Czochralski's activity developed very fruitfully in Germany. Also realize that there are only a few years in which the number of Czochralski's publications did likely not exceed one. Nevertheless, Czochralski is commonly mentioned as the one being best worldwide recognized, also being one of the most cited Polish scientists ever [8]. The original FIGURE with the colors is available on request from Author/Publisher.


Czochralski's Record 1913-1940 [1]
#Publications
Years Range 1913-1940
0
2
4
6
8
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12
14
16
18
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TABLE: The set of data and events, containing 28 rows and 5 columns, expressing the scientifically most productive life-and-activity interval 1913-1940 of Jan Czochralski (1885-1953). Some specific notation inserts used in the TABLE ought to be explained to a reader – they are mainly contained in parentheses, and also indicated by italic. First, they may indicate that the number (#) of Czochralski's publications should increase by one. Second, they may show some repetitive matter in his publications because at Czochralski's times it was quite acceptable to publish the same matter at least twice within the same year due to its very novel character or large practical implications. And third, the patents (co)authored by Czochralski, thanks to which he might be taken as a relatively rich person (especially, when invoking the metal B, and the bearings used then by railway national companies [2,4,7]), have been indicated in the italic mode in fifth column, also marked by round parentheses. The column heading reads 'Remarks on the System Properties, and Other Additional Informations'.

Years (28) of Czochralski's Life and Research Activity	Juxtaposition of Relevant or Other Events Associated to Czochralski's Life	Number of Publications, in Accordance with [1]	Basic Subject/Area of Research	Remarks on the System Properties, and Other Additional Informations
1913	Three years after marriage, and almost ten years after coming to Berlin from Kcynia, and working then for A.E.G.	2	Chemistry of metal crystallization	Technologial means of crystallizing metals; chemical examination of *Al*
1914	Beginning of WWI	1	Metal mechanics	Structural translation viz straining as a cause of metal ductility
1915	Nothing special happened, abbreviated hereafter by N.s.h.	5	Physical chemistry of metals	Liveliness of metals; their thermal treatment; etching, a metallographic means as applied to metals; black colors of *Al* (#Repetition = 1.)
1916	N.s.h.	5	Metal mechanics and physical metallurgy	Pulling-out as a method of shaping and nobelizing metals; degree of graininess as a property of metals; phase transitions in metals and their alloys; metallography of *Sn* as applied to changing shapes of ductile metals
1917	October Revolution in Russia; moving from Berlin to Frankfurt on Main	1	Physical metallurgy	Change of grain size and structure in metals

	by Czochralski with his family, working then for *Metallbank und Metallgeselschaft*			
1918	End of WWI; independence of the Polish State, and appearence of Czochralski's major achievement as finally published [3], though first invented in August 1916 while working for A.E.G.	2	Mechanochemical propeties of metal (poly)crystals	Procedure of measuring the crystallization rate of metals; relation between durability and internal structure of cast iron
1919	N.s.h.	0	Physicochemical metallurgy (grain purification [2])	Polycrystal's grain purification *(#Publication = 1, cf.* [2]*, p. 195.)*
1920	First book by Czochralski on bearing metals, published with a Luxembourg engineer, G. Welter; offensive of Russian Army on Poland, stopped at Vistula river close to Warsaw by the Army of Polish Independent State	5	Chemistry of doped metallic systems under phase-change and external influence	Small *Al* contribution effect on the brass II; bearing metals; blackness of *Al* dish; *Zn* alloy; phase diagram of *Pb-Ba* system
1921	N.s.h.	5	Phase-change properties of doped metallic systems, and their alloys, a physicochemical approach	*Sb/ As / Pb* influencing bronze properties; light alloys; phase diagrams for alloys
1922	N.s.h.	3	*As above (toward physical chemistry)*	*Bi* influencing bronze properties; solubility of gases in *Al*; applications of *Al*
1923	Czochralski's proposal on recrystallization diagrams of metals [4], drawn in terms of strain-, grain-size and temperature conditions applied	8	Mechanochemical propeties of metals as revaealed by *X*-ray application	Principles of strengthening of metals; nobelizing the *Al-Si* alloys; *X*-ray examination of metal straining
1924	Metal B patented in Germany; second book on theory and practice of metal science [4], published by Czochralski as single author	6	*As above (toward mechanochemistry)*	Metal straining by X-ray examination; *Si* and *Fe* effect on *Al* properties; elasticity of metals; bearing alloys; practical metallurgy as a whole
1925	Czochralski's radiomicroscope constructed in Frankfurt on Main [5]	6	Surface science	Dislocated reflection on metal surface; metal surface

