**SELF-PRESENTATION**

1. Name and Surname

   **Beata Górka-Kostrubiec**

2. Scientific titles and degrees, including names, place, date and the title of Ph. D. thesis

   1990 – M.Sc. in Physics, Institute of Physics, University of Silesia in Katowice, the title of Master thesis: "*Answer of the thermoluminescent detectors placed in the tissue-like phantom on electron beam with an energy of 6, 9, 12, 21 MeV*".

   2000 – Ph.D. in Technical Sciences, Department of Technical Science, Institute of Materials Science, University of Silesia in Katowice, the title of Ph.D. thesis: "*The kinetics of disappearance of structural defects and their impact on the reversible martensitic transformation in copper alloys"*.

3. Information about the scientific / artistic employment

   1990-1995, assistant at the Institute of Physics and Chemistry of Metals, University of Silesia in Katowice,

   1995-2000, Ph.D. at the Institute of Physics, University of Silesia in Katowice,

   2000-2008, adjunct position at the Institute of Materials Science, University of Silesia in Katowice,

   2008 until now, adjunct position at the Institute of Geophysics, Polish Academy of Sciences in Warsaw

4. Scientific achievement, according to art. 16 par. 2 of the act Dz. U. nr. 65, poz. 595 with later changes):

   a) Title of the scientific / artistic achievement

      ***The magnetic properties of the iron compounds used for the evaluation of air pollution inside buildings***

   b) Author / authors, title/titles of the publication, year, journal name:

[1] Jeleńska, M., Górka-Kostrubiec, B., Król, E. (2011). *Magnetic properties of dust as indicators of indoor air pollution. Preliminary results.* Management of Indoor Air Quality (ed. Dudzińska); Taylor & Francis Group, London, pp. 129-136.

[2] Król E., Górka-Kostrubiec, B., Jeleńska, M. (2013). *The magnetometric study of indoor air pollution inside flats located in Warsaw and its suburbs.* Environmental Engineering IV – Pawłowski, Dudzińska & Pawłowski (ed) Taylor & Francis Group, London, pp. 323-328.

[3] Górka-Kostrubiec, B., Jeleńska, M., Król, E. (2014). *Magnetic signature of indoor air pollution: Household dust study.* Acta Geophysica, 62, pp.1478-1503, DOI: 10.2478/s11600-014-0238-1.

[4] Górka-Kostrubiec, B. (2015). *The magnetic properties of indoor dust fractions as markers of air pollution inside buildings.* Building and Environment, 90, pp. 186-195, DOI:10.1016/j.buildenv.2015.03.034.

[5] Szczepaniak - Wnuk, I., Górka – Kostrubiec, B. (2016). *Magnetic particles of indoor dust as marker of pollution emitted by different outside sources.* Studia Geophysica et Geodaetica, 60, pp. 279-315, DOI:10.007/s11200-015-1238-6

[6] Górka – Kostrubiec, B., Szczepaniak - Wnuk, I. (2016). *Magnetic study of a mixture of magnetite and metallic iron in indoor dust samples*. Air Quality, Atmosphere & Health, DOI:10.1007/s11869-016-0412-5, (Open Access).

c) Description of the scientific goal of the above papers and achieved results, including discussion of their possible applications.

***Introduction***

My scientific work is focused on experimental studies of different materials using magnetic, resistometric and mechanical methods. At the Institute of Materials Science, University of Silesia in Katowice. I conduced the studies of alloys exhibiting shape memory effect and examined the properties of amorphous alloys with various chemical compositions. The brief summary of the research together with the list of papers is presented in the section 5: discussion of other scientific achievements.

Since 2008, at the Institute of Geophysics Polish Academy of Sciences I have participated in the study conducted by the Environmental Magnetism research team. I have involved my knowledge and experience to develop the magnetic methods to environmental study. Together with my co-workers I took part in the following research topics:

a) the study of the magnetic properties of different soil types, their genetic horizons and soil-forming processes (pedogenesis),
b) the study of pollution accumulated in soils, e.g. in the vicinity of high traffic roads,
c) the study of particulate matter (PM) in Warsaw during 1977 - 1985 and to the study of current atmospheric pollution in the center of Warsaw and Kiev.

The short description of important results of the works which I am the co-author with the list of papers is presented in the section 5: discussion of other scientific achievements.

In the section 4, I present the monothematic set of six papers (published between 2010 and 2016) which constitutes a significant contribution to study of indoor air pollution by measuring the magnetic properties of indoor dust from buildings. I would like to make it the basis for the assessment of my scientific achievement in the procedure of applying for a *doktor habilitowany* degree. The main topics of individual papers will be discussed according to below list.

1. Testing the possibility of using magnetic methods to study the indoor air pollution for a small collection of indoor dust samples.
2. Development of the method for analysis of spatial distribution of indoor dust magnetic susceptibility. Using the method for assess the level of air pollution in homes/flats in large urban environment.
3. Identification of mineralogy, magnetic domain structure and size of magnetic particles of indoor dust. Determination of the correlation between magnetic susceptibility and concentration of heavy metals and other toxic trace elements; using for analysis the Pollution Load Index (PLI).
4. Magnetic characteristics of the granulometric fractions of indoor dust; comparison of samples collected in the area with the high and low air pollution levels.
5. Application of magnetic methods to assess the level of indoor air pollution in buildings located in the small town.
6. Magnetic properties of a mixture of magnetite and metallic iron in indoor dust samples.

***Introduction—motivation for undertaking described topics***

During the last decade, a number of experimental and numerical studies advanced understanding of the emission, formation, dispersion, exposure and health effect of particulate matter (PM) in urban atmospheres. The pollution of outdoor and indoor air belongs to one of most important factors, which dramatically influence the quality of human life. The statistical data gathered systematically by the World Health Organization (for example: WHO Report, 2012) indicates that more than 1.5 million of diseases annually in the world is directly caused by indoor air pollution. For the same reason about 2.7% of general amount of serious illnesses of breathe and blood systems, together with allergies have been caused by air pollution inside houses, apartments, offices, factories, schools, magazines, recreation centers, etc.

The pollution of atmosphere has been in the center of interest of scientists and it has been studied intensively from some dozen years. The result of these studies was the number of publications on concentration, composition and dynamic of transport processes of outdoor air pollution. Moreover, the system of continuous monitoring of air quality has been developed in the most polluted regions and cities over the world.

Recently, there has been growing interest in the study of a quality of indoor air. On average, urban inhabitants spend more than 90% of their lives inside their flats, work places, education and recreation centers (de Brun et al., 2008). The health risk to people had forced scientist to search for explanation of the manners of transport of outdoor particles into buildings, the identification of pollution sources and the indication of the main factors, which decide about the quality of indoor air in urban environments.

Main sources of atmospheric pollution can be grouped in the following order: (i) emissions connected with industrial activity: metallurgy, cement works, production of fertilizers and different other chemical compounds; (ii) products of liquid and solid fuel combustion during production of electric energy and heat, (mainly combustion of bituminous and brown coal, heavy fractions of petroleum, etc.) and (iii) processes connected with road transport, this means: combustion of liquid and gas fuel and emission of non-combustion pollution. Hjortenkrans et al., (2007) analyzed a very fast, continuous increase in car transport in Stockholm what indicated that in the future more than 50% of total emission of heavy metals and other toxic elements to atmosphere and soils well came from an non-combustion emitters involving mechanical abrasion and corrosion, wear of road surface, car tires, brake pads and brake discs.

