A semianalytic study on: To what extent metal science wins over chemistry (or, vice versa) when based on some illuminating example of Jan Czochralski while celebrating his Year 2013 in Poland?

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Some preliminary address

The comprehensive life story of Professor Jan Czochralski (1885–1953) is to be explained to a researcher by his record of the research performed quite more than one hudred years ago and thereafter until 1940 [1]. The research done by Czochralski [2] was an exceptional and unique scientific attempt of those times because it has actually been done by a "freshman", or as the German people used to say, an *Autodidakt*, namely a gifted and skilful person who was able, being formally not strongly educated, to teach himself, and was then capable of taking direct practical advantage of such intense self-teaching [2].

Jan Czochralski was a person who achieved a formal scientific success in at least three subdisciplines of physicochemical metallurgy to which he might clearly belong. 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 considered as his greatest achievement, so much influencing the modern high-technology, involving the integrated microelectronic circuits, microprocessors, memory circuits, and the likes [2]. The second subdiscipline appears to be the phase-change, metallic-systems involving research, adopting the recrystallization phase diagrams, depicted in terms of strain- temperature and grain size of a final polycrystalline material outcome [4]. The third area of Czochralski's activity concerns the metal-surface science original research, especially the one performed around 1925 with the aid of on-his-own invented radiomicroscope, the device itself apparently uncovering future scanning-tunelling and atomic-force microscopy basic ideas [5]. It served to scan the metal-piece surface in terms of determining its roughness by means of detecting the changes in acoustic wave reception by the investigatior performing the type of research [2, 5].

The aim of the article is to shed a thorough light on the research achievements by the well-known and respected researcher, Jan Czochralski, the achievements juxtaposed in Table 1 provided below, upon placing them within an appropriate historical and geopolitical context (see, Tab. 1 contents), assumed that Czochralski performed 15 of 24 active research years under German research administration, and the remaining 9 years under its Polish counterpart, while 4 years of his research activity, witnessed by both Table 1 and Figure 1 included within the present text body, were remaining as more or less inactive, when looking at four zeros (*0*-values) provided by the middle column of Table 1, in accord with the internet source [1]. In addition, there remains a certain hope coming from [2] that those research years were not necessarily totally empty in terms of some at least minor and historical-context addressing activity of Czochralski, especially when the time interval of the world's economic crisis in the beginning of the 1930s has to be indicated [2], and rediscovered within Table 1.

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Brief descritption of main Czochralski's achievements with their discussion

Let us take for granted that we are in a position to uncover the main-subject of Czochralski's research when embarking on the data provided by Table 1, and complemented by Figure 1 provided.

Of course, Table 1 contains much more data than Figure 1 because it is designed as to reveal properly the basic historical and immersed-personal context associated with Jan Czochralski during the time span of 1913–1940.

First of all, the time span was full of decisive facts and many breathtaking historical events, being full of huge reprecussions on one's destination in life. As can be inferred from Table 1 such a property is assigned to Czochralski's life addressing history, with very complex impact on him and his family, even until the present time [6-8].

Secondly, when looking at both graphical sources involved, one may infer from them that there is a publishing-irregularity (and slight repetition-bearing) matter involved in the Table 1, so well graphically unravelled by Figure 1, where the peek of Czochralski's research activity goes toward the narrow interval of 1936–37. It remains a solid but separate topic to be debated why mostly other than those of that period research achievements are the ones of the greatest reception by the scientific community of interest. In other words, is Czochralski's research while in Germany more worthy in terms of its value than that performed after coming to Warsaw? Frankly, it seems to the present author that while in Germany, Czochralski succeeded more in terms of research value but he worked really successfully as to plant the former success into Polish ground, the latter being substantiated by the greatest publishing achievemenets while working in Poland. The question remains, in general, unanswered, since Czochralski's activity has finally been interrupted by the World War II (cf., WWII in Tab. 1) overwhelming and negative influence [2, 6, 7].