				radiomicroscopy (Patent(#1).)
1926	N.s.h.	4	Chemistry of metals	Metal structure
1927	Metal B patented in Poland; being a director of a big world exhibition in Berlin on achievements in materials research and development; Czochralski's trip to the USA/Detroit on invitation of Henry Ford	10	Physical metallurgy	Recrystallization; Nobelizing; *Pb-Li* alloys (Patent(#3).)
1928	Unexpectedly finishing the job by Czochralski at *Metallbank und Metallgeselschaft*	6	Mechanics of metals	Breaking up a durable piece of metal; *X*-ray research; fatigue properties affect their mechanical counterpart
1929	Coming to Warsaw on the invitation of the Polish President, Ignacy Moscicki, and heading a metallurgical department at the Warsaw University of Technology/W.U.T., after receiving honorary doctorate, becoming a professor of W.U.T.	2	AS ABOVE	None more as the ones above
1930	Real beginning of the world's big economic crisis	1	Chemistry of metal alloys	Noble bronzes
1931	N.s.h.	1	Engineering	Economic crisis and engineering (Patent(#1).)
1932	N.s.h.	1	History of technics	Technics musea in Poland and abroad (Patent(#1).)
1933	N.s.h.	0	AS ABOVE	Nothing more than above
1934	Real end of the world's big economic crisis	0	Metal science and engineering (editorial note on metals [2])	Nothing more than above (*#Publication = 1*, cf. [8], p. 200.)
1935	Increasing the real property by Czochralski, and making some investments, necessary for his mecenate; accepting the position of an editor to a well-established Polish professional journal,	7	Physical chemistry of metallic systems with nonmetallic inclusions	Nonmetallic inclusions in metal; *Fe*, *Mn* and *Fe-Mn* dissolution in molten *Cu*; brasses and bronzes devoid of oxygen; electrolytic

	Przegląd Mechaniczny (Mechanical Review) - after translating the name from Polish			rafination of *Al* in molten chlorides; *Cd* recrystallization; steel corrosion and influence of inclusions and that of thermal treatment
1936	The greatest Czochralski *et al.* score in terms of the publication number, entirely published in Polish, very often with foreign-language abstracts	16	Mechanochemistry of metals, and their alloys	Metal B as applied to bearings; hardness of anisotropic *Zn* crystals; *Na* crystallization; atomic heat of crystallization versus its rate; recrystallization of *Zn*; *Pb* bronzes; alkali metals versus silumin; high-purity *Al* crystallization rate, and its corrosion; third component influence on *Pb* alloy structure with *Fe*, *Ni* and *Co*; *Sb* recrystallization; inclusions in steel; thermal self-recovery of *Al* alloys; *Hg* affected corrosion of *Al* alloys
1937	As in 1936, thus, almost repeated, see last column, as the greatest Czochralski *et al.* publication score, with the only one paper not published in Polish	16	Physical and chemistry-involving metallurgy	*Bi* recrystallization; nobelizing of silumin by alkali metals; recrystallization diagram of *Al* bronzes; *Ag* recrystallization; brass corrosion in *N*-containing atmosphere; crystallographic orientation of metallic crystals; thermal self-recovery, and its theory (#Repetition = 3.)
1938	N.s.h.	5	AS ABOVE	Purification of *Al* alloys; electrolytic extraction of *Al* from molten chlorides; *Ca* recrystallization

1939	Beginning of WWII; a huge disruption of research and scientific activity in W.U.T.	0	Physical and chemistry-involving metallurgy, including *AI* research in Poland [2]	Nothing more than above (*#Publication = 1*, cf. [2], p. 202.)
1940	End of Czochralski's activity in terms of his publishing achievements; no permission from the occupants of Warsaw for W.U.T. administration to prolong any normal activity of University	1	AS ABOVE	*AI* research (in Poland and abroad), and its results