The above information decided about application of magnetic methods, which has been used about 20 years for environmental studies, also for analysis and description of a level of indoor air pollution. The application of magnetometry to evaluation of environmental pollution based on the general assumption that pollution (i.e. waste products, emission from industrial activities and vehicle traffic) is linked to the magnetic fraction of iron-oxides. The magnetic methods allow to measure the magnetic parameters, firstly of mass magnetic susceptibility ($\chi$), of polluted soli, sediments, dust, air, etc., in which heavy metals, other toxic elements and their compounds appear as well. The magnetic parameters are very sensitive to changes in concentration of magnetic particles and their variety let to identify sources of their origin. Magnetometry is one of the most effective, fast and low cost methods for qualitative estimation of a level of environmental pollution (soil, sediments, air). Magnetic experiments have been carried out for examination of pollution in urban and industrial areas by measuring polluted soil (Magiera et al., 2011, Jeleńska et al. 2008), street dust settled on roads (Hoffman et al., 1999; Kim et al., 2009; Bućko et al., 2009; Wang et al., 2012; Qiao et al., 2011; Zhang et al., 2012 and Yang et al., 2014), particle matter suspended in atmospheric air (Sagnotti et al., 2006; Górka-Kostrubiec et al., 2012; Castaneda-Miranda et al., 2014) and airborne particles captured on vegetation (Monaci et al., 2000; Mitchell et al., 2010; Salo et al., 2012).

The study carried out by the group of environmental magnetism at the Institute of Geophysics PAS in Warsaw has started in 2010. We have applied the magnetometry to describe the level of indoor air pollution in flats by investigation on indoor dust samples.

Our works published between 2011 and 2016 show the dependence between the quality of indoor air and the outdoor air pollution levels. We identified the different categories of particles derived from outside sources, which were infiltrated inside buildings. There are two printed papers only which undertake this object of studies in this years, except of our works. Halsall et al. (2008), studied the correlations between the total concentration of polycyclic-aromatic-hydrocarbons and the magnetic parameters reflecting content of magnetic pollution in outdoor and indoor air. Jordanova et al. (2012) examined the magnetic characteristics of the pair indoor–outdoor dust collected in six schools in different parts of Bulgaria.

My experiences indicate that household dust is a good indicator of indoor air pollution level and lets to apply magnetometry to its evaluation. Household dust accumulates organic and inorganic substances (natural or anthropogenic origin) from indoor and outdoor sources. Gas cooking, tobacco smoking, burning wood in fireplaces, domestic chemicals, furnishings, and activity of people and animals (Martuzevicius et al., 2008) contribute primarily to indoor particulate matter and organic pollution levels. Urban sources of PM and organic contamination mainly arise from fuel combustion processes in transportation traffic-related particles and energy production are recognized as an important contributor to outdoor PM concentrations (Kingham et al., 2000; Wahlin et al., 2006; Thorpe and Harrison et al., 2008; Zhang et al., 2012).

By now, indoor dust had been considered mainly as the source of dangerous allergens of organic origin, but its part is also the source of dangerous chemical substances, e.g. toxic heavy and trace metals, which can be responsible for adverse health disorders among adults, but among small children especially. Children have smaller body mass comparing to adults and they are very active playing in domestic spaces, very often with the close contact with dirty surfaces and different objects. They have increased exposition to pollution for these reasons.

***Description of study results***

**Ad. [1].**

The preliminary study of indoor air pollution was conducted during 2010 year for small group of 12 flats in Warsaw, Poland (Jeleńska M., Górka-Kostrubiec B., Król E., 2011). The study was based on the evaluation of indoor dust by measurement of the magnetic susceptibility, which is proportional to the total amount of magnetic particles in sample. The amount of magnetic particles in indoor dust mainly depends on their indoor and/or outdoor sources. From available literature (See and Balasubramanian, 2006; Langer et al., 2010; Wan et al., 2011) it is known that cooking and gas-stove usage generate mainly fine-grained particles consisting of phthalate esters and polycyclic aromatic hydrocarbons. Out of remaining indoor sources, ashes from smoking cigarettes and remains from burning wood in fireplaces are main sources of magnetic particles (Jordanova et al., 2006).

On the other hand, many authors (Kulmala et al., 1999; Kingham et al., 2000; Chao, 2001; He et al., 2004; Martuzevcius et al., 2008; Layton and Beamer, 2009; Guo et al., 2010) report the studies of air contamination levels inside buildings from a city center in relation to the outdoor pollution levels by using non-magnetic methods. They reported that the high indoor PM levels were observed in traffic rush hours on weekdays, indicating the predominant effect of vehicle emissions. Assuming that the indoor pollution sources are not significant we can infer that variations in amount of magnetic fraction of indoor dust are due to outdoor sources producing magnetic particles.

The object of the study was the magnetic fraction of indoor household dust collected from floor surface of apartments and from furniture. The samples were gathered in vacuum cleaner bags by residents of the apartments, according to their common method of cleaning. The locality of chosen flats was differentiated: a part of them was situated in the center of Warsaw, other flats were in buildings close to busy, main streets with big intensity of vehicle traffic, but some samples were taken from suburb flats and from the areas with relatively low level of outdoor air pollution. Samples of dust were collected in flats situated on different floors levels, and in rooms from a front and a courtyard sides of buildings.

The following magnetic parameters, which let us to describe mineralogy and concentration of magnetic particles, as well as, dimension and domain structure of magnetic grains were measured for each dust samples: (i) mass magnetic susceptibility ($\chi$) and (ii) parameters of magnetic hysteresis loop: saturation magnetization ($M_s$), saturation remanence ($M_{rs}$), coercivity ($H_c$) and coercivity of remanence ($H_{cr}$). The curves of continuous thermal demagnetization of saturation isothermal remanence (SIRM) measured up to 700$^o$C were used to identify of magnetic minerals present in the dust. The unblocking temperatures of magnetic minerals were determined.

Dust from flats situated in the center of Warsaw had the highest values of magnetic susceptibility, similar values were observed in the dust from buildings located very close to heavy traffic streets and in the city center. There was no substantial difference in magnetic susceptibility between samples collected from rooms in the same flat in front and courtyard side of a buildings. The decreasing trend of coercivity ($H_c$) values with increasing magnetic susceptibility confirmed the slightly differences in magnetic mineralogy between dust samples.

The unblocking temperatures of SIRM indicated that magnetic fraction of dust consists mainly of magnetite. The study SIRM(T) curves conducted by Górka-Kostrubiec et al., (2012) indicated that the top-soil from Warsaw except the coarse-grained magnetite and/or maghemite contains also the small amounts of hematite. Therefore, the small amounts of hematite detected in dust from the flats from Warsaw suburbs were interpreted as the polluted particles of soil, which were introduced inside by people and/or animals.

The ratios of magnetic hysteresis parameters: $M_{rs}/M_s$ and $H_{cr}/H_c$ presented on the Day-Dunlop diagram indicated that magnetic fraction of household dust consists of magnetite grains, which are the mixture of multi-domain grains (MD) with the small participation of single-domain grains (SD).

