Monika Walkowicz, PhD, Eng.
AGH University of Science
and Technology in Kraków
Faculty of Non-Ferrous Metals
al. A. Mickiewicza 30, 30-059 Kraków

Summary of Professional Accomplishments

presenting a description of the scientific achievement, in particular those referred to in Article 16 Section 2 of the Act of 14 March 2003 On Academic Degrees and Academic Title and on Academic Degrees and Title in the Arts

Kraków 2019

1. First and Last Name

Monika Walkowicz

2. Diplomas, scientific degrees held – with the name, place and year of their acquisition and the title of the doctoral dissertation

PhD in technical sciences (dissertation awarded by the Council of the Faculty of Non-Ferrous Metals)

Major:	Metallurgy
Speciality:	Plastic Processing
Title of the dissertation:	"The impact of casting parameters on the formation of material characteristics in oxygen-free copper for highly advanced applications in electronics and electrical engineering"
Date of doctoral defence:	26.03.2013
Place of doctoral defence:	AGH University of Science and Technology in Kraków, Faculty of Non-Ferrous Metals
Thesis supervisor:	Prof. Tadeusz Knych, PhD Eng.
Reviewers:	Prof. Ferdynand Romankiewicz, PhD Eng. (University of Zielona Góra) Prof. Józef Zasadziński, PhD Eng. (AGH)

Master of Science in Engineering

Major:	Production Management and Engineering
Speciality:	Engineering of Production and the Use of Non-Ferrous Metals
Title of the paper:	"Parametrisation of material properties of ETP copper from the Contirod line and OFC copper from the Upcast line subjected to heat treatment and deformation processes"
Date of doctoral defence:	27.06.2008
Place of doctoral defence:	AGH University of Science and Technology in Kraków, Faculty of Non-Ferrous Metals
Thesis supervisor:	Prof. Tadeusz Knych, PhD Eng.
Reviewer:	Beata Smyrak, PhD, Eng., Associate Professor

3. Information on previous employment in research units

Assistant Professor

AGH University of Science and Technology in Kraków, Faculty of Non-Ferrous Metals, Department of Metal Working and Physical Metallurgy of Non-Ferrous Metals
01.12.2017 – currently

Assistant

AGH University of Science and Technology in Kraków, Faculty of Non-Ferrous Metals, Department of Metal Working and Physical Metallurgy of Non-Ferrous Metals
01.06.2013 – 30.11.2017

4. Indication of an achievement resulting from Article 16 Section 2 of the Act of 14 March 2003 On Academic Degrees and Academic Title and on Academic Degrees and Title in the Arts (Journal of Laws of 2017, item 1789):

a) Title of scientific achievement

Monograph entitled "Antimicrobial copper. Materials – Touch surfaces – Applications"

b) Author/authors, title/titles of publication, year of publication, name of the publishing house, editorial reviewers

Author:	Monika Walkowicz
Title:	"Antimicrobial copper. Materials - Touch surfaces - Applications"
Year of publication:	2018
Name of publisher:	Oficyna Wydawnicza „Impuls”
Editorial reviewers:	Barbara Juszczyk, PhD Eng., Institute of Non-Ferrous Metals, Gliwice Prof. Elżbieta Anna Trafny, MD, PhD, Military University of Technology, Warsaw

c) Discussion of the scientific purpose and results achieved, discussing their use

The scientific goal of the paper was an experimental analysis of a broad context of material issues related to the practical use in public places of products with copper touch surfaces with antimicrobial properties. The scope of the monograph covered the most sensitive problems which, with the appearance of antibacterial copper and its alloys on the market, were noticed by various groups of its customers - both metallurgical and processing plants producing copper-matrix materials, manufacturers of medical equipment, as well as hospital personnel - and indicated as necessary to be resolved. The importance of the issues discovered resulting largely from the material nature of copper and its alloys, in relation to which analyses of source literature and experimental research have been undertaken, resulted from their direct impact on both social perception and the subsequent placement of antibacterial copper products on the market. Therefore, it was aimed at undertaking a theoretical-empirical study to determine the possibility of meeting the high requirements of this very specific market in relation to antimicrobial copper.

Problems in the field of metallurgy and material engineering discussed in the paper, including surface engineering in the context with aspects of microbiological tests of antimicrobial effectiveness included five groups of issues relating to copper products with antimicrobial properties already installed in public places and resulting directly from the working conditions that these surfaces are subjected to on a daily basis. They were also related to their direct influence on the effectiveness of the metal in the elimination of bacteria. Firstly, the dissertation analyses one of the most alarming issues, namely oxidation, i.e. corrosion of copper and its alloys, caused both by contact with human hands and atmospheric air, depending on the place of installation of antibacterial objects, chemical composition, and its measurable effect on the metal's effectiveness in the elimination of microorganisms. Secondly, taking into account the selection of the right alloy for copper antimicrobial surfaces, as a response to the suggestion that this role would be perfectly met by copper/nickel alloys with improved corrosion resistance, which have been successfully used worldwide for coin production for years, considerations focused on the problem of allergenic release (to the human skin) of nickel from Cu alloys containing this element. Thirdly, the focus was on the issue of machining copper-based materials mainly in terms of the impact caused by working conditions of scratching the surface on antimicrobial effectiveness. The paper also analyses the topic of surface wettability of copper and its alloys (hydrophobic and hydrophilic) mainly in the context of its role in microbiological antimicrobial tests. The whole of literature and experimental dissertations was complemented with the characterisation of the impact of different active substances contained in the disinfectants used in Polish healthcare units on the corrosion resistance of copper and its alloys.

The first of the aspects discussed in the paper concerned oxidation, which is related to the natural susceptibility of copper and its alloys to the reaction with the surrounding environment, whether natural or artificial. At ambient temperature, copper, reacting with the oxygen contained in the air, consequently darkens and loses its metallic gloss. This is the result of the formation of a corrosion layer on its surface containing copper (II) oxide CuO and/or copper (I) oxide Cu_2O in its chemical composition, among other compounds. This issue becomes even more important if we consider the fact that copper touch surfaces are intended for direct contact with human hands, which is a highly corrosive solution, among others, of sodium chloride. In connection with the above, one of the most frequently asked questions regarding the antimicrobial properties of copper and its alloys is whether and how the oxidation of the surface affects the antimicrobial performance of the metal. This monograph shows the results of experimental research on this issue, whereby the analysis of the problem and the method of solving it are presented in two aspects, i.e. both in terms of corrosion due to human hand sweat and due to atmospheric corrosion. The deliberations began with adopting a thesis that in order to precisely determine the antibacterial abilities of surface layers formed on copper and its alloys, either as a result of their contact with human skin or atmospheric air of various types (e.g. marine atmosphere or a specific environment of a hospital ward rich in high concentrations of chloride ions), it is first necessary to precisely determine the conditions for their formation and to perform a comprehensive analysis of their morphology and chemical composition. In addition, the study of the problem is supported by the knowledge that under laboratory conditions, the aforementioned outer layers with properties (chemical composition, thickness) corresponding to the layers formed on the surfaces of copper alloys used under real conditions can be reproduced by controlled thermal processing and/or chemical treatment. Therefore, as part of own research on the subject of corrosion of copper and its alloys, layers were formed on the surface of various Cu-matrix materials to simulate layers formed on copper alloys under actual conditions of use. Subsequently, commercial copper alloys, i.e. ones which due to strength and functional properties can be used in the form of finished products with touch surfaces, described in this manner in terms of material properties of surface layers, were subjected to microbiological testing of antimicrobial effectiveness in contact with bacterial strains most commonly found on touch surfaces both in public places, as well as healthcare centres in Poland.

The tests began with laboratory tests simulating the contact of copper touch surfaces with active substances contained in human sweat. The main premise of undertaking the work was the need to answer the question about the surface condition of Cu-matrix materials after short and long-term contact with this highly corrosive mixture. Therefore, the planned methodology included both tests carried out in the solution, as well as in the atmosphere of synthetic sweat imitating/simulating human sweat. As a result of experiments carried out in accordance with standards PN-EN 1811 and PN-ISO 3160, the corrosion resistance of copper-matrix materials was evaluated, and then the layers formed in the manner on flat samples were subjected to structural analysis using scanning electron microscopy. Describing the testing procedure corresponding to the above standards in more detail, it should be noted that in accordance with the first of the standards (EN 1811), the tests included immersion tests of copper alloys (and for comparison purposes of other metallic materials - mainly those constituting main additives in Cu alloys) in the solution consisting of urea (CH_4N_2O), sodium chloride (NaCl), lactic acid ($C_3H_6O_3$) and sodium hydroxide (NaOH), which is necessary to obtain a pH equal to 6.5. According to the requirements of the standard, the test was carried out at the temperature of 30°C for a duration 168 hours, i.e. 7 days, but in order to obtain a more comprehensive knowledge of the effect of salt and acidic agents on the surface of copper and its alloys, the tests were extended by adding short and long-term tests, from 15 minutes to 336 hours, i.e. 14 days. In turn, the second corrosion test - based on the methodology specified in the ISO 3160 document - included tests of the same materials, but this time it was conducted in the atmosphere of artificial sweat. The test solution above which samples of metallic materials have been suspended, prepared in accordance with the requirements of the aforementioned standard, consisted of sodium chloride (NaCl), ammonium chloride (NH_4Cl), urea (CH_4N_2O), acetic acid (CH_3COOH) and lactic acid ($C_3H_6O_3$) as well as sodium hydroxide (NaOH), used for the purpose of obtaining a pH value of the solution equal to 4.7. The tests, lasting in accordance with the methodology specified in ISO 3160 for 24 hours at the temperature of 40°C, were extended with tests carried out with a duration from 15 minutes to up to 1 year.

