Summary of the habilitation thesis

Jacek Przybytek

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Contents

1 Personal data

Full name: Jacek Przybytek

nationality: polish

position and scientific degree: senior research and engineering advisor, doctor of philosophy

employment

Solid State Physics Division
Institute of Experimental Physics
Faculty of Physics
University of Warsaw

2 Education, diplomas, scientific degrees – specifying the names, places and years of obtaining, and the title of the PhD Thesis

- **1991 - Master's degree in Physics** in the field of solid state physics and teaching physics from Faculty of Physics, University of Warsaw after master degree studies in physics in years 1985-1991. Master thesis entitled *High-pressure investigations of antimony-antisite defect in gallium arsenide* supervised by prof. dr. hab. Michał Baj completed in Solid State Division of Institue of Experimental Physics, Faculty of Physics, University of Warsaw.
- **1997 r. Doctor of Philosophy in physical sciences** obtained from Faculty of Physics, University of Warsaw. The PhD Thesis entitled *Stabilization of the distorted configuration of the EL2-defect in GaAsP under high hydrostatic pressure* supervised by prof. dr. hab. Michał Baj completed in Solid State Division of Institue of Experimental Physics, Faculty of Physics, University of Warsaw.

3 Information about employment in the scientific units so far

- **1997 r. - 2000 r.** adjunct professor at the Faculty of Physics, University of Warsaw;
- **2000 r. - 2002 r.** Marie Curie Industry Host Fellowship at Schlumberger - Montrouge Technology Center / France
- **2003 r. - 2014 r.** associate professor at the Faculty of Physics, University of Warsaw
- **2014 r. - 2017 r.** senior research and engineering advisor at the Faculty of Physics, University of Warsaw

3.1 Stays at foreign research or academic centers

- 1991-1992 (12 months) DAAD (German Academic Exchange Service) scholarship at Fachhochschule Emden and at Institut für Halbleitertechnik, Technische Universität Braunschweig, Germany;
- 2000-2002 (30 months) postdoctoral Marie Curie Industry Host Fellowship (of the European Commission) at Schlumberger Montrouge Technology Center, France;
- conference scholarship of the Foundation for Polish Science for attending the Fluctuations and Noise 2003 conference, Santa Fe, New Mexico, USA (1 week);

- in years 2005-2006 (altogether 2 months) 2 scientific stays at Groupe d'Etude des Semiconducteurs, Université Montpellier II, France;

4 An indication of the achievements effecting from the article 16 §. 2 of the Act of March, 14th, 2003 on Law on Academic Degrees and Title and Degrees and Title in the Arts (Dz. U. (Official Journal of Laws) item 882 from 2016 with changes in Dz. U. item 1311 from 2016.):

I hereby present a cycle of 9 publications published after the completion of the PhD thesis.

4.1 The title of scientific achievement

Voltage and current fluctuations in the condensed matter research.

4.2 Publications constituting the part of scientific achievement.

H1 *Low-frequency noise in AlGaAs/InGaAs/GaAs Hall micromagnetometers*
V. Mosser, G. Jung, J. Przybytek, M. Ocio and Y. Haddab
Fluctuations & Noise 2003, Noise and Information in Nanoelectronics, Sensors, and Standards, L. B. Kish, F. Green, G. Iannaccone, J. R. Vig, Editors, Proc. SPIE Vol. 5115 (2003), 183-195
My contribution to this work consisted in performing almost all noise measurements, performing the numerical calculations by finite elements method and discussing / interpretting the experimental results. I estimate this contribution at 25%

H2 *LF noise in cross Hall effect devices - geometrical study*
J. Przybytek, V. Mosser and Y. Haddab
Fluctuations and Noise 2003, Noise in Devices and Circuits, M. Jamal Deen, Zeynep Celik-Butler, Michael E. Levinshtein, Editors, Proc. SPIE Vol. 5113 (2003), p. 475-483
My contribution to this work consisted in performing all noise measurements, participation in planning the technological process of sample growth and processing, performing the numerical calculations by finite elements method and discussing / interpreting the experimental results and writing the published article. I estimate this contribution at 70%

H3 *Current Fluctuations in Single Barrier Vertical GaAs/AlAs/GaAs Tunneling Devices*
J. Przybytek, M.Baj
Acta Physica Polonica A, **112**, 221 (2007)
My contribution to this work consisted in designing, building, and programming the experimental setup for noise measurements, performing all the measurements, processing and interpreting the data and writing the publication. I estimate this contribution at 75%