The preliminary results encouraged me and my colleagues to continue the study using many more samples, as the magnetic particles present in indoor dust can be potentially good indicator of indoor air pollution.

**Ad. [2].**

The study presented in the paper Król E., Górka-Kostrubiec B., Jeleńska M. (2013) was conducted at the Institute of Geophysics PAS with the financial support of the Miele Co. Ltd.-Polish Section in the frame of the Undusted Warsaw project. During the study, the magnetic susceptibility, which is proportional to the total amount of magnetic particles in the dust sample, was applied to assess the level of indoor air polluted in different area of Warsaw agglomeration.

The collection of 195 samples of indoor dust was taken from flats situated in buildings close to heavy traffic street as well as from apartments in low outdoor air pollution areas, such as nearby green spaces, suburbs and in the typical habitable (residential) districts of the city. The sampling procedure was the same as in the previous, preliminary study. It is important to emphasize that some dust samples were taken twice from the same flats: the first time during the spring season of 2011 and ones again in the autumn of 2011. The residents filled in a form containing questions about the location of a flats (distance from the main roads, green areas and a type of public transport in the area), the floor on which the flat is situated, the equipment of a flat such as manner of heating, cooking (electric or gas) and customs of inhabitants such as cigarette smoking, home animals and their own hobby, which can additionally influence the quality of air in their flats.

The five point scale of the level of indoor air pollution has been proposed on the base of measured values of magnetic susceptibility, which changed from minimal value of $19{\cdot}10^{-8}m^3kg^{-1}$ up to maximum of $1541{\cdot}10^{-8}m^3kg^{-1}$. The scale was based on the comparison of the data with magnetic susceptibility of polluted and unpolluted soils and atmosphere air in Warsaw. The study of atmospheric air pollution in Warsaw, which was published in the paper Górka-Kostrubiec et al., (2012), showed the decreasing trend of mean annual values of magnetic susceptibility from $250{\cdot}10^{-8}m^3kg^{-1}$ in 1977 to $115{\cdot}10^{-8}m^3kg^{-1}$ in 1985. This set of data was used to establish the criteria for scale of the level of indoor air pollution in Warsaw apartments.

We adopted the values of $\chi$ lower than $50{\cdot}10^{-8}m^3kg^{-1}$ as very low level of indoor air pollution and called the it background level. In this way, the values of magnetic susceptibility between the background level and $100{\cdot}10^{-8}m^3kg^{-1}$ represented the low pollution level, the next two ranges from $100{\cdot}10^{-8}m^3kg^{-1}$ to $150{\cdot}10^{-8}m^3kg^{-1}$ and from $150{\cdot}10^{-8}m^3kg^{-1}$ to $250{\cdot}10^{-8}m^3kg^{-1}$ were established as the medium and high level of pollution, respectively. Finally, the values of $\chi$ higher than $250{\cdot}10^{-8}m^3kg^{-1}$ belonged to extremely high level of pollution.

The proposed scale for magnetic susceptibility of indoor dust gave us the opportunity to create the map of indoor air pollution levels in Warsaw. It was found that more than 50 % of flats had the low and medium pollution levels, but for about 10 % of flats the values of $\chi$ were higher than $250{\cdot}10^{-8}m^3kg^{-1}$.

The territorial distribution of indoor air pollution level was analyzed after dividing the area of Warsaw into 10 districts. The criterion for division was adopted by levels and kinds of pollutions emitted from outside sources. For 10 areas, the average values of $\chi$ were in the range between $102{\cdot}10^{-8}m^3kg^{-1}$ and $155{\cdot}10^{-8}m^3kg^{-1}$. It means that they belong to the medium pollution level in the five point scale of magnetic susceptibility. The dust from flats located in the center of Warsaw and around of the city center (on the left as well as on the right bank of Vistula river) had the highest concentration of magnetic particles. The big differences between minimal and maximal values of $\chi$ were noted in those part of the city, what was connected to location of flats in immediate vicinity or closer to roads with high traffic density and/or cross-roads. The magnetic susceptibility of dust taken from suburb flats had, as a rule, lower values, than the average value for whole the city. However, in the suburb flats the higher values of $\chi$ were observed in the autumn, in the winter and in the early spring seasons. It was immediate consequence of magnetic particles emission from the local, so-called low-emitters, mainly from domestic fire place, which can seriously pollute atmosphere during specific meteorological conditions, i.e. low degree of vehicle air convection.

The results did not indicate the relation between concentration of magnetic particles and a floor level in buildings from which the dust was collected. Nevertheless the dust taken from the flats located on lower levels had bigger differences between minimal and maximal $\chi$ values.

One of the effects of this work was creation of the five point scale of magnetic susceptibility for evaluation and comparison of indoor air pollution levels. Another important result was to perform the comparative analysis of air pollution levels in different districts of Warsaw (also in the graphical form of the map) on the basis of results showing changes in the concentration of magnetic particles (magnetic susceptibility measurements) contained in indoor dust.

**Ad. [3].**

The big collection of indoor dust samples from Warsaw, presented in the previous paper, was additionally submitted for more detailed study of magnetic mineralogy, domain structure and dimension of magnetic particles, as well as for analyses of chemical elements presented in household dust (Górka-Kostrubiec B., Jeleńska M., Król E., 2014).

It was found that the values of magnetic susceptibility visible on the histogram had asymmetric normal distribution with the shift in direction of higher values. For the asymmetric frequency distribution of magnetic susceptibility the mode value (defined as a random variable corresponding to the maximum probability) was $114\pm4\cdot10^{-8}m^3kg^{-1}$. After the rejection of the samples with $\chi>220\cdot10^{-8}\ m^3kg^{-1}$, the distribution of susceptibility did not deviate significantly from a normal one for which the mean value was $115\cdot10^{-8}m^3kg^{-1}$.

Further research was continued for two groups of samples separately. The samples with $\chi$ lower than $220\cdot10^{-8}m^3kg^{-1}$ and showing the normal distribution were assigned to the first group. The second group consisted of samples with $\chi$ values higher than $220\cdot10^{-8}m^3kg^{-1}$. The study was focused on determining the magnetic mineralogy and domain structure of magnetic particles, and finding the similarities and differences between samples of indoor dust from both groups.

The analysis of the curves of magnetic susceptibility changes with temperature $\kappa(T)$ indicated that magnetite with the Curie temperature of $T_c$ = 570-580°C is the main magnetic phase in both groups of dust samples. This result was confirmed by the Vervey`s transition in low temperature experiment.

For the second group of samples the curves of $\kappa(T)$ showed specific behaviour of $\kappa$ in the temperature range from 600°C to 700°C. In this range the magnetic susceptibility did not reach zero value, which means that other magnetic mineral with the Curie temperature higher than 700°C was presented in dust.

For the first group samples the linear correlation of magnetic susceptibility with the parameters of hysteresis loop of $M_s$ and $M_{rs}$ (all the parameters depend on concentration of magnetic particles) was found. The result confirmed the homogenous magnetic mineralogy and the changes of magnetic parameters were mainly caused by fluctuations in magnetic particles concentration. The weak correlation of $\chi$ with $M_s$ and $M_{rs}$ observed in the second group of samples suggested the non-uniform (non-homogeneous) composition of magnetic fraction of dust and/or the differences in the domain structure of magnetic grains.