The experiments showed that despite the similar chemical composition of the solution and atmosphere of synthetic sweat, the surfaces of the materials tested in these two different tests differentiated in terms of overall appearance (aesthetics), chemical composition and surface morphology of the corrosion layer. It was observed that tests carried out in the atmosphere of artificial sweat were, due to the nature of the layers formed, much more invasive tests, i.e. interfering with the general surface condition of copper alloys, in comparison to the tests that were carried out in submersion of samples in a solution of synthetic sweat. Nevertheless, as a result of both tests, different susceptibility of materials with different copper content and individual alloy additives was found to the intensity of surface corrosion. For example, in the test conducted in submersion of samples in a solution of synthetic sweat (i.e. in accordance with standard EN 1811) it was found that the highest resistance was demonstrated by CuZn37 brass, on the surface of which corrosion occurred only in some places. The UNS C274 alloy has also retained an unchanging metallic lustre throughout the duration of the test, i.e. up to 2 weeks. At the same time, it was observed that the surface of high-temperature alloys (CuSn6, CuZn15) in terms of corrosion products became visually similar to pure copper (these materials reacted by changing their characteristic brown colour to pink). Also high nickel alloys (i.e. CuAl10Ni5Fe4, CuNi10Fe1Mn, CuNi18Zn20, CuNi12Zn20), which due to their additives (i.e. Ni, but also Al and Zn) are considered more resistant to corrosion, after the test they became dull and completely covered with precipitates. Analysing the results of tests conducted in the atmosphere of artificial sweat (according to standard ISO 3160), it can be concluded that all materials lost their lustre and became dull. The turquoise spots observed on the surface of copper and its alloys were the result of the presence of copper chlorides. The CuZn37 brass, which in the test submerged in a solution of synthetic sweat showed the highest corrosion resistance, in tests in the atmosphere according to standard ISO 3160, changed the colour of its surface to pink and additionally was covered with a pink-white precipitate. After the year-long test, all materials selected for testing were covered with turquoise and white corrosion products (UNS C274).

After finishing the submersion tests and tests in the atmosphere of artificial sweat, the metal samples were rinsed in demineralised water, air dried and subjected to observations by means of scanning electron microscopy (SEM). After the submersion test lasting a maximum of 14 days (336 hours) it was found that the surface of the corrosion layer on Cu-ETP copper (UNS C110), CuZn15 brass (UNS C230) and CuZn37 (UNS C274) as well as on CuSn6 tin bronze (UNS C519) is smoother than in the case of CuAl10Ni5Fe4 aluminium bronze (UNS C706), CuNi10Fe1Mn copper nickel (UNS C706) and CuNi18Zn20 (UNS C752) and CuNi12Zn24 nickel silvers (UNS C757), in which the corrosion products have a rougher structure. The main reason for this is the formation of surface layers with irregular morphology by copper oxides and chlorides and other alloy additives, which was demonstrated in the chemical composition tests using the EDS method. It is worth noting that the outer layers, which were formed after the year-long test in the atmosphere of artificial sweat on the surface of all copper-matrix materials, were much more uneven and rough compared to the films formed as a result of the submersion test of the samples in the artificial sweat solution. Their turquoise colours on all materials, except for CuZn37 brass, confirmed on the basis of EDS analysis, proved that they are copper chlorides as well as oxides. UNS C274 brass became coated with white zinc oxide (ZnO), which was also confirmed in the EDS microanalysis.

Summarising the results of preliminary corrosion tests of copper and its alloys, as well as of other metallic materials for comparative purposes, which were carried out both in solution and in the atmosphere of a highly invasive environment of synthetic sweat, it was found that they provided practical information on the corrosion resistance of metallic materials subjected to the impact of a solution that imitates human sweat, thus being an indispensable starting point for further deliberations on the title issue of the effect of the copper surface on its antimicrobial properties. In the light of only estimated results of the chemical composition of surface layers on copper and its alloys, and in the face of the need for a precise answer to the question of what are the properties (chemical composition, thickness) of the corrosion layers formed on antimicrobial copper touch surfaces as a result of their daily and long-term use, further work was undertaken on the qualitative and quantitative analysis of copper oxide surface layers.

For this purpose, experimental tests were carried out, which in particular in the first stage of experiments consisted using heat treatment of copper layers and its alloys to form oxide coatings with properties that reproduced layers formed on touch products made of Cu under real working conditions. The knowledge which was the basis for the tests consisted of information from previous tests studies on the corrosion of copper and its alloys in relation to antimicrobial touch surfaces, namely the fact that as a result of impact of human hand sweat on copper and its alloys, a layer of copper (I) oxide (Cu_2O) is formed on their surface, which after two years of use under real conditions has a thickness - depending on the chemical composition of the material - from about 50 nm to about 250 nm. Based on this knowledge, as part of our own tests, samples of flat products made of copper and its alloys underwent oxidation in air atmosphere using elevated temperatures in the range of 120°C to 900°C and duration from 1 minute to 24 hours. As a result of subjecting the ETP copper and its alloys to the heat treatment process at the specified temperatures and time intervals, extremely spectacular colour layers of oxide films were obtained on the surface of materials, which were a colour combination of copper (I) oxide (Cu_2O) and/or black copper oxide (II) (CuO) and/or in the case of copper alloys - oxides which are derived from the main alloying constituents. For example, for classic copper, the colour of the oxide top layers formed on the surface of flat rolled products has covered a wide palette of colours, ranging from orange, pink, yellow and silver, and ending with saturated shades of grey. As mentioned above, the oxidation process was also carried out for commercial Cu alloys, i.e. ones used in many technical applications, the surface of which - similarly to copper - oxidised at elevated temperatures in the form of coloured oxide layers. The surface layers thus produced were then subjected to qualitative and quantitative analysis using a cathodic (coulometric) reduction method. In the test, each of the oxidised materials was a cathode in the electrolysis circuit (on the cathode, a reduction occurs of the compound which is a component of the layer formed on the surface of the metal or alloy due to corrosion), the anode was a platinum wire, and the electrolyte was 0.1 M sodium sulfate (Na_2SO_4). The cathodic reduction of the oxide layers at the temperature of 25°C was carried out at a constant current density in the range of 0.1-1 mA/cm^2 (Autolab potentiostat/galvanostat). During the electrolysis, the cathode potential (of an oxidised copper or copper alloy sample) was recorded at one-second intervals relative to the silver/silver chloride reference electrode. The result of the tests were the chronopotentiometric curves obtained for copper (Cu-ETP) and its alloys (CuSn6, CuZn37, CuNi18Zn20) oxidised at various temperatures (200-600°C) and durations (1 minute - 24 hours). As a result of the tests, it was found that depending on the temperature-time conditions of heat treatment of samples selected for experiments the $E_K=f(t)$ curve showed one or two jumps in the cathode potential resulting from the presence of, respectively, a single Cu_2O oxide or two Cu_2O and CuO oxides. As a result of experimental tests - an increase of the total thickness of the oxide layers was observed for both the copper and its alloys. For example, for copper: from about 135 nm - for a material oxidised at 200°C in a short time of 5 minutes, to over 2400 nm - for a heat treated material at a higher temperature of 300°C for 30 minutes (for CuSn6 tin bronze from about 95 nm - 200°C/1 hour to about 280 nm - 200°C/24 hours; for CuZn 37 brass from about 20 nm - 300°C/1 h to about 800 nm - 300°C/24 hours; for CuNi18Zn20 nickel silver average at the level of 20-40 nm for materials oxidised at 300°C for 1-24 hours). Thus, referring to the data found in source literature, in the simulated/laboratory conditions, layers with chemical composition and thickness were obtained reproducing oxide layers, which are formed on the copper surface under real working conditions as a result of contact of metallic material with human hands. The test results for oxide layers obtained by means of the cathodic reduction method were then confirmed in the multipoint quantitative analysis (EDX multipoint) of the chemical composition of surface layers in flat products with varied copper content in the normal direction to the surface using high resolution SEM scanning electron microscope (qualitative analysis - distribution maps of analysed elements, quantitative "multipoint" analysis along a defined measurement line - an image of the analysis area with a marked measurement line and graphs of the concentration of the analysed elements with spectrograms from the characteristic X-ray spectrum and micrographs of the analysed areas).

The samples of metallic materials (Cu-ETP, CuSn6, CuZn37, CuNi18Zn20) oxidised in this manner and fully described in terms of the properties of surface layers in the next step of the test procedure were subjected to microbiological tests of antimicrobial effectiveness in contact with Staphylococcus aureus and Escherichia coli bacteria. The initial density of the bacterial suspension (approximately 10^7 CFU/ml), which was applied to the surface of the samples - both oxidised and (for comparison) non-oxidised, was completely or partially reduced by all materials, thus proving their bactericidal or bacteriostatic properties. The fastest rate of reduction of the initial density of Gram-positive Staphylococcus aureus and Gram-negative Escherichia coli was noticed for Cu-ETP copper and CuSn6 tin bronze after 60-240 minutes. Also copper alloys, i.e. CuZn37 brass and CuNi18Zn20 nickel silver, were characterised by high microbiological efficiency in contact with the aforementioned microorganisms. In particular, in the case of these materials, either a full reduction of the initial inoculum density of SA and EC after 240 minutes (bactericidal properties), or a partial reduction by about 2-3 log after 300 minutes (bacteriostatic properties) was recorded. Thus, it was found that while the oxidation of the surface does not affect the antimicrobial effectiveness of copper and its alloys, the effect of the Cu content in the material on its antibacterial activity has been noted. The difference for materials containing 94-99% Cu, in relation to alloys containing copper at the level of about 63% (CuZn37, CuNi18Zn20), amounted to about 180-240 minutes. The final conclusion from the conducted microbiological tests is contained in the statement that the similar character of the curves showing the relationship between the decrease in the amount of bacterial inoculum and time for all materials tested proves that oxidation does not worsen the antibacterial properties of ETP copper and its technical alloys Cu-Sn, Cu-Zn and Cu-Ni-Zn. This - due to the application potential of using these materials as antimicrobial touch surfaces measurably affecting the reduction of the spread of bacterial infections - is highly beneficial information.