H4 *Low-Frequency Noise Measurements of the Tunneling Current in Single Barrier GaAs/AlAs/GaAs Devices*
J. Przybytek, M. Baj
American Institute of Physics CP1129 (2009), Noise and Fluctuations, 20th International

Conference (ICNF 2009) edited by M. Macucci and G. Basso
My contribution to this work consisted in designing, building, and programming the experimental setup for noise measurements, performing all the measurements, processing and interpreting the data and writing the publication. I estimate this contribution at 75%

H5 *Observation of Thermally-Activated Electron Traps in GaAs/AlAs/GaAs Heterostructures in Low-Frequency Noise Measurements*
J. Przybytek, R. Stankiewicz, M. Gryglas-Borysiewicz, M. Baj, A. Cavanna, G. Faini
Acta Physica Polonica A **119**, 723 (2011)
My contribution to this work consisted in designing, building, and programming the experimental setup for noise measurements, supervising the measurements (measurements and data processing were performed by my MSc student R. Stankiewicz), interpreting the data and writing the publication. I estimate this contribution at 60%

H6 *Impurity-related noise in single-barrier GaAs/AlAs/GaAs resonant tunneling devices*
J. Przybytek, M. Gryglas-Borysiewicz, M. Baj, A. Cavanna, G. Faini, U. Gennser, A. Ouerghi
Proceedings of 22nd International Conference on Noise and Fluctuations ICNF 2013, IEEE 2013
My contribution to this work consisted in designing, building, and programming the experimental setup for noise measurements, performing all the measurements, processing and interpreting the data and writing the publication. I estimate this contribution at 60%

H7 *Noise signatures of metastable resistivity states in ferromagnetic insulating manganite*
J. Przybytek, J. Fink-Finowicki, R. Puźniak, V. Markovich, G. Jung
Journal of Applied Physics **118**, 043903 (2015)
My contribution to this work consisted in designing, building, and programming the experimental setup for noise measurements, performing all the noise and electrical transport measurements, processing and interpreting the data and participating in writing the publication. I estimate this contribution at 60%.

H8 *High frequency cut-off in 1/f conductivity noise of hole-doped $La_{1-x}Ca_xMnO_3$ manganite single crystals*
J. Przybytek, J. Fink-Finowicki, R. Puźniak, G. Jung
Journal of Statistical Mechanics: Theory and Experiment 054024 (2016)
My contribution to this work consisted in designing, building, and programming the experimental setup for noise measurements, performing all the noise and electrical transport measurements, processing and interpreting the data and participating in writing the publication. I estimate this contribution at 70%.

H9 *Robust Random Telegraph Conductivity Noise in Single Crystals of Ferromagnetic Insulating Manganite $La_{0.86}Ca_{0.14}MnO_3$*
J. Przybytek, J. Fink-Finowicki, R. Puźniak, A. Shames, V. Markovich, D. Mogilyansky and G. Jung
Physical Review B **95**, 125101 (2017)
My contribution to this work consisted in designing, building, and programming the experimental setup for noise measurements, performing all the noise and electrical transport measurements, processing and interpreting the data and participating in writing the publication. I estimate this contribution at 60%.

4.3 Report on scientific goal of aforementioned works and on results achieved, with the discussion of their potential applications

In electrical measurements of quantities characterizing properties of materials and heterostructures noise and interferences play an important role. These are phenomena which limits the accuracy of performed measurements of e.g. average current or voltage. Therefore experimentalist performing measurement try to supress the external interferences or to limit them to minimum. However, even if the experimental setup is ideally screened from external interferences, the measured physical quantities fluctuate themselves, which reflects the internal dynamic of the investigated system, e.g. the thermal movements, the granulation of the electric charge, and, in case of semiconductor devices, the quantum nature of the processes ruling the performance of these devices. Hence the interest in noise investigations has usually two aspects - a practical one aiming at the recognition of the sources and noise optimization, to enable the precise measurement without harmful noise, and the second, cognitive one, which is much more interesting and reaches to the nature of investigated physical processes. As the nanotechnology and miniaturization of semiconductor devices progress, fluctuation phenomena are getting more and more of significance and therefore the development of experimental techniques for noise measurements enables more insight into the investigated system than simple time-averaged ones, giving the possibility to get more complementary data about the dynamics of occuring processes.