The analysis of domain structure was conducted using the Day-Dunlop plot, where the ratios of hysteresis parameters of $M_{rs}/M_s$ and of $H_{cr}/H_c$ are assigned to the appropriate areas describing domain structure of magnetic grains. It was found, that the dust having homogenous magnetic mineralogy contained the mixture of single-domain (SD) and multi-domain (MD) grains.

In order to confirm the domain structure of magnetic grains the model elaborated by King (King et al., 1982) was used. The model analyses the dependence between magnetic susceptibility (parameter very sensitive to superparamagnetic grains (SP) presence) and anhysteretic magnetic susceptibility (parameter sensitive to stable-single-domain (SSD) grains presence). The distribution of grain size was in the range from 0.2 to 5 μm, what means that domain structure of magnetic particles was limited to the pseudo –single domain (PSD) and the small coarse multi-domain (MD) grains.

The magnetic fraction of dust at heterogenic magnetic mineral composition is more coarse-grained. The samples were shifted towards higher values of coercivity ratio and lower values of magnetization ratio and were placed close to the area for MD grains on the Day-Dunlop plot.

The indoor dust was characterized by only small amounts (less than 10 %) of super paramagnetic grains (SP). The content of superparamagnetic grains was detected by measuring the frequency dependence of magnetic susceptibility $\chi_{fd\%} = 100\% \frac{\chi_{fd}}{\chi_{lf}}$ where $\chi_{fd} = \chi_{lf} - \chi_{hf}$, which had values in the range between 0.5 and 3.5%. The SP grains are sensitive for frequency of magnetic field, therefore the $\chi_{fd\%}$ parameter gives the information about percentage contribution of SP grains (Dunlop i Özdemir, 1997). The values of $\chi_{fd\%}$ higher than 4% indicate significant contribution of SP grains and relatively strong influence on the rise in the magnetic susceptibility.

Measurements of magnetic properties of dust were supplemented by analysis of chemical composition. The correlations of magnetic parameters, such as magnetic susceptibility and/or saturation magnetization $M_s$ with the concentration of heavy metals are the base to application of the magnetic parameters as the indicator of air pollution level by heavy metals.

The concentrations of heavy metals and other toxic elements for health of people were analyzed by the Pollution Load Index (PLI) which was proposed by Tomlinson (Tomlinson et al. 1980) to estimation the toxic level in biologic environment. The PLI is defined as the $n^{th}$ root of the product of the Concentration Factors (CF).

$$PLI = \sqrt[n]{CF_1 \cdot CF_2 \cdot \ldots \cdot CF_n}, \qquad \text{where} \qquad CF_n = \frac{C_n}{C_{n(background)}}.$$

The concentration factor is a ratio of the concentration of a heavy metal ($C_n$) to the corresponding background value obtained for a reference site. The PLI is approximately 1 if the elemental load is near the background level and greater than 1 if the environment is exposed to metal toxicities (Qiao et al. 2011). It is very difficult to establish a reference site for collecting indoor dust because of the influence of different outdoor and indoor sources. Therefore, the lowest concentrations ($C_{n(background)}=C_{n(min)}$) measured for each heavy metal were adopted as background values. In this manner, the PLI shows how much the concentration of heavy metals for a particular sample exceeds the minimum value.

Two linear correlations of magnetic susceptibility with the PLI were observed for indoor dust samples. The first line ($R=0.89$, $P<0.01$) approximated dust samples having the normal distribution of $\chi$ and the values ranging from 20 to $220 \cdot 10^{-8} m^3 kg^{-1}$. The second line was fitted to samples heaving the magnetic susceptibility higher than $220 \cdot 10^{-8} m^3 kg^{-1}$. Two linear trends were observed also between the PLI and saturation magnetization ($M_s$).

Recognition of morphology and chemical composition of the magnetic particles has been carried out using scanning electron microscope (SEM) and an energy dispersive X-ray spectrometer (EDS). The SEM observations of magnetic extract of dust showed spherical particles originating from combustion processes and traffic-derived irregular aggregates. The surface of spherical particles was characterized by orange peel morphology and their diameter was in range from 5μm to 200μm. The EDS analysis of spheres surface revealed the dominant of Fe, C and O, and minor amount of other chemical elements as Al, Si, and Ca. The large variations were observed in the composition of irregular-shaped magnetic particles. Some of them contained varying amounts of iron with minor contributions of C, O, Mg, Al, Si, and Ca elements, the other iron and Mg, Al, Si, Ca, Mn, Na K, S and Cl elements. Very fine irregular-shaped particles contained iron as the main component with carbon and oxygen only were additionally observed in the magnetic fraction of the dust from the second group.

The comparison of the magnetic properties and the results of SEM observation and EDS analysis of indoor dust with the results for the outdoor pollution (air filters, soil and dust collected on surface of streets) allowed to conclude that the magnetic particles of indoor dust are similar to the external pollution. The conclusion was reinforced by the fact that in spite of great diversity of flats locations, in about 90% of indoor dust samples so much homogeneous mineralogy and morphology of magnetic particles were observed. Only the values of magnetic susceptibility varied indicating differences in the level of indoor air pollution. On this basis we suggest that the major source of indoor dust are the outdoor particles of pollution which penetrate inside via mechanical and natural ventilation system and by activities of flats' residents.

**Ad. [4].**

The differences and similarities in granulometric fractions of indoor dust collected in the city center and suburbs of Warsaw were studied and described in my publication Górka-Kostrubiec B. (2015).

The thesis for this study included: (i) in the absence of relevant indoor sources the magnetic properties of individual fractions of indoor dust reflect penetration of particles from anthropogenic and/or natural outdoor sources to the interior of apartments, (ii) because of a size and mass of the particles, the coarse-grained dust could be attached to footwear of residents and paws of pets, (iii) The fine-grained fraction could mainly contain the airborne particles suspended in the atmosphere, which probably penetrate into the apartments through the natural and/or mechanical ventilation and (iv) on the basis of morphology and the very specific chemical composition of the individual fractions, it is possible to indirectly reveal the origin of the pollution source.

Two private apartments located in the city center and in the suburbs of Warsaw were chosen to study. The first apartment in the city center was situated close to medium traffic roads (cars, trams). The second apartment was located in a clean residential quarter of suburbs approximately 10 km from the city center and close to a crossroad with medium traffic volumes (cars and buses) in rush-hours (morning and early evening). Both apartments had the similar floor area and were situated on a ground floor. Additionally, their residents had similar life habits (such as smoking, fireplace, pets and activities of residents).