Fundamental, due to the application of antimicrobial copper products, is also the fact that these surfaces are subjected to contact not only with sweat from human hands, but also with atmospheric air of diverse chemical composition, as well as the impact of various specific environments, such as urban, industrial, marine atmosphere, or the space of a hospital ward, very distinctive due to the concentration of Cl^- chloride ions. Therefore, in order to simulate the formation of layers of chemical compounds under the influence of various environmental conditions on the surface of copper and its alloys, an experiment was carried out in laboratory conditions involving chemical treatment of selected copper-based materials (flat rolled products made from Cu-ETP copper, CuSn6 tin bronze, CuZn37 brass, high-nickel brass, CuNi12Zn24 nickel silver) to produce different layers on their surface, which consisted of, among others, sulphur or chlorine compounds. The experiment was aimed primarily at examining the effect of the presence of surface chemical compounds on the antibacterial effectiveness of copper and its alloys.

The results obtained in the course of experimental work and analysis of source literature have proven the possibilities of the formation of corrosion layers on the surface of pure copper and its alloys, through chemical oxidation processes, carried out at both elevated temperatures and in ambient temperature. These types of surface layers are typically used for decorative dyeing purposes (creating an artificial patina) or anti-corrosive protection against adverse weather conditions. The synthetic formulation in the paper of the recipes for the chemical treatment of copper-matrix materials on the basis of various chemical reagents allowed for the selection of process parameters (bath temperature, chemical composition and proportions of reagents used, duration of chemical oxidation), thus allowing to obtain layers with a compact structure permanently adhering to the copper matrix. In particular, the surface of flat products made of pure copper was subjected to the impact of the following solutions: iron (III) nitrate ($Fe(NO_3)_3$), resulting in a brown layer; ammonium chloride (NH_4Cl) and copper (II) sulphate ($CuSO_4$), resulting in a dense yellow layer; or lead (II) acetate ($(CH_3COO)_2Pb$) and sodium thiosulphate ($Na_2S_2O_3$), which caused a colour change of the surface layer of Cu-ETP copper samples from the characteristic orange to green-blue. Also as a result of chemical oxidation treatments carried out at elevated temperatures in the range of 60-80°C and duration of 5-30 minutes in solutions of bismuth (III) nitrate ($Bi(NO_3)_3$), as well as copper (II) nitrate ($Cu(NO_3)_2$) and acetic acid (CH_3COOH), or ammonium chloride (NH_4Cl), ammonium acetate (CH_3COONH_4) and copper (II) acetate ($C_4H_6CuO_4$), the surface of Cu-ETP copper was covered with layers, respectively, with a white, cloudy pink or brown colour. In the course of experimental works, it was also found that flat samples made of ETP copper undergo chemical dyeing also at ambient temperature, an example of which is obtaining a compact surface layer with an extremely attractive celadon colour in the process using a solution of potassium chloride (KCl), potassium permanganate ($KMnO_4$) and copper (II) sulphate ($CuSO_4$) for about 20 minutes. The surface layers obtained in this manner on the surface of the copper were then subjected to structural observations by means of scanning electron microscopy. The characteristics of the layers were also supported by EDS microanalysis allowing for the identification of the chemical composition of the layer in a given micro-area. As a result of the research, it was found that the surface layers produced on Cu-ETP copper consist, among others, of from sulphides, chlorides, copper oxides, potassium, manganese, sulphur and other elements included in the chemical reagents used. In the course of the work, experiments were also carried out on the selection of appropriate parameters of the oxidation chemical process in order to obtain surface corrosion layers for CuSn6, CuZn37 and CuNi12Zn24 alloys. The result of the tests was the conclusion that in the temperature range of 50-80°C and the time duration from 5 minutes to 30 minutes, compact surface layers of various shades can be obtained for the analysed materials, in particular: brown - as a result of the dyeing process in the solution of potassium permanganate ($KMnO_4$) and copper (II) sulphate ($CuSO_4$); violet gold - as a result of chemical oxidation using copper (II) nitrate ($Cu(NO_3)_2$) and oxalic acid ($C_2H_2O_4$); yellow - as a result of oxidation in a mixture of potassium permanganate ($KMnO_4$), zinc sulphate ($ZnSO_4$), copper (II) sulphate ($CuSO_4$) and iron (III) sulphate ($Fe_2(SO_4)_2$); brown - due to the impact of a solution of copper (II) nitrate ($Cu(NO_3)_2$) and nitric acid (HNO_3); black and grey - as a result of tests carried out with reagents such as iron (III) nitrate ($Fe(NO_3)_3$), and sodium thiosulphate ($Na_2S_2O_3$); orange - after chemical oxidation in potassium dichromate ($K_2Cr_2O_7$), potassium chlorate ($KClO_3$), potassium permanganate ($KMnO_4$) and copper (II) sulphate ($CuSO_4$); or chocolate colour - due to the impact of a mixture of copper (II) acetate ($Cu(CH_3COO)_2$), potassium aluminium sulphate ($KAl(SO_4)_2$) and copper (II) sulphate (CuSO4). In addition, analysis of the structural state and chemical composition of the Cu-Sn, Cu-Zn, Cu-Ni-Zn layers formed on the surface of the copper alloys proved their homogeneous and compact structure and the presence of chlorine, sulphur, sodium, potassium, manganese and other precipitates contained in the mixtures of elements used.

In the next step of the test procedure, copper-matrix materials modified in such manner in chemical oxidation processes were subjected to the tests of their antimicrobial effectiveness in contact with bacterial strains that occur on touch surfaces in various public facilities, including healthcare centres.

Microbiological tests for selected materials, i.e. Cu-ETP copper, CuSn6 bronze, CuZn37 brass and CuNi12Zn24 nickel silver, were carried out in contact with methicillin-resistant Staphylococcus aureus (MRSA) and Escherichia coli. The obtained research results clearly indicate that chemical treatments of the surface of copper and its alloys do not reduce/deteriorate the antimicrobial or bacteriostatic activity of the analysed materials. In particular, a positive conclusion from the analysis of results observed for Cu-ETP copper samples with chemically modified surfaces is the total reduction of the initial density of the bacterial suspension after 120-300 minutes for antibiotic-resistant Staphylococcus (MRSA) and after 60-300 minutes in the case of Escherichia coli. Thus, these results demonstrate the bactericidal effect of copper in spite of the chemical interference in the surface of the material. Similar conclusions can be drawn from the analysis of the results of microbiological tests for the tested copper alloys, i.e. CuSn6 tin bronze and CuZn37 brass, which after oxidation treatments in various chemical solutions are characterised by the reduction of the bacterial strain of MRSA and E. coli after 180-300 minutes. At the same time, based on experimental observations, it has been determined that CuNi12Zn24 nickel silver despite the presence of surface corrosion layers also shows a reduction in bacterial inoculum, whether Staphylococcus or E.coli within 240-300 minutes. Therefore, it can be concluded that the tested copper alloys have antimicrobial and bactericidal properties.

It should also be noted that for copper alloys whose surface was subjected to the impact of chemical compounds based on heavy metals, in particular chromium (Cr^{3+} ions), a corrosion layer was formed, which inhibited the bactericidal effect of Cu-Sn, Cu-Zn and Cu Ni-Zn materials. In addition, it was noted that potassium, contained, for example, in potassium dichromate ($K_2Cr_2O_7$), potassium chlorate ($KClO_3$), or potassium permanganate ($KMnO_4$) compounds also weakens the reduction in the initial density of bacterial suspension of MRSA and E. coli (approximately 10^7 CFU/ml) by approximately 0.5-1 log. Probably this tendency should be explained by the presence on the surface of materials of metallic corrosion layers rich in high concentrations of K^+ ions, responsible for the weakening of the microbiological sensitivity of the inoculum to antibacterial activity of Cu^{2+} ions, which was reported in other researchers in their studies. Nevertheless, for the vast majority of copper alloys tested, on the surface of which corrosive surface layers were formed in the process of using varied chemical compounds, preferential behaviour in contact with bacteria was observed, consisting in a total or partial elimination thereof, which proves the health-promoting effect of Cu-matrix materials in contact with selected Gram-positive and Gram-negative representatives of bacterial strains.

Another research topic described in this monograph focused on the problem of allergenic release of nickel from copper alloys containing this element. This issue, due to the practical application of products with antimicrobial touch surfaces in public places, is of great importance. This is because antimicrobial surfaces, which are being used more and more commonly mainly in health care facilities - primarily due to the scale and danger of nosocomial infections - are required, in addition, of course, to being effective in the elimination of harmful micro-organisms, undoubtedly proving high functional values, also, and perhaps above all, to have a health-promoting character, understood as a positive impact on the protection of patients' health, and thus full safety for humans. Therefore, in the face of reports in the mass media around the world, nickel is currently the most sensitising contact allergen in the world, which in contact with human skin, releasing its Ni^{2+} ions, causes 20% of the global delayed type hypersensitivity, this problem in the case of using Cu-Ni alloys on antimicrobial touch surfaces, casts a shadow over the application potential of this type products, which after all should have a medicinal aspect. As a matter of fact, an unquestionable consequence of the scale of the problem, noticed by international manufacturers of various products, whether everyday use products (including eyeglass frames, jewellery items, belt buckles, sliders and trouser buttons, cutlery), or interior design elements such as door handles, connection threads, valve elements), observed for several years, is the dynamic development of a new range of products marked with the 'nickel-free' logo bearing the information that the product, due to the care for the health of its users, does not contain this allergen. It is therefore a tendency to completely abandon the use of nickel-containing materials in applications intended for direct contact with human skin.

A comprehensive review of copper grades and its alloys, which, according to the results of laboratory and clinical tests, are characterised by antimicrobial effectiveness, in terms of the selection of the most optimal material for the touch surfaces, brings focus to Cu-Ni alloys. Nickel as an alloy additive significantly increases their anti-corrosion resistance to many invasive environments, both natural and artificial. Besides, this fact, in connection with their undeniable antibacterial activity that limits the spread of infectious diseases, has made them widely used in the manufacture of coins for years. *Incidentally*, in people who have direct and long-term contact with them, they develop inflammation of the hands, which is one of the most common sources of occupational skin diseases in various employee groups (including salespersons, taxi drivers).