The present thesis will formulate the achievements in chronological order:

H1 - H2 Getting to know the nature and optimization of electronic noise in magnetic field Hall sensors based on the two-dimensional electronic gas in pseudomorphic AlGaAs/InGaAs-/GaAs heterostructure. These sensors are used in millions of commercially available electric meters and should have a stable level of electronic noise not exceeding the accepted standard. Research has led to the determination of noise sources, its optimization and to minimization of the sensor dimensions and, effectively, to lowering the production costs. My main contribution to these investigations were the numerical calculations of the noise for series of different device geometries and performing almost all noise measurements. All this research has been performed during my postdoctoral fellowship *Marie Curie Industry Host Fellowship* in Schlumberger Montrouge Technology Center in cooperation with Service de Physique de l'Etat Condense, CEA Saclay (Gif-sur-Ivette);

H3 - H6 The investigations of the current fluctuations in single-barrier structures performed in the unique experimental setup constructed by myself at the Faculty of Physics, University of Warsaw. In noise measurements different electron transport mechanisms through the single barrier system have been observed, whereas in ordinary current-voltage characteristics they not always were noticed. In noise characteristics the different scattering mechanisms have been revealed. It could have an significant implications for solid-state quantum information devices based on the trapped electric charge. In such devices the $1/f$ noise can be a source of phase decoherence and the knowledge about possible electron scattering mechanisms influencing the coherence length and phase relaxation rate is of a great importance [1];

H7 - H9 Investigations of the electronic noise in system of strongly correlated electrons in bulk manganites $La_{0.86}Ca_{0.14}MnO_3$ and $La_{0.82}Ca_{0.18}MnO_3$. Because of the subtle equilibrium of many ordering mechanisms in this material (structural, spin, orbital and charge), this material has a complicated phase diagram, where the most interesting for us was the state of ferromagnetic insulator, just below percolation threshold $x < 0.225$. This is the strongly inhomogeneous material exhibiting insulator and metallic ferromagnetic phase-separation, where the electric conduction has percolative character, and, especially in the vicinity of metal-insulator transition, exhibits intensive $1/f$ or random telegraph noise of unknown origin. Investigations of these fluctuations combined with structural and magnetic characterization (SQUID, EMR) enabled us to relate these fluctuations to the appearance of different phases of material and its magnetic properties. The main achievements presented in articles [H7 - H9] are

– the discovery of noise signatures of different metastable states of the material;
– observation and investigations of the high-frequency cut-off in power spectral density of conduction fluctuations, which allowed to infer the hopping transport model patameters [H8];
– observation and investigations of robust random telegraph noise, which, in contrast to typical observations in this material, occurs in wide temperature range, not only in the vicinity of metal-insulator transition, and is magnetic-field independent [H9].

All aforementioned research of the conduction fluctuations in devices and materials aimed to recognize the origin and mechanism of noise generation, and, in case of Hall sensors, also optimization of the the noise level.

4.4 Description of scientific goal and research results.

4.4.1 Noise in magnetic field Hall sensors - Montrouge Technology Center/ Service de Physique de l'Etat Condense, CEA Saclay / Ecole Polytechnique Palaiseau, years 2000-2002, papers [H1, H2]

My interest in fluctuation phenomena started during my postdoctoral stay (Marie Curie Industry Host Fellowship) in research center of Schlumberger in Montrouge - Montrouge Technology Center near Paris, in France. My main task there was to optimize the electronic noise level in magnetic field sensors based on two-dimensional electron gas in pseudomorphic HEMT heterostructures AlGaAs/InGaAs/GaAs. Because of the confidentiality of industrial research only part of my investigations was published at world conference *Fluctuations and Noise, SPIE, Santa Fe 2003*, which integrates both the academic and industrial scientific community in the field of fluctuations and noise research. The working principle of Hall sensors is based on classical Hall-effect occuring however in two-dimensional electron gas in quantum well. The origin of electronic noise in this heterostructure is mainly the dynamic exchange of electrons between 2DEG in quantum well and Si-impurities creating the so called DX centers situated inside the barrier. This is an example for the so-called generation-recombination noise, which in limit of many participating fluctuators generates the resistance noise of the sensor of non-typical spectrum, which deviates slightly from the $1/f$ noise. The explanation of the shape of this noise spectrum and the recognition of its origin was aimed at the reduction of the noise to the level accepted from the point of view of application in electricity meters produced in millions for the european and US market (nowadays this production is taken over by Itron). In paper [H1] it have been shown that at that time commonly accepted model of $1/f$ noise as a superposition of discrete lorentzians is not correct. The proper model which perfectly fit the experimental data is the model based on the continuous distribution of relaxation times depending on density of electronic states at the GaAs/dielectric interface. Moreover we have shown that dynamic admittance of electronic states at the interface remaining in thermal equilibrium with two-dimensional electron gas measured on the one hand by means of impedance meter and, on the other hand, calculated from fluctuation-dissipation theorem and measured surface density of states, agreed very well.