The standard method i.e. the laboratory shaker with sieve set was applied to prepare the following five fractions of indoor dust: diameter between 1-0.5 mm (fraction “0.5”), between 0.5-0.25 mm (fraction “0.25”), between 0.25-0.1 mm (fraction “0.1”), between 0.1-0.071 mm (fraction “0.071”) and less than 0071 mm (fraction ”<0.071”)

Results of thermomagnetic analysis (curves κ(T)) revealed that the individual granulometric fractions had very heterogeneous mineralogy. Magnetite decided about magnetic properties of coarse-grained fractions (“0.5” and “0.25”) of indoor dust collected in both flats. The magnetic fraction has been mixture of single domain and multi-domain grains. In the medium-grained fraction (“0.1”) and fine grained fractions (“0.071” and “<0.071”mm) the heating curves show rapid decrease in susceptibility at 575$^o$C and during heating in range 600-700$^o$C susceptibility continues to decrease but in different manner. For medium fraction at the temperature of 700°C (the highest possible in this experiment), susceptibility does not reach the value typical of paramagnetic phase. This may indicate the presence of a high temperature ferromagnetic phase, most likely pure iron, for which Tc=770$^o$C. During cooling, the susceptibility still decreased until the start of the reverse transformation for magnetite at ~ 575$^o$C. It suggests that the chemical reactions (oxidation) initiated at high temperatures transform pure iron into magnetite, which is in a paramagnetic phase at these temperatures, what causes the reduction of magnetic susceptibility. For finest-grained fraction the continuous heating between 600-700$^o$C causes the decrease in susceptibility to a value of nearly zero, but during cooling, the susceptibility does not show changes up to the Curie temperature of the reverse transformation for magnetite. It indicates that some part of ferromagnetic particles transformed into paramagnetic phase close to temperature of 700$^o$C.

The increase in the magnetic susceptibility values for fine-grained granulometric fractions was observed in the dusts from both Warsaw flats. The suburb flat dust had higher concentration of magnetic particles in coarse- and medium- grained fractions. On the contrary, in the city center the fine-grained fractions had the higher concentration of magnetic particles than the same fractions from the suburb.

The important differences were observed also in morphology of magnetic particles of individual granulometric fractions. The magnetic extract of medium-grained fraction was dominated by the shaving-shaped particles containing metallic iron and traffic-related chemical elements, such as Ca, Mg, Si, Ti, K, Al and Ba. The finest granulometric fractions contained mainly spherical particles very separated in surface morphology. SEM observation revealed the spherules with surface: “orange-peel”, hexagonal-pattern and thread-like and with the surfaces similar to fine crystals (druse-like). They were composed mainly from Fe and the following elements: C, O, Mg, Al, Ca and Si. The fine-grained fractions of dust from the suburb contained irregularly-shaped particles, which varied in Fe concentration and substantial amount of Ba, Mo, W, V and Cr. This kind of magnetic particles was not observed in the dust collected in the center of Warsaw.

A detailed description of the properties and morphology of magnetic particles in indoor dust can identify their origin by comparison with the information available in the literature. For instance, Kim et al. (2009) exanimating the magnetic minerals from roadsides recognized that the products of motor vehicles are in the form of irregularly-shaped particles differ in chemical composition: the first type rich in pure Fe and Al, Ca, Fe, K, Mg and Si, and the second type consist of iron-oxides and Fe, C and S. The morphology and chemical composition of the medium-grained fraction suggest that the components of the dust containing irregularly-shaped particles are derived from vehicle emission. The source of particles having a metallic surface and shaving shape are processes associated with the motion of motor vehicles, such as abrasion of the discs and pads and the working parts of the engine. The shaving-like particles include a very high content of Ba in the suburb dust. The specific shape of the Ba-containing particles indicates that they are certainly of anthropogenic origin. As the barite appeared in the company of iron and carbon, it can be identified as barium ferrite (BaFe2O4) because barite is a common component in automobile brake pads, and is used in diesel fuel as a smoke suppressant (Mosleh et al. 2004, Thorpe and Harrison, 2008). The appearance of particles containing Ba is related to the location of suburban apartment; this site is close to the crossroads, stopping cars generate particles in the brake pad wear.

The study revealed that the metallic iron present in dust samples, in which the magnetite is the main phase of magnetic fraction changes parameters of magnetic hysteresis loop. For granulometric fractions with the very high content of metallic iron (medium and fine-grained fractions) the narrow hysteresis loops were observed. They were characterized by the lower values of coercivity $H_c$ and the higher values of saturation magnetization $M_s$ comparing with the samples which consisted only of magnetite (coarse-grained fractions). For this reason the samples were shifted towards the region characteristic for MD grains on the Day-Dunlop plot, where the ratio of $M_{rs}/M_s$ has lower and the ratio of $B_{cr}/B_c$ has higher values.

The detailed study of magnetic properties of the individual granulometric fractions of indoor dust in conjunction with scanning electron microscopy observations and energy dispersive X-ray spectrometer analysis give a tool to tracking the differences and similarities between samples of dust collected at locations with various contribution from outdoor pollution sources. Moreover, the results demonstrated that it is possible to compare the indoor air pollution of apartment situated in different localities of a city and to identify sources of magnetic particles coming and infiltrating inside buildings.

My studies of magnetic properties of several granulometric fractions may help explain the fact of presence of only magnetite in PM (Sagnotti el al. (2006, 2009, 2012) and Petrovsky et al. (2013), Górka-Kostrubiec et al., 2012) and the significant contribution of metallic iron to indoor dust. As it was shown, the largest numbers of elongated metallic iron particles are observed in the indoor dust fraction of 100-250 μm. The contrast in the granulometry can be related to the fact that PM samplers cannot collect grains larger than roughly 50 μm due to its construction. The PM samplers collected smaller grain size population than vacuum cleaner or simple sweeping of a floor. This can explain why the metallic iron is present in the ID and it was not detected on filters collected by PM samplers.

**Ad. [5].**

The potential relation between outdoor pollution and quality of indoor air was studied on the example of small town Zyrardow, situated in the Masovia region 45km south-west of Warsaw (Szczepaniak-Wnuk I. and Górka-Kostrubiec B., 2016). The small town was chosen because the impact of local pollution sources is limited to a relatively small area and it allows to control the influence of individual anthropogenic factors on atmospheric air pollution. Four areas were investigated, each dominated by different pollution emitters such as vehicle traffic, local heating plant, re-emission of soil-dust from post-industrial area and, so called, low-emission, from individual domestic heating and combustion. Assuming that the indoor pollution sources are not significant we can infer that variations in amount of magnetic fraction of dust are due to outdoor sources which produce magnetic particles. The subject of the study was the magnetic fraction of indoor dust for which the magnetic properties analysis was performed, and supplemented by analysis of chemical elements.

The highest values of magnetic susceptibility were measured for indoor dust from flats located in the town center, along main, very busy streets. Magnetite was the dominant magnetic mineral, similarly as it was observed for indoor dust in Warsaw. It is important that the dust from this area contained second magnetic phase i.e. metallic iron which was Fe which was confirmed by the Curie temperature of iron ~760$^{o}$C noted on the heating curves of induced magnetization vs. temperature M(T) and soft hysteresis loops with relatively low values of $B_c$ ~1.5-5mT. The high content of metallic iron contributing to magnetite caused magnetic enhancement revealed as high values of magnetic susceptibility and saturation magnetization. The detailed analysis of relation between the magnetic parameters depending on the concentration of magnetic particles and the chemical composition of dust proved relatively good correlation with the content of traffic-related heavy metals, such as: Fe, Zn, Ni, Cr, Mn Cu and Co. These allow us to infer that magnetic fraction of dust enriched by metallic iron and traffic-related elements came from outside sources, primary from vehicle exhaust emissions and other processes associated with motion of motor vehicles, involving mechanical abrasion and corrosion. Road surface, tire and brake deterioration are the most important mechanical processes which produce the traffic-related heavy metals. The fine particles created by brake abrasion comprise a long list of heavy metals: Cr, Fe, Cu, Zn, Zr, Mo, Sn, Sb, Ba, and Pb. The coarse particles with significant contribution of Al, Si, K, Ca, Ti, Mn, Fe Zn, and Sr are formed by abrasion of road surface and tires (Wahlin et al., 2006)