In relation to the above, some of the touch products made of copper alloys containing nickel can be considered as sources of skin allergies (including door handles, stair handrails, light switches, furniture handles). The problem becomes serious when we imagine a child who, as a result of several hours of (daily) contact with a school bench made of copper alloy containing nickel gets a rash resulting from skin allergies, or a passenger travelling every day to work by means of communication and holding a handrail made of Cu-Ni alloys, or a patient in a hospital ward using a cup holder made with cupronickel or nickel silver. There are much such examples... Therefore, in this paper, the problem of skin sensitivities resulting from contact with products containing nickel in their chemical composition is so strongly emphasised, because - as it can be in the case of copper antibacterial products - very quickly, instead of emphasising their pro-health, positive action, there may become infamous as contact allergens.

The problem of the adverse release of nickel from products intended for direct contact with human skin has been noticed at the legislative level of the European Union, whose "nickel directive" 94/27/EC in 2006 became part of the REACH regulation (regarding the "Registration, Evaluation, Authorisation and Restriction of Chemicals") and together with standard EN 1811 constitute the current legal and standardisation documents regarding the issue of nickel release from products containing this element. The said standard recommends that the object to be tested for the release of Ni^{2+} ions be submerged for one week in a solution of synthetic sweat with a strictly defined chemical composition and pH, and then tested for the concentration of dissolved nickel in it by means of atomic absorption spectrometry, inductively coupled plasma atomic emission spectroscopy or other analytical method used. On this basis, an assessment is made as to whether the value obtained exceeds the "safe" threshold (i.e. not causing nickel-allergy) of nickel release rate of 0.5 $\mu g/cm^2$/week established by the European Parliament and European Council. If it is higher than this threshold, the result of the submersion test in the solution of artificial sweat imitating human sweat provides information that the tested product, very likely be in contact with the skin of persons with hypersensitivity to metals, will be a source of allergies and inflammation. The above-described procedure, based on an *in vitro* chemical test that correlates as closely as possible with the variable human biological reactions occurring at the moment of contact of metal products containing nickel with human skin, is the only to describe the methodology of quantitative sensitisation tests for nickel allergen. At this point, it is also worth mentioning a different method of detecting Ni^{2+} ions in metallic materials. It is the colour reaction of nickel to the chemical compound dimethylglyoxime, also called - from the name of its creator - Chugaev's reagent. The test consists in rubbing for a period of several seconds the surface of the object analysed in terms of probability of nickel release using a cotton applicator soaked in a suspension of two solutions, i.e. 1% DMG in 96% ethyl alcohol and 10% ammonium hydroxide in water, and then assessment with the naked eye whether a pink precipitate of nickel (II) dimethylglyoxime was precipitated, indicating that the material is susceptible to unfavourable release of the allergen. This method is used when it is necessary to obtain immediate information on whether there is a danger of sensitisation by the given nickel-containing object, however it should be remembered that it is only a qualitative analysis, not providing - in contrast to the methodology according to standard EN 1811 - a full, i.e. quantitative, characteristics of the concentrations of Ni^{2+} ions released.

Basing on the above methodology of both tests, tests of nickel release from selected antimicrobial copper alloys were carried out. Some of the materials were produced in the form of flat metallurgical semi-finished products, i.e. tapes, sheets, plates and flat bars in Polish metallurgical and processing plants operating in the non-ferrous metals industry. In particular, they included: CuAl10Ni5Fe4 aluminium bronze, CuNi10Fe1Mn cupronickel and two high nickel brass grades - CuNi12Zn24 and CuNi18Zn20 nickel silvers. Still other materials, resulting from own analyses carried out to obtain alloys with strictly defined chemical compositions, have been obtained in a laboratory casting process in a station equipped with a crucible furnace with induction heating (the effect of "mixing" with an electromagnetic field). In this way, 5 cupronickels have been produced with a content of Ni in the range 2-30% (i.e. CuNi2, CuNi5, CuNi10, CuNi20, CuNi30) and 11 spinodal alloys with a variable Ni content in the range of 2-30% and a constant content of Sn - 4% (i.e. CuNi2Sn4, CuNi5Sn4, CuNi10Sn4, CuNi20Sn4, CuNi30Sn4) and 8% (CuNi2Sn8, CuNi5Sn8, CuNi10Sn8, CuNi15Sn8, CuNi20Sn8, CuNi30Sn8). The desired chemical composition of each of the materials produced under laboratory conditions has been confirmed by spectrometric analysis. Subsequently, the material samples were submerged in a solution of synthetic sweat (chemical composition: sodium chloride (NaCl), urea (CH_4N_2O), lactic acid ($C_3H_6O_3$), 1M and 0.1M sodium hydroxide (NaOH) pH = 6.5) at the temperature of 30°C for the recommended - according to standard EN 1811 - duration of 168 hours (7 days), whereas tests were also carried out over a longer period (up to 6 months), after which nickel content in the solution was determined by means of optical emission spectrometry with inductively coupled plasma. The results obtained were directly related to the results of the colour reaction with dimethylglyoxime (DMG) forming a salt with a purple colour with free nickel ions.

As a result of the experiments conducted for all analysed antibacterial alloys, there was a negative tendency for releasing nickel, exceeding the limit (even by 70 times) allowed in the standard and the European directive (confirmation was also provided by the results of the test with dimethylglyoxime). Therefore, in the light of the above, the work continued in the form of testing for the impact of selected alloying additives on the reduction of Ni release. Based on source literature reports on the effect of adding tin and advanced methods of heat treatment of Cu-Ni-Sn spinodal alloys, tests were carried out on the impact of annealing of this type of materials in terms of phase changes occurring on their susceptibility to nickel release. Although as a result of the conducted experiments, the possibility of shaping the above-average material properties was revealed (including the increase of hardness from 130 HV10 to 260 HV10 and electrical conductivity from 3.7 MS/m to 4.8 MS/m) of these alloys as a result of the impact of heat treatment strengthened by spinodal decomposition, its impact on nickel release was not found, despite many research papers reporting the effect of this type of heat treatment on increasing the corrosion resistance of spinodal alloys. It is worth mentioning here that as part of the analysis of the issues of the impact of various factors on the release of nickel from Cu alloys containing this additive, tests were also carried out to determine the effect of the condition of antibacterial surface of copper-matrix materials on the recorded concentration of nickel ions dissolved in the synthetic sweat solution. It was observed that the greater the coefficient of roughness *Ra* [μm] for a given material, the more visible are the significant discrepancies in the recorded values of nickel concentrations in the mixture of artificial sweat: greater discrepancies are observed for samples subjected to mechanical treatment in the polishing process (before the actual submersion test) than for materials not subjected to such surface interference. Direct dependence of the amount of nickel released on the duration of the submergence test of the material in the solution of synthetic sweat was also recorded (results convergent with the results presented in the work of other authors). In particular, as a result of completed experimental tests lasting for 6 months, it was found that with the duration of the corrosion test according to standard EN 1811, the amount of released allergen per unit of time decreases with the extension of the interval, the highest amount of Ni being released from copper alloys within the first 168 hours of subjecting the materials to the impact of the components of the synthetic mixture. This result explains why, in accordance with the requirements of standard EN 1811, the submersion test simulating the release of nickel from products intended for direct and long-term contact with the skin to determine whether the release rate of Ni^{2+} from such products is higher than 0.5 μg/cm^2, refers to the duration of one week (7 days, 168 hours).

The conclusion from own experimental tests aimed at analysing the issue of nickel release from copper-matrix antimicrobial materials, which were supported by studies of source literature on the subject, is that copper-nickel alloys should not be recommended for antimicrobial touch surfaces.

During the experimental work on many material issues related to the use of copper and its alloys in antimicrobial touch surfaces, another issue under consideration was to decide whether the daily use of these products has an impact on the effectiveness of their antibacterial activity. The term "daily use" means scratches of the surface of copper and its alloys as a result of mechanical injuries that are inherently associated with the practical use of many different materials, not only metallic ones. Therefore, in the course of deliberations, the following question was posed: does the change in the degree of expansion of the active surface of the alloy by its mechanical treatment - specifically the greater roughness associated with the *Ra* coefficient (average arithmetic profile deviation from the mean line) - affect the effectiveness of copper and its alloys in the elimination of harmful microorganisms?

Two opposing theories in response to the above question have become the premise for the experimental studies on this subject. The first of these, based on the aspect of the metallic material, which together with the increase in roughness shows a larger active surface that has direct contact with bacteria, indicates that such alloys should have better effectiveness in eliminating microorganisms. The second theory, having a microbiological basis, proves that the bacteria tend to settle in the surface cavities and to additionally produce a biological membrane (biofilm layer) protecting against the impact of external factors. On this basis, it can be assumed that the rougher the surface, the worse its efficiency in eliminating bacteria - due to the creation of more optimal (favourable) survival conditions for microorganisms. Because there is a lack of scientific papers that based on the results of experimental investigations would address this issue strictly in regard to antibacterial copper touch surfaces (the vast majority of source literature is focused on the issue of colonisation of surgical implants and catheters by biofilms, microbial colonisation of water supply networks, increasing microbial corrosion, as well as also on the analysis of rough surfaces based on steel, silicon, titanium dioxide, metallic glasses, etc.), the procedure planned for implementation based on proprietary experiments was aimed at obtaining an answer to this issue.

Therefore, the main aspect of this issue was the effect of the machining of the copper surface and its alloys on antibacterial effectiveness. As part of the tests, an experiment was carried out involving the preparation of the surface of Cu-ETP copper, CuZn37 brass and CuNi12Zn24 nickel silver in a mechanical machining process using abrasive materials with various methods of interaction with the work material and varying gradation (grain size according to the P scale according to FEPA), resulting in a texture on the surface of copper-matrix materials with different roughness coefficients (Ra at the level of 0.1-7.0 μm). The samples of copper and its alloys Cu-Zn and Cu-Ni-Zn thus prepared were then subjected to microbiological tests in contact with reference strains of methicillin-resistant Staphylococcus aureus (MRSA) and Escherichia coli (EC). The results obtained, showing the dependence of the reduction in the density of MRSA and EC bacterial suspension over time for materials after mechanical surface treatment (with different Ra roughness coefficient), proved that higher rougher materials showed higher effectiveness, which can be explained by their more extensive surface. This conclusion, concerning both Cu-ETP copper, CuZn37 brass and CuNi12Zn24 nickel silver, provides positive information that scratching antimicrobial surfaces does not adversely affect (does not worsen) their effectiveness in eliminating microorganisms.