Thirdly, there remains a principal question of the present study to be answered, as to which main topic did Czochralski's research ultimately belong? The question is legitimate to pose since many people discover Czochralski as chemist while others describe him as a metal-science researcher, whereas some speak about him as a crystallographer; a minority of nowadays' researchers describe him even as a technical physicist, and they also seem not to be devoid of some right on the subject-matter addressed. (There are some that classify Czochralski as a member of pharmaceutical community – they may be right form very early historical point of view, also indicating before-dying episode of him, when a pharmacy enterprise called Bion was created by him in his birth place in Kcynia at the turn of the 1940s and 1950s [2, 7].)

Summing up in part, when looking at Table 1, one can see that all invoking properly Czochralski's research interest and activity may be right. This is confirmed by the column headed as 'Main Subject or Area of Research'. From its contents it follows that Czochralski's research can be most appropriately, according to the present author's knowledge, assigned to the physicochemical metallurgy, presumed that mechanical properties of metals and their alloys (and/or, composites) belong to specific, though well-established, physical properties of the system under consideration [6]. By the way, the main fruitful time period (1936–37) of his research activity, when working in Poland, confirms in full a quite interdisciplinary-in-nature descriptive statement. In our opinion, the contents of Table 1, being, in fact, a collection of Czochralski's life milestones, also corroborated by Figure 1 in terms of its adequate graphical depiction, immersed within those colorful and pleanty-of-consequences (thus, really complex) historical-geopolitical contexts, fully approve for arguing the overall matter in such way.

It is, however, worth to note unequivocally that the most informative part of this section is built in the Table 1, and its contents (thus, to be analyzed by the reader on her/his own), also graphically emphasized by Figure 1, as far as the publication matter analysis of Czochralski's achievements has been concerned. Then, the reader is able to discover for her- or himself the answer to the question involved in the article's title. Anyway, the author's answer has been provided for comparative reasons. The answer is included in the following, and it might be taken as not really unique, though being of more interdisciplinary nature, which is really the case advocated by the present author. Namely, none of the sciences mentioned in the title wins readily but rather both, as an entirely interdisciplinary science, are actually the winners.

Table 1

The so-prepared collection of events and data, containing 28 rows and 5 columns, is going to express semi-quantitatively the scientifically most productive life span of Jan Czochralski (1885–1953), who was born in Kcynia, and died unexpectedly (after former Polish secret service action while at home [2, 7]) in Poznań, both of the towns located in central part of Poland, namely in Greater Poland; Czochralski was born Kcynia in 1885 when the small town belonged to the German part of the occupied Polish territory. Some specific notation applied to the Table 1 ought to be explained to a reader – they are mainly contained in parentheses, and 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 it has been customary to publish the same matter at least twice within the same year due to its very novel character or large practical consequences. 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, and within the round parentheses. It is entitled by 'Remarks on the System Properties, and Other Additional Informations'.

Year series(*i*), i=1,...,28	Publication Year, with a Recognition of Important Events Associated	No. of Publications According to [1]	Main Subject or Area of Research	Remarks on the System Properties, and Other Additional Informations
1	1913 (three years after marriage, and almost ten years after coming to Berlin, and working then for A.E.G.)	2	Chemistry of crystallization of metals	Technologial means of crystallizing metals; chemical examination of *Al*
2	1914 (beginning of WWI)	1	Metal mechanics	Structural translation viz straining as a cause of metal ductility
3	1915 (nothing special happened, abbreviated as n.s.h. hereafter)	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.)
4	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
5	1917 (October Revolution in Russia; moving from Berlin to Frankfurt am Main by Czochralski with his family, working then for *Metallbank und Metallgeselschaft*)	1	Physical metallurgy	Change of grain size and structure in metals
6	1918 (end of WWI; independence of the Polish State, and appearence of Czochralski's major achievement as finally published [3], though 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
7	1919 (n.s.h.)	0	Physicochemical metallurgy (grain purification [2])	Polycrystal's grain purification *(#Publication = 1, cf.* [2], *p. 195.)*
8	1920 (first book by Czochralski on bearing metals, published with a Belgian engineer, G. Welter; offensive of Russian Army on Poland, stopped at Vistula river close to Warsaw by the Army of Polish Independent State, conducted by J. Pilsudski)	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
9	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
10	1922 (n.s.h.)	3	As above (toward physical chemistry)	*Bi* influencing bronze properties; solubility of gases in *Al*; applications of *Al*