The dust collected in buildings situated in the post-industrial area of town had the uniform (homogeneous) mineralogy of magnetic fraction it was dominated by magnetite. It was found that the samples had one of the highest concentrations of following heavy metals: Zn, Ni, Cr, Co, Cd and Pb and the highest value of PLI = 21. The industrial area in Zyrardow has been intensively studied by Parafiniuk et al. (2005) due to the elevated heavy metal levels of top-soil. Authors have found the concentrations of Cr, Cu, Zn, Pb and Co several times exceeding their geological background levels. The source of heavy metals were tanneries and textile plants that have worked until the end of the twentieth century. Fuller et al. (1990) reported that tannery and textile industry emit mainly Cr, Cu, Zn, Cd and Pb. For example, waste water from a tannery is the main source of chromium and lead. Industrial waste water from textile production also contains lead coming from used dyes, and copper originating from corrosion of elements in the equipment. Under appropriate conditions these heavy metals can remain in top-soil for a very long time, then as a particles taken up by wind and/or adhered to people's shoes and clothes can be introduced into buildings.

The study included only two samples from apartments located near the urban heating plant area therefore it was difficult to form a more general conclusion about the direct impact of such outdoor pollution sources on indoor air quality. Both samples had very similar magnetic mineralogy, they contained mainly magnetite grains with a small contribution of metallic iron. However, the samples differed in magnetic susceptibility and in composition of the individual chemical elements; i.e. the first sample contained a high concentration of Ni, Zn and Cu while the second had a high concentration of Fe and Mn.

The magnetic properties of indoor dust from apartments located in Zyrardow suburbs were differentiated and they depended on a content of metallic iron. However, the dust contained less metallic iron particles as well as more fine grains than the indoor dust from the town center.

The important result of the study was demonstration of very similar magnetic mineralogy of magnetic fractions of dust from Warsaw and Zyrardow. The samples from both cities mainly consisted of magnetite and variable amounts of metallic iron.

In both cities, Warsaw and Zyrardow, the relations between magnetic susceptibility and the concentrations of heavy metals expressed by PLI were approximated by two straight lines with different slops. The first line approximated the samples showing relatively homogenous magnetic mineral contained mainly magnetite and the second line fitted the samples contained magnetite with variable amounts of Fe-reach magnetic particles.

The results of the study allow to conclude that because the metallic iron is mainly generated by the processes associated with the motion of motor vehicles its presence in the indoor dust can be a potential indicator of traffic-related pollution sources. In the dust from the suburbs as well as from the city center, the mineralogy of magnetic fraction, especially the contribution of metallic iron can indicate approximate vehicle traffic volumes and the location of an apartment in relation to high traffic density roads and crossroads. The presence of magnetic traffic-related particles in indoor dust allow to apply magnetic methods to estimate the influence of this source on a level of indoor air pollution in residential buildings.

**Ad. [6]**

In the work Górka-Kostrubiec B. and Szczepaniak-Wnuk I. (2016) was examined the coexistence of magnetite with metallic iron in indoor dust. We studied the samples from the second group collected in Warsaw and the samples collected from flats in the center of Zyrardow. Our attention was focused on determination of the magnetic properties of the magnetite –Fe mixture and its thermal product, i.e. after a heating and cooling cycle. The Day-Dunlop plot is commonly used in environmental magnetism for discriminating domain state and, by implication, grain size. It was important to explain how contribution of metallic iron controls the distribution of the hysteresis parameters ratios on this plot.

The set of samples was characterized by the magnetic enhancement of magnetic susceptibility ($\chi$>220·$10^{-8}m^3kg^{-1}$) and saturation magnetization ($M_s$=160-1999·$10^{-3}$ $Am^2kg^{-1}$), and by the narrow hysteresis loop with its parameters: $M_{rs}$= 16-54·$10^{-3}$ $Am^2kg^{-1}$, $H_c$=3-5,5mT, $H_{cr}$=10-25mT.

In the first stage of investigation, the variations of induced magnetization M(T) in the temperature range from 20°C to 800°C were measured. The curves of M(T) showed a magnetic transformation for magnetite. Above 600$^o$C, the magnetization still decreased with the increasing temperature and, finally, the second magnetic transition with estimated Curie temperature for iron ($T_{CFe}$ = 765°C) was pronounced. The decrease in magnetization between 600$^o$C and 750$^o$C was interoperated as the transformation of metallic iron to magnetite. It was effectively visible as the magnetic enhancement because the cooling curves were below the heating onces.

From previous study it is known that in sample dominated by magnetite the presence of the softer-magnetic mineral like metallic Fe impacts the shape of hysteresis loop and its parameters, and by implication on the distribution of hysteresis rations on the Day-Dunlop plot. We expected that the $B_{cr}/B_c$ hysteresis ratio should shift upwards since the increase in iron content decreases $B_c$ more than $B_{cr}$ and the $M_{rs}/M_s$ should shift downwards since the increase in iron content increases $M_s$ more than $M_{rs}$ compared to a sample comprising only magnetite. In order to verify this hypothesis, the hysteresis loops for samples before heating and after a heating-cooling cycle were determined. On the Day-Dunlop plot, the samples before heating had lower values of $M_{rs}/M_s$ and higher values of $H_{cr}/H_c$ compared to the values after the heating and cooling cycle. Initially, the data points clustered in the MD area of the plot, after heating, all the data shifted towards the region of SD grains. The effect was controlled by the reduction of sam amount of metallic iron during its thermal oxidation.

Detailed analysis of thermal induced processes was performed after separation of the dust samples into two fractions. The first one called magnetic fraction" was consisted of mainly metallic iron and magnetite. The second one called "fraction remaining after separation of magnetic particles" contained residual magnetite and Fe-rich particles due to separation was not perfect, and/or hard-magnetic minerals like hematite, and other para and dia-magnetic minerals. The result of thermomagnetic analysis indicated two processes taking place simultaneously in indoor dust. The first process was associated with the oxidation of metallic iron resulting in production of magnetite and the second with formation of magnetite from paramagnetic minerals as a product of chemical transformation. The newly formed magnetite, as the final thermal product of both processes, affects the magnetization of sample. The amount of new-formed magnetite depends on both the content of metallic Fe in sample as well as the chemical composition of the indoor dust.

The study showed that the coexistence of magnetite and iron in indoor dust makes its magnetic properties complex. Variable amounts of metallic iron are responsible for the degree of magnetic enhancement expressed by the high value of saturation magnetization and magnetic susceptibility. Moreover, the presence of Fe particles contributing to magnetite influences the shape of the hysteresis loop and its parameters. The heating of indoor dust in air shows several distinct features on the thermomagnetic curves of M(T) as well as κ(T), caused by oxidation of metallic iron and neo-formation of magnetite.

The mixture of magnetite and metallic iron has been characterized for environmental study because of its application as a potential indicator of traffic-related sources. Since the processes associated with the motion of motor vehicles generate Fe-rich particles such as magnetite and metallic iron, their contribution to the magnetic fraction of indoor dust can approximate the impact of traffic-related sources to the indoor air pollution.