The monograph also analysed the problem of shaping the surface wettability of copper antimicrobial products by means of thermal-chemical treatment of the surface, mainly in terms of its role in microbiological antimicrobial tests. The right choice of materials for the applications in question is dictated by their measurable effectiveness in the elimination of microorganisms, which in relation to the touch surfaces is determined on the basis of microbiological tests. They consist in applying a drop of a bacterial inoculum with a defined volume to a flat sample and then, depending on the methodology used, covering it with a sterile polyethylene film, in order to reduce free surface energy, i.e. to ensure better adhesion of the bacterium to the metal material (in accordance with the requirements of the standard JIS Z 2801), or leaving the drops to dry completely (draft new standards, including a Polish one) and only after the said stages of incubation of microorganisms - their sowing to the surfaces after prior dilution and counting of colony forming units. With regard to the aforementioned methodology, the wettability of the antimicrobial surface is important, which is defined by the value of the contact angle formed between the surface of the solid body (metal surface) and the tangent to the drop surface (bacterial inoculum) from the point of contact of the three phases: solid - liquid - air. Depending on its value, engineering materials are classified as hydrophobic, i.e. non-wettable, or hydrophilic, i.e. wettable by liquids. This issue is deliberately mentioned to consider the effect of the contact angle values for a single microdrop evaporating from the metal surface having a given volume (in the conditions of healthcare facilities, a drop of bacterial inoculum is transferred to the surface of products by drop or contact) on the size of the contact surface with the analysed surface, as well as the evaporation time of drops having a given volume.

Therefore, in order to answer the question about the effect of wettability of the surface of copper and its alloys on their antibacterial effectiveness, experimental tests were carried out involving subjecting the materials to chemical treatment in order to obtain surface layers with different values of contact angles. As a result of oxidation of copper-matrix materials in a solution of sodium hydroxide (NaOH) and ammonium persulphate ($(NH_4)_2S_2O_8$) they were given hydrophilic properties, and by modification with stearic acid ($C_{17}H_{35}COOH$) - hydrophobic (non-wettable) properties. The change of the free surface energy of copper and its alloys was obtained by shaping the morphology of the surface layer formed by the separation of wettable copper (II) hydroxide ($Cu(OH)_2$) and the non-wettable copper (II) oxide (CuO) filled with stearin. The recorded contact angle values for copper and its alloys with hydrophilic properties were only a few degrees (<5°), while for hydrophobic samples they covered a range of about 110-130°.

The veracity of the hypothesis of the effect of surface wettability on its antibacterial effectiveness was verified in practice by means of effectiveness tests of hydrophilic and hydrophobic copper materials (Cu-ETP, CuZn37, CuSn6, CuNi12Zn24) in the elimination of bacterial methicillin-resistant staphylococcus aureus (MRSA) and Escherichia coli. As a result, it was found that the value of the contact angle translates into the size of the contact area of the bacterial inoculum droplets with the surface, and consequently the evaporation time of droplets from the surface (the evaporation time of droplets from the surface with hydrophilic properties is shorter compared to the evaporation time of droplets from hydrophobic material; in our own tests the difference was even 1 hour!), and thus unquestionably affects the result of the antimicrobial effectiveness test. Hydrophilic surfaces with a copper and copper alloy matrix showed better antibacterial properties compared to hydrophobic surfaces, which is identified with larger areas of contact of the microorganism suspension with the tested material, as well as the effect of stearic acid on the mobility of copper ions.

Another research problem raised in the monograph concerned the use of antimicrobial copper products in healthcare facilities and related strict cleanliness procedures that apply there. All surfaces in hospitals are not only washed on a regular basis, but first of all disinfected with strong chemical agents that can enter into corrosive reactions with copper or its alloys, therefore the question of how the metallic materials with a Cu matrix react with active substances contained in these chemicals appeared at the stage of experimental tests. In order to find out the answer to this question, tests were conducted on the impact of the atmosphere of 18 disinfectants different in terms of active substances (including alcohol, chlorine, phenolic compounds, quaternary ammonium compounds, oxidants, glucoprotamine) on copper surfaces and its alloys in terms of corrosion resistance and the general visual state of metallic materials. Thus, the idea of experiments planned in this manner was related to the need for the recommendation of a product with active substances specified in terms of type and quantity, which do not cause a deterioration of aesthetic values of metal in direct contact with copper and its alloys.

Therefore, the methodology included the placement of each sample of four materials (Cu-ETP, CuZn37, CuSn6, CuNi12Zn24) in sealed containers above a solution of a selected disinfectant with concentration and chemical composition adapted to disinfect products with touch surfaces (including handles, counter tops, surfaces of bedside tables, drip stands) for a limited time (15 minutes -24 hours), after which the surface condition of the materials was examined with the naked eye. A positive overtone of the conducted tests included the possibility of indicating disinfecting products, which are characterised on the one hand by high disinfecting abilities, and on the other hand do not cause corrosion of copper and its alloys, i.e. do not affect the deterioration of the aesthetic values of the materials. Thus, agents based on active substances, such as quaternary ammonium compounds, glucoprotamine, phenols (except CuSn6 tin bronze) and combinations of alcohols (including n-propanol and ethanol - except for CuSn6 alloy), provide a safe compromise between disinfecting effectiveness in the elimination of microorganisms and the lack of influence of activators on corrosion, unfavourable from the point of view of using copper and its alloys, in particular in the context of using these materials for touch products.

Conclusions from the tests conducted stand in the vanguard of charges that often appear in relation to copper antibacterial products, that as they oxidise, corrode or their surfaces get scratched, they lose their pro-health potential to eliminate pathogenic microorganisms. The research results presented in this monograph clearly indicate that it is just the opposite, and copper and its alloys are effective tools in eliminating dangerous microorganisms that the most advanced pharmacological methods cannot cope with today.

The interdisciplinary research topic presented in this monograph focused mainly on the material aspects in the selection of copper alloy optimum in terms of performance (including resistance to corrosion from human hand sweat, having high antimicrobial properties), but also microbiological aspects in terms of the effectiveness of Cu-matrix materials in the elimination of microorganisms, in particular those typical for Polish healthcare facilities, as well as social aspects due to the nationwide problem of nosocomial infections and bacterial infections caught by people in public places. Because the mainstream of research on the issues of antimicrobial copper was associated with the most bothersome problems regarding the selection and use of this type of materials in the context of their antimicrobial effectiveness, the obtained results have high cognitive and application value and can be fully used to produce finished products made with copper antibacterial surfaces as ready-to-use know-how. In particular, interesting from the point of view of domestic manufacturers of semi-finished metallurgical products are the results of the tests of various copper grades and its alloys from the point of view of their technological properties and processability in both hot and cold processes. On the other hand, for the group of finished product manufacturers - the results of tests on the corrosion resistance of various copper alloys under the influence of perspiration of human hands, as well as surface treatment of these materials by thermal, mechanical and chemical processes, which were additionally supported by a comprehensive analysis of antimicrobial properties of these materials in contact with bacteria typical of public places in Poland, are of particular interest. Thus, it should be stated that the results of experimental work obtained have created the potential of their practical use as guidelines for specific technologies for the manufacture of products with touch surfaces dedicated to healthcare facilities and public places in Poland.

It should be clearly emphasised that the result of work on the selection of material optimal in terms of functionality and strength presented in the monograph, as well as the expression of the developed technology for manufacturing semi-finished products, their plastic processing and connection technology has been a demo system in the form of balustrades and stair handrails made of antimicrobial copper alloy, installed at the Faculty of Non-Ferrous Metals at the AGH. Thus, this health-oriented system received a very positive reception from the entire academic community, and the whole event thanks to the wide promotional campaign in the mass media meant that the leading Polish manufacturers of sanitary fittings, medical equipment and interior design components became interested in the subject of antimicrobial copper for ready-made products. Therefore, we should recognise the potential of the results obtained as a part of the paper, which due to their widespread dissemination not only in scientific but also in industry journals caused an intense interest of the Polish industry in the topic of antimicrobial copper.

The idea of this study was to present the state of research found in source literature and experimental tests on problems related to the use of antibacterial products made from copper and its alloys. Attention has been mainly focused on the issue of corrosion resistance of the metal in contact with human hands, atmospheric air and surface disinfectants used in Polish healthcare facilities, as well as surface engineering issues related to machining and wettability as well as the problem of allergenic release of nickel from Cu-Ni alloys, because these topics have the greatest impact on the widespread perception of antimicrobial touch surfaces made from copper. This monograph, of course, does not exhaust all aspects of the problem defined in this way, but is only an attempt at their comprehensive, interdisciplinary presentation. The literature sources dedicated the antimicrobial activity of copper and its alloys as well as the processes of shaping the properties resulting from the material nature of the metal is very comprehensive and each year brings an ever growing number of scientific and industry publications devoted to these issues. Growing interest in touch surfaces made of materials with immanent antimicrobial properties, which can be observed, especially in recent years, being a response to the growing number of infections caught by people in public places every year, from the point of view of the social market economy, is a topic worth attention.

5. Discussion of other scientific and research achievements

5.1. General information

I am a graduate of the Faculty of Non-Ferrous Metals majoring in Production Management and Engineering (June 2008). My master's thesis entitled "Parametrisation of material properties of ETP copper from the Contirod line and OFC copper from the Upcast line subjected to heat treatment and deformation processes" was written under the supervision of Prof. Tadeusz Knych, PhD Eng., and the reviewer of the dissertation was Prof. Beata Smyrak, PhD Eng. The subject matter of the paper concerned research on shaping the structural state as well as mechanical and electrical properties of blanks and rods manufactured at KGHM Polska Miedź S.A. The dissertation referred directly to the issues of material science and technology, with which I became acquainted during the month-long internship (August 2007) at the Cedynia Copper Smelting Plant in Orsk. The topics contained in the paper were presented, among others, at the 6th scientific seminar "Integrated Studies in the Basics of Plastic Deformation of Metals" in Łańcut and the 3rd International Drawing Conference in Zakopane.