11	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
12	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
13	1925 (Czochralski's radiomicroscope constructed in Frankfurt am Main [5])	6	Surface science	Dislocated reflection on metal surface; metal surface radiomicroscopy (Patent(#1)
14	1926 (n.s.h.)	4	Chemistry of metals	Metal structure
15	1927 (metal B patented in Poland; being a director of a big 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)
16	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
17	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
18	1930 (real beginning of the world's big economic crisis)	1	Chemistry of metal alloys	Noble bronzes
19	1931 (n.s.h.)	1	Engineering	Economic crisis and engineering (Patent(#1)
20	1932 (n.s.h.)	1	History of technics	Technics musea in Poland and abroad (Patent(#1)
21	1933 (n.s.h.)	0	As above	Nothing more than above
22	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. [2], p. 200)
23	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, Mechanical Review - after translating the name from Polish)	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 rafination of *Al* in molten chlorides; *Cd* recrystallization; steel corrosion and influence of inclusions and that of thermal treatment
24	1936 (the greatest Czochralski *et al.* score in terms of 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
25	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 od 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)
26	1938 (n.s.h.)	5	As above	Purification of *Al* alloys; electrolytic extraction of *Al* from molten chlorides; *Ca* recrystallization
27	1939 (beginning of WWII; a huge disruption of research and scientific activity in W.U.T.)	0	Physical and chemistry-involving metallurgy, including *Al* research in Poland [2]	Nothing more than above (*#Publication = 1*, cf. [2], p. 202)
28	1940 (end of Czochralski's activity in terms of his publishing accomplishments; no permission from the Warsaw occupants for W.U.T. administration to prolong any normal activity of University)	1	As above	*Al* research (in Poland and abroad), and its results