Epidemiological studies (Donaldson et al. 1998, 2003; MacNee et al. 2003) show that the ultrafine, iron-rich particles interacting with cellular components lead to oxidative stress in the fluid of the lung lining which plays an important role in development of inflammation in humans.

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5. Discussion of other scientific / artistic achievements.

***Dissertation***

The subject of my dissertation was "*The kinetics of disappearance of structural defects and their impact on the reversible martensitic transformation in copper alloys*." I studied the alloys exhibiting specific properties and phenomena such as the shape memory effect, super pseudo-elasticity and ability to reduction of mechanical vibrations. Nowadays, the materials exhibiting the shape memory effect are widely used in various technical fields, e.g. as permanent mechanical connections in heat engines, electrical sensors and regulators of temperature, and in medicine, e.g. as clamp connecting bone fragments, implants, orthodontic wire and filter of blood clots.

The shape memory effect is related to the reversible martensite transformation. In order to obtain martensite phase the alloys are quenched from high-temperature β phase or from liquid phase. It is well known that this thermal treatment introduces to alloy a relatively high concentration of point defects, so-called quenched-in vacancies. The defects affect the course of reversible martensite transformation and they are also responsible for the martensite stabilization effect. The stabilization of martensite is manifested by the increase of the start and the finish temperatures of reversible martensite transformation during the first cycle after quenching.

I investigated the impact of heat and mechanical treatments and the chemical composition of alloys on the martensite stabilization effect by the resistometric methods. I have demonstrated that the low-temperature diffusion of monovacancies and divacancies is responsible for the time and the temperature instability of physical properties and the changes in the characteristic temperatures of the reversible martensite transformation. The speed up diffusion of quenched-in vacancies causes the locking of the martensite plate boundaries and/or the immobilization of surface between the martensite phase and the parent phase. It makes the course of martensite transformation difficult and induces the martensite stabilization effect.

Three topics presented below are a continuation of the researches initiated in the dissertation. They include: (i) theoretical description of the point defects diffusion in cooper-based alloys exhibiting the shape memory effect, (ii) the study of the martensite stabilization using the mechanical spectroscopy and (iii) the study of the martensite stabilization effect in the melt - spinning alloys obtained by rapid cooling from the liquid phase.

***The model of monovacancies and divacancies diffusion in quenched-in copper-based alloys***

The paper presents the kinetics of decay and redistribution of quenched-in vacancies in Cu-Al-Zn and Cu-Al-Ni alloys. The study showed that the low-temperature diffusion of excess vacancies is a complex process. For Cu-Al-Zn alloys two elementary processes were distinguished: the first related to the formation and disappearance of divacancies and the second connected to the decay of monovacancies. In Cu-Al-Ni, the disappearance of excess vacancies occurred via the single process associated with the decay of monovacancies only. The differences in the vacancy diffusion were explained by the Fukushimy-Doyamy electron model. In Cu-Al-Zn, the aluminum and zinc alloying additions decrease the energy of vacancy formation in relation to pure metallic copper. The low energy of vacancy formation is responsible for a high concentration of monovacancies and the formation of divacancies with a relatively short relaxation time. The nickel as alloying addition in Cu-Al-Ni leads to the decrease of the energy of vacancy formation compared to the pure metallic copper. In consequence, the relatively low concentration of quenched-in vacancies was observed.

- Kostrubiec, B., Rasek, J., Salamon, A., Morawiec, H. 2002. *Analysis of structural defect annealing in copper-base alloys exhibiting the shape memory effect*. Journal of Materials Science, 37, pp. 369-373.

***The study of the martensite stabilization effect by mechanical spectroscopy.***

The aim of the study was to estimate the influence of different types of heat treatments on the martensite stabilization process. The mechanical spectroscopy i.e. the measurement of the elastic shear modulus and the internal friction was applied to investigate the reversible martensite transformation. The mechanical spectroscopy allows to observe the martensite transformation because the crystal structures of martensite phase and austenite phase differ in mechanical properties (elasticity). The changes of the elastic shear modulus and the internal friction with temperature showed that the annealing of alloy at temperatures corresponding to the activation energy of vacancy migration causes mobilization of the martensite plates and the subsequent cycles of transformation occur without the stabilization effect.

- Kostrubiec, B., Rasek, J., Wisniewski, R., Morawiec, H., 2003. Mechanical spectroscopy in Cu-Al-Zn and Cu-Al-Ni alloys. Solid State Phenomena, 89, pp. 287-292.

***Martensitic transformation in the ribbons copper-based alloys obtained by a rapid cooling from the liquid phase***

The shape memory effect is also observed in the thin ribbon alloys (melt-spun ribbon) in which the martensite phase is obtained during alloy production by the fast cooling from the liquid phase (melt-spinning technique). The melt-spinning technique as well as the rapid quenching introduce into alloy the high concentration of point defects. The strong defected structure affects the time and the temperature instability of their physical properties, such as electrical resistance, elasticity and structural transformations. This is the reason why the melt-spun ribbon alloys immediately after production are not attractive in practical application.

The study demonstrated that the application of suitable thermal treatment speeds up the diffusion of vacancies to their disappearance places. This leads to mobilization of the martensitic plates and the subsequent cycles of transformation occur without the changes in the start and the finish characteristic temperatures. The other main result of my work was to show that the size and the structure of the grains affect the characteristic temperature of the reversible martensite transformation and the width of their thermal hysteresis. It was found that the fine-grained structure of the melt-spun ribbons stronger influences on the start temperature and the thermal hysteresis of martensite transformation than in the bulk alloys having the average grain size of about two orders magnitude higher. This feature makes the melt-spinning ribbon alloys more attractive in practical application.

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- Goryczka, T., Lelątko, J., Górka-Kostrubiec, B., Ochin, P., Morawiec H., 2008. *Martensitic transformation in melt-spun Ni-Mn-Ga ribbons*. The European Physical Journal ST, 158, pp. 131-136, DOI:10.1140/epjst/e2008-00665-3.

The results of my participation in the projects "*Selection, production and development of Heusler alloys exhibiting magnetic a shape memory effect*", and Excellence Centre – "*New materials: ferromagnetic alloys exhibiting a shape memory effect*" were published in several papers. The brief summary of this work I presented below.

***The study of martensitic transformation induced by magnetic field in the ferromagnetic alloys exhibiting a shape memory effect***

In the ternary intermetallic Co-Ni-Ga and Ni-Mn-Ga alloys the shape memory is connected to a magnetoelastic martensitic transformation. The transformation is induced by stress that is caused by an external magnetic field. Our research showed that two factors, i.e. the thermal treatment and the precipitation of additional phase (γ-phase) affect the mechanical and the magnetic properties of alloys and the course of reversible martensitic transformation. It was found that the increase in volume of the γ-phase significantly improves the mechanical and the plastic properties of alloys and influences the characteristic temperatures of martensitic transformation. The annealing of alloy at the temperature of 1223K for 40 minutes causes the upwards shift of the start temperature of martensitic transformation of about 50K and narrowing the thermal hysteresis of about 10K. Moreover, in ferromagnetic shape memory alloys the high-temperature annealing causes the increases in the Curie temperature of about 70K and the separation the martensitic transformation from the magnetic transformation. The increase in electron concentrations per atom improves the magnetic properties of alloys, i.e. rises the values of saturation magnetization. The optimal mechanical and magnetic properties and the relatively low characteristic temperatures of martensitic transformation (working in the room temperature range) allow to apply the ferromagnetic shape memory alloys in practice as an excellent and fast actuators (switches, pushbuttons).