My interest in the research issues of copper used in technical applications, shaped during the course of my studies and as part of participation in subsequent four-week internships (including in Hutmen S.A. in Wrocław - July 2007 and Tele-Fonika Kable S.A. in Krakow - July 2008), caused that in October 2008 I started doctoral studies at my faculty. I completed the studies in 2012 in submitting to the Council of the Faculty of Non-Ferrous Metals a dissertation entitled "The impact of casting parameters on the formation of material characteristics in oxygen-free copper for highly advanced applications in electronics and electrical engineering", for which in 2013 I received a PhD degree in technical sciences with a distinction in the field of metallurgy. The supervisor of the dissertation was Prof. Tadeusz Knych, PhD Eng., and the reviewers Prof. Ferdynand Romankiewicz, PhD Eng., (University of Zielona Góra) and Prof. Józef Zasadziński, PhD Eng. (AGH). The results obtained during the work on the doctoral thesis were published in 29 scientific articles, including 4 in journals on the JCR list (according to the AGH Main Library list: https://bpp.agh.edu.pl/autor/walkowicz-monika-06155) and presented at 38 scientific conferences, including 18 international and 20 national ones (according to the data from the AGH Main Library). During this time, I was awarded two prizes: Marshall V. Yokelson Memorial Medal Award (for the paper "Research on the influence of the structural state of Cu-ETP wire rod on the annealing susceptibility of wires" presented at the International Technical Conference in Monterrey, Mexico, 2010) and Silver Certificate Award (for the paper entitled "Dynamic recrystallization of continuous cast copper wire rod and the rapid tensile test" presented at the Interwire conference in Atlanta, USA, 2012). I also received two scholarships funded by the European Union, i.e. "Lesser Poland PhD Scholarship" (2009) and "Doctus - Lesser Poland Scholarship Fund for PhD Students "(2010, 12th place out of 273 participants). In 2012, I received the award of the Marshal of the Lesser Poland Province for my scientific achievements. During my doctoral studies I took an active part in 20 research projects, including my own supervisor research grant awarded by the National Science Centre (2011-2013). My research interests from the beginning of cooperation with Professor Tadeusz Knycz were focused on material issues related to technologies of non-ferrous metals production and processing, their properties and applications. In particular, they focused on practical work on selected copper grades with high chemical purity, concerning, among other things, the impact of oxygen content on hydrogen embrittlement of fireproof cables (cooperation with Tele-Fonika Kable S.A.), impact of the chemical composition of cathodes on the properties of blanks with special regard to annealing ability (cooperation with Legnica Copper Smelting Plant), impact of the methods of forming washer cathodes on their flatness and stiffness (cooperation with the Głogów I Smelting Plant) and determination of causes and mechanisms of the wear of barrier blocks in the casting process on the Hazelett machine (cooperation with the Cedynia Copper Smelting Plant). In 2013, I was employed as a research and teaching assistant at the Faculty of Mechanical Working and Metallurgy of Non-Ferrous Metals, and since 2017 I have been working as an assistant professor at my original unit.

5.2. Research and development and expert activity

After obtaining the degree of doctor of technical sciences, my research and development activity is still related to metallurgy, mechanical working and material engineering of non-ferrous metals. The dominant directions include:

- The use of copper alloys on touch surfaces with antimicrobial properties - I became interested in this subject in 2012/2013, when a research consortium "Cu+" was established under the auspices of the Polish Agency for Enterprise Development, comprising 11 Polish leading industrial plants and 2 scientific units whose common goal was to develop nationwide strategies for the dissemination of antimicrobial copper products. This objective was implemented by creating a broad forum for the exchange of knowledge and experience for managers, technologists, engineers and sales representatives from metallurgical and processing plants working with copper and its alloys, manufacturers of products in the medical and construction industry and scientific centres. It was carried out through original workshops on material science and technology devoted to copper with antimicrobial properties, of which I was a co-author and co-host (see Appendix 4 - III A1). As a result, and following the specific range of products justified by market conditions and requirements, and as a result of the available machinery in production plants in Poland, the production technology of new copper alloys and products was developed and their production started in the country (see Appendix no. 4 - II B4, B5). Nevertheless, irrespective of the technical aspects solved, many issues - especially of a scientific nature - directly related to the specificity of copper as a metallic material and the characteristics of bacteriological threats in public places in Poland remained unresolved.

The need to find answers to further issues has caused that the development of the discussed subject has continued through a research and development project entitled "*Research on the antimicrobial properties of copper and its alloys used in products with touch surfaces for applications in healthcare facilities*" financed by NCBiR as part of the 3rd Programme of Applied Research. In 2015-2018, when I worked as the manager of the programme, I coordinated the work of the "Antibakter" consortium created by AGH's Faculty of Non-Ferrous Metals, the Chair of Microbiology at the Jagiellonian University Collegium Medicum and the European Copper Institute. The results obtained in the course of the project were presented in a number of scientific publications related to, inter alia, the issues of corrosion of copper alloys ("*Impact of oxidation of copper and its alloys in laboratory-simulated conditions on their antimicrobial efficiency*") and antimicrobial effectiveness of the metal, which is its direct result („*Antimicrobial properties of selected copper alloys on Staphylococcus aureus and Escherichia coli in different simulations of environmental conditions: with vs. without organic contamination*”). I presented the results of further research - for example - on the oxide layers on the copper surface by cathodic reduction, nickel release from Cu alloys with various chemical compositions and strengthening states, measurements of the surface contact angle after thermal-chemical treatment, at numerous conferences in Poland and abroad, which resulted, among other things, in receiving distinctions for the papers or awards of a scientific or popular nature (see Appendix 4 - III D1).

Parallel to the work as part of the projects, still developing the subject of antimicrobial copper, in the years 2016-2018, I managed over expert work (see Appendix 4 - III M5, M6, M8). This work concerned both tests focused on optimising the material properties of copper alloys used for antibacterial touch surfaces, as well as tests being conducted in terms of assessing the applicability of selected technologies from the group of mechanical working, founding and machining techniques for the manufacture of specific products. This work also had a typically scientific character, for example, as their result a draft of a new Polish standard was created under my direction, entitled "*Antimicrobial touch surfaces - Quantitative method for determining the antimicrobial activity of non-porous touch surfaces*", concerning the methodology of microbiological tests on the antimicrobial properties of copper and its alloys as a new topic of the Polish Standardisation Committee according to the procedure R2-P3. The results of these tests became an inspiration to apply for a dean's grant entitled "*Shaping and testing the surface wettability of copper and its alloys*", which, funded by the Ministry of Science and Higher Education as part of research and development work of young scientists, was awarded to me in 2018. The results of this experimental work were included in the monograph presented, constituting the basis of the main scientific and research achievement. Thus, substantively, the work supplemented and continued the issues focused on by me as part of the statutory activity of the WMN AGH financed by the Ministry of Science and Higher Education. In this case, I am talking about the projects that I have been managing, entitled "*Tests of the surface wettability of metallic materials in the aspect of improving the quality of finished products*" (2017) and "*Material testing of copper and copper alloys with antimicrobial properties*" (2018).

The subject of antimicrobial copper alloys was also related to my postdoctoral internships at Polish academic facilities (Jagiellonian University Collegium Medicum: 2015-2018), or research and development facilities (European Copper Institute: 2014).

It is worth mentioning that in the near future in Poland we should see a dynamic increase in the installation of products with copper antimicrobial touch surfaces in healthcare facilities, which will be the result of the research project currently implemented in the NCBR, carried out by the Faculty of Non-Ferrous Metals at AGH in cooperation with manufacturing companies in the construction and medical sector.

- Processing of high purity copper for wires and microwires - I have been continuing the subject started in the doctoral thesis as part of research, publication and seminar activities. It mainly concerns the influence of chemical composition of batch materials in the Cu-OFE and Cu-ETP grade on their susceptibility to drawing and analysis of strength parameters and strengthening of wires. The research is also focused on determining the flow rate of cooling water for the crystallizer and the casting speed of oxygen-free copper on shaping the mechanical and electrical properties and the structural condition of the material after cold forming processes. On the one hand, the research is in the form of laboratory work carried out as part of research projects and statutory work (see Appendix 4 - II J1, J2, J11, J12, J14), resulting in patent solutions (see Appendix 4 - II C1, C2), documentation of experimental work (see Appendix 4 - II F2, F5) and expert work (see Appendix 4 - III M7). On the other hand, the research focuses on direct cooperation with engineering staff in Polish production plants (see Appendix 4 - II B1, B13, B14), often taking the form of research consortia (see Appendix 4 - III E1, E6, E8), but also of business ventures implemented in cooperation with specialists/technologists from outside Poland. A manifestation of the last of these cooperation projects is my participation in the international "Leonardo Energy" programme financed by the European Copper Institute in Brussels under the "Copper Academy" project, consisting in co-authoring the paper ("Processing high conductivity materials") presented at a webinar for over 20 ECI member enterprises (see Appendix 4 - III A2).

  New trends observed in recent years in the production and processing of non-ferrous metals for electrical purposes have resulted in my increased professional activity in the implementation of work commissioned by the leading Polish organisation promoting practical copper applications in Poland - the European Copper Institute (EIM) in Wrocław. My nearly 10 years of cooperation with the EIM, after obtaining the doctoral degree - in the discussed area - turned towards co-authorship of targeted analyses or simulation of the economic profitability of replacing copper wires with aluminium wires using the example of power cables and wires (see Appendix 4 - III M2), or studies supplementing this work dealing with the growing problem of Cu replacement by Al in the electrotechnical industry (see Appendix 4 - III M3, M4). The aforementioned work constitutes a superposition of analyses found in source literature and own experimental research of the team from the Laboratory of Non-Ferrous Metals Processing Technology under the supervision of Professor Tadeusz Knych. This work has been collected in the form of a unique electronic database of copper alloys called "Copper Alloys Knowledge

Base" (available at: http://www.conductivity-app.org), which is an indispensable source of information for students of technical universities, as well as engineers and technologists and all people associated with the metal industry (see Appendix 4 - II F1). I contributed to this work as the author of the chapters titled "*Cu-Overview*", "*Cu-ETP*" and "*Cu-OFC*".