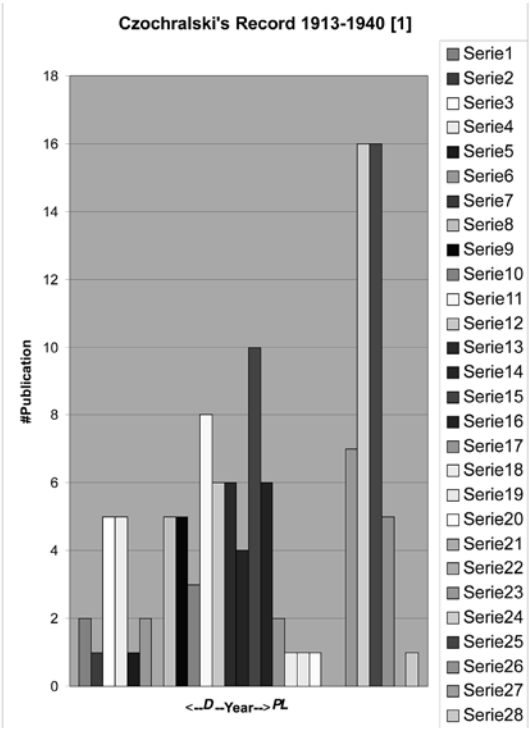

Fig. 1. Research activity of the „freshman" Jan Czochralski, the pioneer of crystal research [6], lasted over ca. 28 years, expressing some really small gaps in his publication record (see, Tab. 1) the latter being inevitably related with the corresponding historical events, listed consecutively in Table 1, and associated with Czochralski's overwhelming research activity [1–7]. (The total record of publications (co)authored by Jan Czochralski, while based on [1], amounts to a bare number of 119; it might, however, be either slightly less or above [2] the value set, cf. some information in Table 1.) The plot includes on the vertical axis the number of Czochralski's (co)authored publications per year [1], whereas on the horizontal axis the corresponding years within the (year) span of 1913–1940 are marked in suitable colors, see the r.h.s. legend attached. The horizontal (sub)axis also involves the information that a vertical bar (Serie 17; cf. r.h.s. legend of Series), pointing to the year 1929, started readily Czochralski's research activity in Poland (PL) upon finishing it in 1940 (mind the horizontal right arrow, reflecting this tendency). Note that both years 1936 and 1937 were the years of immense publication activity of Czochralski (notice 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 1. Since 1928, and back to 1913, one anticipates very successful and quite a bit longer than in Poland time period of Jan Czochralski's activity expressed very fruitfully in Germany (denoted by the horizontal axis beneath by *D*, following by left-hand arrow). Also note that there are a few years in which the number of Czochralski's publications did likely not exceed one, an attitude not well accepted in really hard-to-survive present publication efforts in modern science and research sector, describable by Hirsch index, and the likes. By the way, Czochralski is commonly mentioned to be one of the best recognized, also most cited persons ever, representing the Polish science as a whole [2].

Summary

By performing a study of the type proposed herein, it has been attempted to show that Jan Czochralski, a very talented and deeply touched by twentieth-century historical context personality, cf. the column headed by 'Publication Year, with a Recognition of Important Events Associated' (Tab. 1), did his research as extremely well-immersed within physicochemical, and specifically, mechanochemical metallurgy, a discipline of very complex as well as truly practical systems that he was able to both address, and comprehend, by his successful and rich-in-results, very prominent investigations [1–7].

Literature

1. Internet address, available from the Warsaw University of Technology, on the day of writing the article, at *http://bcpw.bg.pw.edu.pl/dlibra/docconten t?id=3410&dirids=1*.
2. Tomaszewski P.: *Powrót. Rzecz o Janie Czochralskim [freely translated from Polish as: Jan Czochralski. Restored]*. Oficyna Wydawnicza ATUT & INTiBS PAN. Wrocław, 2012 (in Polish).
3. Czochralski J.: Zeitschrift für physikalische Chemie **92**, 219 (1918).
4. Czochralski J.: *Moderne Metallkunde in Theorie und Praxis*. Verlag von Julius Springer. Berlin, 1024 (in German).
5. Czochralski J.: Zeitschrift für anorganische und allgemeine Chemie **144**, 263 (1925).
6. Gadomski A.: Chemik **57/1**, 26 (2004).
7. Gadomski A.: Europhysics News **42**, 22 (2011).
8. Prusak P.: *Przywrócony Pamieci [freely translated from Polish as: Got Back to Recognition]*. Wydawnictwo Pejzaz, Kcynia-Bydgoszcz, 2013 (in Polish).

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KONKURSY, STYPENDIA, STAŻE

Stypendia na START

136 młodych uczonych, którzy mogą pochwalić się własnym dorobkiem naukowym nagrodzono w 22. edycji programu Start – Fundacji na rzecz Nauki Polskiej. Każdy z nich otrzyma stypendium w wysokości 28 tys. PLN, które może przeznaczyć na dowolny cel.

W ramach stypendium START Fundacja przyznała również specjalne wyróżnienia dla najwyżej ocenionych w konkursie kandydatów. Podstawowym kryterium przyznawania wyróżnień jest wyjątkowo wysoka jakość dorobku naukowego kandydatów, uznana przez recenzentów konkursu za wybitną. Stypendia wyróżnionych laureatów zostaną podwyższone do 36 tys. PLN.

W tym roku po raz pierwszy przyznano także Stypendium im. Barbary Skargi – osobie której dorobek naukowy i plany badawcze, przedstawione w konkursie o stypendium START zostały bardzo wysoko ocenione, wyróżniają się odważnym przekraczaniem granic pomiędzy różnymi dziedzinami nauki, otwierają perspektywy badawcze i tworzą nowe wartości w nauce. (*em*)

(http://www.naukawpolsce.pap.pl/aktualnosci/news,400198,136-mlodych-uczonych-otrzyma-stypendia-na-start.html, 5.05.2014r.)

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