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The several papers on the kinetics of crystallization process and the magnetic properties of amorphous alloys with different compositions were the result of my collaboration with dr Sabina Lesz from the Institute of Engineering Materials and Biomaterials of Silesian Technology University. The several papers were published in materials science journals.

***The improvement of the magnetic and the mechanical properties of amorphous alloys with different alloying additions.***

The amorphous alloys of the type $TL_{1-x}M_x$ where TL=Fe, Co, Ni and M=B, Si, C, N, P, Ge obtained by melt spinning technique have excellent soft magnetic properties, i.e. the low coercivity and hysteresis loss, and the high values of magnetic permeability. These special features make such alloy a good candidate for application: in electronics as magnetic reading heads and magnetic sensors, in large core transformers and in electronic devices. We investigated the magnetic properties of alloys according to their compositions and the kinetics of the crystallization process. In the cobalt-based alloys, the amorphous phase is obtained in the production process by a rapid cooling from the liquid phase or by the appropriate selection of alloying additives. The excellent properties of the soft magnetic cobalt-base alloys are due to an amorphous phase. The crystallization of alloying additions in amorphous phase leads to deterioration of the magnetic properties of the alloys. The kinetics of the crystallization process was analyzed by measuring of the electrical resistivity and the magnetic susceptibility after the step-annealing in the temperature range from 773K to 837K. Our research showed that the crystallization occurs with the relatively high effective activation energy, which indicates the high thermal stability of the crystalline phase.

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At the Institute of Geophysics PAS I was interested in the environmental study. I participated in the investigation of soil formation processes, magnetic structure of natural soil profiles and pollution of atmospheric air and soil in an urban environment. The results of those studies have been presented at the international conferences, including the 12th, 13th and 14th Castle Meeting - New Trends on Paleo, Rock and Environmental Magnetism in 2010, 2012 and 2014, and the European Geosciences Union General Assembly in 2014 and 2016.

***The soil formation processes (pedogenic processes) and the magnetic structure of different soil types***

The aim of this work was to show the subtle differences between the Chernozem profiles which were formed in different climatic conditions in Central Ponland (Europe) and in Humutovsky steppe (Ukraine). We studied the magnetic properties of individual genetic horizons, the changes in magnetic mineralogy and the distribution of magnetic grains along the profiles. Detailed analysis of individual magnetic parameters and their appropriate relations allows to determine the differences in genetic horizons and the soil formation processes depending on the climatic conditions. Our result indicates that Chernozem from Humutovsky zone developing under typical steppe condition was characterized by the highest values of magnetic susceptibility in the upper layer as well as in the parent rock (loess). It was explained by the strongly developed pedogenic process in loess which occurred before the Chernozem began to form. A slightly different changes were observed in the Chernozem formed on the loess layer in Central Poland. The relatively low values of magnetic susceptibility along the profile and the large changes in magnetic susceptibility in relation to parent rock were linked to the favorable climatic conditions. It was found that for the Chernozem formed under the steppe condition, the time was the main factor responsible for the large development of soil processes. In the Chernozem from Central Poland the intensive soil formation processes occurring in favorable climatic conditions were rapidly stopped by a negative water balance.

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***Application of magnetometry to study of the atmospheric air pollution in Warsaw***

In this work, we studied the particulate matter (PM) of airborne by measuring of the magnetic properties of polluted filters collected in the Warsaw Air Monitoring Station in 1977, 1980, 1981 and 1985. The first aim of the study was to examine the impact of weather seasonal changes on the spread of contaminations. For this purpose we determined the correlations between magnetic susceptibility and the meteorological parameters such as temperature, pressure and humidity. It was found two different trends between the magnetic susceptibility and the meteorological parameters for warm and cold seasons of the year. In the cold months, the magnetic susceptibility linearly increased with increasing of the average temperature and the average absolute humidity. In the warmer months, the relation was reversed for both meteorological parameters. In the transitional seasons (early spring and late autumn), the short-time (2-3 days) and the extremely high peaks of the magnetic susceptibility were observed. This phenomena was interpreted as episodes associated with the formation of a quasi-smog during weather inversions and/or as a short-time emission of pollution from local emitters.

The second aim of study was to examine the changes in the air pollution levels during the several years. We established the decline trend in the average annual values of magnetic susceptibility between 1977 and 1985. The decreasing level of air pollution was connected to the reduction of industrial production in Warsaw in this time.

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These researches were conducted as a part of my collaboration with dr Ksenia Bondar from the Geology Institute of Taras Shevchenko University in Kiev, Ukraine.

***The study of pollution accumulated on the surface of tree leaves in the selected sites in Warsaw and in Kiev.***

The biomonitoring is one of the method for investigation of pollution in different environments. The method uses the bio-indicators, i.e. plant living organisms such as leaves and bark of trees, moss, lichen, etc., animal organisms and microorganisms for qualitative and quantitative assessment of the level of pollution.

In our work we used the biomonitoring to quantify the level of air pollution in two big urban agglomerations, i.e. in Warsaw (Poland) and in Kiev (Ukraine). As a plant bio-indicator we chose the leaves of chestnut tree, which are very good biomaterial for accumulation of air pollution on their surface. The study was conducted on the trees growing directly close to busy roads, in parks, in the city center and in areas of the city with very low vehicle traffic. Our research showed that the magnetic susceptibility of leaf samples collected in autumn (October) was about 80% higher than the values determined for the leaves collected in the spring (May). We found the correlation between the magnetic susceptibility and the intensity of vehicle traffic. The highest values of the magnetic susceptibility were observed for the leaves taken from trees growing along the high traffic roads and the low values of $\chi$ were obtained in the limited traffic area. The results obtained for Warsaw were compared with leaves samples from Kiev, which were collected in the same period of year.

Two important conclusions have been obtained: (i) the tree leaves as traps of pollution particles, allow to observe the short-time and the local changes in the air pollution levels, (ii) the use of leaves of the same type trees gave the opportunity to compare the air pollution levels in different urban environments.

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***The particles of pollution accumulated in soil along busy roads.***

The relation between the intensity of vehicle traffic and the level of air pollution which was observed in studies of air pollution accumulated on the tree leaves, encouraged us to undertake a study of soil pollution at the busy roads, i.e. about 116 thousands vehicles per day, in Warsaw. The measurement of magnetic susceptibility showed that the surface layer of the soil directly at the edge of road is highly enriched in magnetic particles. With the depth the concentration of magnetic particles systematically decreased reaching the constant values at about 20cm. Moreover, the measurement of the horizontal soil profiles showed that the magnetic particles are mainly accumulated within the belt of soil at the width of about 150cm from the edge of road.

We did not found a simple linear relation between magnetic susceptibility and intensity of vehicle traffic. This was due to additional factors, such as intersection with traffic light, shape of the terrain and the high plans growing along the roads (shrubberies and trees) which affect the amount and spread of pollution.

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