In addition to the main fields of research related to antimicrobial and high-conducting copper, I conduct experimental and expert work on the use of Cu alloys in architecture (see Appendix 4 - III M9). The analyses concern the impact of surface condition of metallurgical blanks after thermal, mechanical and chemical treatments (including artificial oxidation) on corrosion resistance in various atmospheric conditions. They also refer to the methods of preparation and protection of copper surfaces of façades and roofs, flashing methods as well as welding and soldering technology.

- Shaping of conductive properties of aluminium alloys for power industry - work was carried out as part of research projects financed by NCBR and NCN, aimed at developing technology for the manufacture and processing of selected Al grades (mainly 1xxx, 3xxx, 5xxx, 6xxx and 8xxx series) as well as tests of the structure and properties of ingots, rods and wires obtained in this way. For example, they concerned the impact of the method of heat treatment on the Al-Mg-Si alloy's microstructure, in particular on the morphology, size and volume concentration of the main strengthening phase, and also on the strength and electrical properties of the material ("*Different metastable 2nd beta phase nucleation routes in precipitation-hardening AlMgSi alloys and their impact on the structure and properties*"), as well as the influence of casting process parameters, hot and cold forming on heat resistance and the set of other functional properties of aluminium alloys with zirconium ("*Development of technological parameters for the manufacture of wires for electrical purposes using Al-Zr alloy*"). The last of the referenced project is carried out in international cooperation with industrial plants. The obtained results have been published in a number of articles dealing generally with the evolution of the structure and properties of aluminium alloys in the Continuus-Properzi line. The focus of interest of other authors is the paper on the effect of supersaturation and artificial ageing on precipitation hardening of 6xxx series alloys (see Appendix 4 - II A4) and patent solution regarding the crystallization system in the continuous Al casting process (see Appendix 4 - II C3).
- Parametrisation of material properties of Zn-Cu-Ti alloys obtained from strips cast using the Hunter method - this topic is being developed thanks to the cooperation with Zakłady Metallurgiczne Silesia (Katowice) in the scope of developing a new market product in the form of zinc-titanium (Zn-Cu-Ti) sheets and strips, as well as their production technology. These products are used for roofing, as protection for building elements (cornices, window sills, façades, balconies, chimneys) and for the manufacture of gutters and downpipes. The originality of the product developed as part of the research and development project ("*Development of new technology for the manufacture of ZnCuTi alloys from strips cast using the Hunter method*") is manifested by the fact that ZM Silesia, using the new product in its business operations since 2015 is its only manufacturer in Poland and one of nine in the world. The creative change in the plant's business operations, possible due to the implementation of this original design/technical achievement (see Appendix 4 - II B9, B10), consisted in the fact that the current manufacture of the type series of sheets and strips involving energy-intensive heat treatment of the charge for the rolling process was eliminated, in its place using a combination of a higher material heating temperature before the rolling process, a higher rolling speed, as well as larger individual gravities in the individual rolling process passes. As a consequence, a finished product was obtained with usable properties significantly exceeding the properties obtained by

the sheets produced so far in ZM Silesia. The period of using the research results obtained as a part of the project and their application in industrial practice is, of course, unlimited in time. Regardless, the results of research on this issue became the basis for two pending international patent applications at the European Patent Office (Munich) („*Fabrication method of flat-rolled products made of zinc-base alloys intended for use in building engineering*", „*Fabrication method of strips and sheets made of Zn-Cu-Ti alloys designed for building industry*"). Issues related to the impact of the charge material's thickness, the arrangement of drafts and the temperature in the reversal rolling process on the structure and properties of flat products made from the zinc-titanium alloy are also the subject of scientific articles published in Polish and foreign scientific journals (see Appendix 4 - II E17, E21).

- Research on the development of technology and the implementation of a full range of wires made of Zn-Al alloys for corrosion protection using metal spraying - research work under industrial conditions at ZM Silesia SA and the AGH WMN's laboratory is carried out as part of a research project launched in 2018 as part of the "Fast Path" contest co-financed by the National Centre for Research and Development. All the experimental work carried out so far has made it possible to design metallurgical synthesis procedures for ZnAl2, ZnAl4, ZnAl15 and ZnAl22 alloys, in order to obtain the desired quality parameters of liquid metal, as well as for the development of casting technology, technology of hot forming in the rolling process, cold forming in the drawing process and heat treatment of blanks and wires made from these alloys in order to obtain material with proper chemical composition, structure and properties (see Appendix 4 - II B28-B32). Thus, the know-how acquired has created the basis for material testing of Zn-Al castings, which will be manufactured based on the developed technical and technological parameters using the new demo COiW line using the Continuus-Properzi method. The results of the work carried out under the discussed project have already been partially presented at international and national scientific conferences (Appendix 4 - III B16, B17, B18) and are the subject of a scientific publication during the review process in a journal on the JCR list - Archives of Metallurgy and Materials ("*Impact of the heat treatment parameters on microstructure, mechanical properties and workability of ZnAl15 alloy wire rod*").

To sum up - the presented scientific achievements are largely the result of the commissioned work and research projects in which I was the manager, main contractor or contractor. So far I have actively participated in 9 expert evaluations (see Appendix 4 - III M) for business entities, managing six of these, and in 19 projects (see Appendix 4 - II J, III F), in 2 of which I served as a manager and in 4 as a task manager. This work was carried out within 10 research consortia (see Appendix 4 - III E), which were composed of Polish research units and manufacturers from the metallurgical and processing industry.

The results obtained in my research, often having an interdisciplinary character, brought many important values to the theory and practice of technical sciences, but also to medical sciences and humanities. They can be used in many fields of metallurgy, mechanical working and metal science, as well as material engineering, including surface engineering and even medical microbiology. For this reason, they were presented at both typical scientific seminars and popular science conferences. In particular, out of 30 papers delivered by me in 2013-2019 (see Appendix 4 - II L), 16 were presented at international symposia, such as EMC: European Metallurgical Conference (2013, 2017), TMS: Annual Meeting & Exhibition (2017, 2018), EUROMAT: European Congress and Exhibition on Advanced Materials and Processes (2017), and MS&T: Materials Science & Technology Conference and Exhibition (2017), and 14 presentations took place at domestic seminars such as SIM: School of Materials Engineering (2013), OMIS: Deformability of Metals and Alloys (2013, 2015, 2017) and PLASTMET: Integrated Studies in the Basics of Metal Deformation (2016).

In connection with the above, the results of experimental and review work carried out by me have been published in international and national scientific journals (27 publications + 4 in journals on the JCR list), monographs (5 chapters) and conference materials (50). Of the above 32 original papers, I published 24 as the first author. I am also a co-author of three national patents and two applications for European patents. Bibliometric analysis (as of 16.04.2019) indicates that after obtaining the doctoral degree, the total Impact Factor of the publications amounts to 13.042 (according to the year of publication), and the total score of the Ministry of Science and Higher Education = 288. The data on the number of citations and the Hirsch index according to different databases are summarised in Table 1 below.

Table 1. Bibliometric indicators

As of 16.04.2019 r.			
	Scopus	Web of Science	Publish or Perish / Google Scholar
Number of citations	11	6	56
Number of citations without self-citations	6	5	22
Hirsch index	2	2	5
Number of publications	Before obtaining a doctoral degree	After obtaining a doctoral degree	Total
	29	32	61
Total IF	1,335	13,042	14,377
Total score of the Ministry of Science and Higher Education	147	288	435

In addition to my scientific achievements, I am a member of international and national organisations and scientific associations: The Wire Association International - Poland Chapter, TMS: The Minerals, Metals & Materials Society and Association of Non-Ferrous Metals Engineers and Technicians – SITMN.

5.3. Organisational and popularising activities

Apart from scientific and research activities, from the beginning of my work at the Faculty of Mechanical Working and Metallurgy of Non-Ferrous Metals, I have been involved in organisational activities for the Department of Non-Ferrous Metals.

Since 2016, I have been the supervisor of 1st year full-time students in the field of "Production Management and Engineering". To this end, I provide constant and comprehensive help in the students' study and development, I solve and pilot individual and group problems reported by young people on a regular basis and I help them during the course of studies and life at the University.

In the academic year 2016/2017, I was a member of the Faculty Committee for Academic Major Examinations and Engineering Diploma Examinations for the "Production Management and Engineering" major. My duties included conducting diploma and academic major examinations in the field of engineering as well as qualifications for MSc studies. In 2016, by decision of the Dean of WMN AGH, I was appointed as a secretary and a member of the Faculty Committee for Academic Major Examinations and Engineering Diploma Examinations for the "Metallurgy" major (specialisation: Mechanical Working and Metallurgy of Non-Ferrous Metals) for a four-year term. The nature of my work - in addition to the aforementioned tasks - also includes the preparation and maintenance of full reporting documentation of the work of the Committee.

I also act as a representative of the "Metallurgy" major at the Faculty Team for Quality of Education (2016-2020 term). As part of the work aimed at improving the teaching process in the academic environment, I participate in surveys conducted among the students of my faculty and co-create the Annual Self-Assessment Faculty Report.

I am the author and presenter of the paper ordered by the Dean of the Faculty of Non-Ferrous Metals, entitled "*Undiscovered areas of the possibilities of copper*", which I presented twice: at the inauguration ceremony of the Academic Year 2018/2019 at WMN AGH (12.10.2018) and at the graduation ceremony for MSc studies at WMN AGH (14.12.2018). Both ceremonies took place in the main hall of the AGH University of Science and Technology with the participation of invited guests.

In 2014, I was a member of the scientific committee, as well as the organiser and leader of thematic sessions entitled "Engineering Sciences" at the conference "*The influence of young scientists on the achievements of Polish science*" - 5th edition" in Kraków. The nature of my participation also included the organisation of a competition for the best paper and the best poster presented at the seminar and the function of the chairman of the competition team.

Also in 2014, I was the editor-in-chief of the scientific monograph "*Methodology of research used by young scientists*" (ISBN 978-83-63058-41-8), which has been published by Creativetime and contains 33 reviewed chapters whose research topics include the cross-sectional character and diversity of proprietary methodical solutions in the field of technical sciences.

In addition to organisational activities, I am involved in work aimed at popularising science and, consequently, promoting the Faculty of Non-Ferrous Metals and the entire AGH University of Science and Technology (see Appendix 4 - III I6-I11). The installation of the anti-microbial system in the form of balustrades and stair railings at the WMN AGH in the first half of 2018 was met with great response from the mass media (the issue is the main topic of the chapter 8 of the monograph "Antimicrobial Copper. Materials - Touch surfaces - Applications"). The system was officially put to use by the entire academic community on April 16, 2018 by the Vice-Chancellor of the AGH University of Science and Technology - Professor Jerzy Lis and the invited guests participated (on the same day) in a popular science seminar in the AGH's General Auditorium, during which I gave a lecture entitled "*Applications of copper and copper alloys in antimicrobial touch surfaces*". The whole subject of antimicrobial copper and the above event, based on the interviews I gave, was widely disseminated in the mass media through:

- Broadcasts on television:
  Teleexpress (main edition, 19.04.2018), TVN24 (programmes "*Polska i świat*" - *24.04.2018* and "*Wstajesz i weekend* " - 29.04.2018), Platon TV - Platform for interactive science television in the Pionier network (programme "*Czas nauki*" - report "*Bakteriostatyczne poręcze*", 24.10.2018)
- Video material on You Tube:
  The report "*Akademia miedzi*" entitled "*Badania stopów miedzi*" (19.12.2017)
- Broadcasts on the radio:
  Radio Kraków (programme "*Pracują na Nobla*" hosted by E. Szkurłat, 21.04.2018), Radio Eska (programme "*Antibakteryjna poręcz na AGH*", hosted by J. Paducha, 22.04.2018), Radio Plus (report "*Są gładkie, koloru złotego i antybakteryjne…*", 20.04.2018) and in: Anty Radio, Melo Radio, Polskie Radio Białystok, Radio Chilli Zet, Radio Zet, Radio RMF FM, Radio Tok Fm, Radio Vox Fm (April - May 2018)
- Publications in the press:
  Rzeczpospolita (the article "*Miedź i jej stopy jako narzędzia wspomagające ograniczenie zakażeń związanych z opieką zdrowotną*", as part of the series of publications "*Nauka-Technologie-Gospodarka. Rozwój Badań w Medycynie i Biotechnologii*", 29.09.2017), Magazyn Hutniczy (article "*Pierwsze w Polsce poręcze z przeciwdrobnoustrojowego stopu miedzi. Wydział Metali Nieżelaznych AGH w Krakowie*", 8-15.05.2018), AGH Newsletter (article "*Poręcz która zabija bakterie*", May 2018)

- Publications on the internet:

  April 2018 - websites: AGH, AGH WMN, Antimicrobial Copper, Biuletyn Informacyjny Studentów AGH, Copper Alliance, Dziennik Polski 24, Gazeta Krakowska, Gazeta Wyborcza, Kraków-Nasze Miasto, Laboratoria Net, Metale-Informator Przemysłu Metali, Mieć Miedź, Nauka Online, Nauka w Polsce-Polska Agencja Prasowa, Oddech Życia, Polish Science, Portal Gospodarka i Ludzie, Puls Biznesu, Rzeczpospolita, Rynek Zdrowia, Świat OZE, Twoje Zdrowie RMF24, Wirtualna Polska Tech, Wykop, Wyposażenie Medyczne,

Thus contributing to the promotion of my Alma Mater. For the aforementioned scientific activity and popularisation of knowledge in April 2019 I received the Team Award of the Vice-Chancellor of AGH (see Appendix 4 - II K2).

5.4. Teaching activity

My work at the AGH to a large extent has the character of teaching activities aimed at education, dissemination of knowledge and awareness in issues related to metallurgy and mechanical working of non-ferrous metals as well as production engineering among future engineers (see Appendix 4 - III I1-I5).

On a daily basis, I implement my own curriculum in the following subjects: "Selection of metals for various applications" (lecture and design training), "Ergonomics" (recitation classes), "Organisation of production systems" (lecture), "Production processes and techniques 1" (recitation classes), "Production processes and techniques 2" (recitation classes), "Information technologies" (laboratory training), "Technologies in the cable industry" (design training), "Technologies for the production of metal composites" (design training), "Technologies of non-ferrous metals production" (design training), "Theory of mechanical working processes "(lecture and design training), "Implementations and patents" (lecture and project training) and "Quality and safety management" (recitation classes). Classes are conducted for students of the Faculty of Non-Ferrous Metals as part of the "Metallurgy" and "Production Management and Engineering" majors, based on the syllabus I have developed. As a result of the "Academic E-learning" certification course completed in 2017, I am gradually implementing the materials made available to students in digital form and exchange opinions with them about the content and quality of my classes, including using the "Mentimeter" electronic platform. These activities are aimed at continuous improvement and enhancement of the substantive scope of lectures and training, as well as encouraging young people to creative and independent thinking.

Since 2013 I have been a co-author and co-coordinator of the "Information Technologies" subject for the "Production Management and Engineering" BSc major at the Faculty of Non-Ferrous Metals. For this purpose, based on a proprietary teaching plan, I developed a compendium of computer laboratory training and created an electronic version of teaching materials and aids containing the most important elements of the training, making them available to students in the form of a pdf file (Walkowicz M., Osuch P.: „Technologie informacyjne. Ćwiczenia laboratoryjne dla studentów I roku na kierunku Zarządzanie i Inżynieria Produkcji na Wydziale Metali Nieżelaznych AGH”, Kraków).

I am a member of the faculty team responsible for developing a new programme for the education of BSC and MSc students in the "Production engineering and quality management" major. The scope of my duties includes: co-authorship of the list of classes (titles and study programmes) of basic majors and specialisations for the different years and levels of full-time studies at the WMN AGH, which will be implemented starting in October 2019, development of syllabuses and presentation materials for subjects forming the new major.

As part of educational activities, since 2012 I have been organising educational trips for BSc and MSc students at the Faculty of Non-Ferrous Metals to metallurgical and processing plants in the non-ferrous metals industry (Eltrim Kable, KGHM Polska Miedź S.A. - Cedynia Copper Smelting Plant, NPA Skawina, Tele-Fonika Kable, ZM Silesia). My activities are focused on planning and organising visits to industrial plants during which students have a valuable opportunity to supplement the theoretical knowledge acquired at the AGH by getting acquainted with the practical aspects of production technology of metal semi-products and final products (from the point of view of processes and equipment), their properties and applications.

In the course of my work at the University, I engage in scientific supervision over full-time students - both in BSc and MSc programmes - at my faculty. Until now, I have been the supervisor of 55 scientific papers, of which 20 have the status of master's dissertations and 35 of them are in the field of engineering (see Appendix 4 - III J1, J2). Completed dissertations concern material issues related to the broad topic of shaping the functional properties of non-ferrous metals obtained by casting and mechanical working methods.

I am the auxiliary supervisor for the doctoral thesis of Małgorzata Zasadzińska, MSc, Eng. The topics of the paper entitled "Study of the causes and mechanisms limiting copper deformability in real technological conditions" are a direct reference and continuation of the subject tackled in my doctoral dissertation, both in terms of susceptibility to processing and thermal resistance of copper wires of the highest chemical purity.

5.5. Summary

In summary, the entirety of my scientific, research, teaching and organisational/popularising achievements after obtaining the doctoral degree consist of:

- Monograph: 1,
- Scientific publications in journals in the Journal Citation Reports database: 4 with a total bibliometric value: Impact Factor = 13.042, Ministry of Science and Higher Education = 130,
- Scientific publications in international and national journals other than those in the JCR database and chapters in monographs: 28,
- Presentation of papers at scientific conferences: 30 (including 16 international and 14 national),
- Co-authorship of papers presented at scientific conferences: 18 (including 11 international and 7 national),
- Completed original design, construction and technological achievements: 33,
- Patents: 3 domestic and 2 international applications,
- Collective studies, catalogues of collections, documentation of research works: 5,
- Participation in research and development projects as the main contractor and contractor: 13,
- Managing research and development projects: 2,
- Managing tasks as part of projects implemented within statutory activities: 4,
- Managing commissioned and expert work: 6,
- Awards for scientific activity: 2,
- Awards for popularising activities: 1,
- Participation in international and national programmes: 2,
- Participation in organisational committees of scientific conferences: 1,
- Participation in research consortia: 10,
- Participation in editorial committees and scientific councils of journals: 1,
- Participation in expert and competition teams: 2,
- Membership in international and national organisations and scientific associations: 3,
- Teaching achievements: 5,
- Achievements in the popularisation of science: 6,

- Scientific supervision of students: 55 (including supervision over 20 master and 35 engineering dissertations),
- Scientific supervision over PhD students as an auxiliary supervisor: 1,
- Internships in scientific or academic centres: 2,
- Other achievements, not mentioned above: 8.

My plans for scientific development for the future focus on the implementation of practical work, the subject of which refers to the broad subject of the development of national metallurgy, processing technology and material engineering of non-ferrous metals. In my professional work I will continue research on shaping the material properties of copper, aluminium, zinc and other engineering materials for the needs of the Polish economy, thus contributing to the development of innovative technological solutions and technical thought.

A detailed list of scientific papers published by me, together with information about teaching achievements, scientific cooperation and popularisation of science, is included in a separate attachment (No. 4) to the application for initiating the habilitation procedure.

Walkowicz
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Monika Walkowicz, PhD Eng.