The above-mentioned model assumed the thermal equilibrium between electron states at the GaAs/dielectric interface and 2DEG and it describes well the power spectral densities of the conduction noise at room temperatures and the thermal transitions above the barrier between DX states and 2DEG. At low temperatures, however, below 100 K, when there is no equilibrium between surface states and electrons in the well, the noise should disappear. In experiment however we observed the 'pure' $1/f$ noise (for big mesas) or few individual (1-3) lorentzians responding to individual fluctuators in submicrometer-sized samples. At low temperatures the fluctuations of the electron number in the well are caused by kinetics between the states inside the barrier which are much more local corresponding to 2DEG and one can observe the spectra of individual fluctuators, its superposition and the process of forming the $1/f$ noise. Also the diminishig of the devices to the submicrometers caused the emerging from the spectrum of the components related to individual quantum fluctuators, which individually influenced the properties of the devices - this is the touch on the physical limits of the electronic devices miniaturization and simultaneously the possibility to investigate the properties of the quantum objects lying behind the fluctuator. In the case of nano- and mesoscopic systems, fluctuations are the clear reflection of the physical processes (the smaller the system the greater the relative fluctuations of the describing quantities).

Aside from the noise of the sensor related to the vertical structure of the heterostructure, equally important was the noise related to the horizontal structure (i.e. the shape) of the devices determining the current density distribution. This current distribution had been simulated numerically for different shapes of the samples. Basing on the calculations of the noise density performed by means of the finite element method I have found the optimal shape from the point of view of the noise generated by the current density distribution. Especially for the purpose of this project the different Hall sensors with different shapes have been produced and the noise measurements agreed very well with calculations just confirming the possibility of shape optimization and leading to the reduction of noise by about dozen or so of decibels. Because reducing the size of the sensor while keeping its shape causes the increase of the noise, effectively it translates to the reduction of the sensor sizes while keeping the noise at level required by standards. Since the sensors are produced by millions - the total costs of the production decreased. My main contribution to these investigations were performing almost all noise measurements and numerical calculations of electric noise by finite elements method. The calculations were based on classical theory of electric networks, adjoint electric networks and Tellegen's theorem - see [2] and references therein.

The aforementioned investigations were based both on theoretical modeling of the fluctuation processes in heterostructures and on direct feedback with technological processing enabling a technological experiment and comparison of predictions with measurements. We have devised the model, presented in [H1, H2], which very precisely described origin and dynamics of the noise processes. Experimental knowledge of electron density of states at the GaAs/dielectric interface and simultaneous consideration of vertical and horizontal structure of the HEMT enabled for the computation of the power spectral density of the Hall sensor resistance noise without any additional external parameters. Even authors of much better published articles didn't succeed with such complete model [3, 4].

Aside from commertial applications in electricity meters, after further development in years 2003-2009, Hall sensors have been applied as 3-dimensional magnetometers for measuring the magnetic field distribution in NASA space mission [5] and as a submicrometer-sized rulers and arrays of sensors - in strictly scientific research, where they were used for determination of local, submicrometer distribution of magnetization fluctuations in spin-glasses [6, 7, 8].

4.4.2 Tunneling current fluctuations in single-barrier systems, Faculty of Physics University of Warsaw, years 2003-2016, articles H3 - H6

Building of the experimental setup.
In year 2003 I came back to Faculty of Physics aiming at creation and development of techniques for measuring electric fluctuations in semiconductors. In my opinion the progressive miniaturization of electronic devices and possibility to make the objects of investigations smaller and smaller (quantum dots, quantum wires, single-electron transistors, tunneling diodes, various qubit implementations, etc.), will impose greater and greater significance of fluctuation processes related to quantum nature of investigated objects. I occupied myself at that time with the building of experimental setup for measuring electric fluctuations at cryogenic temperatures.

The building of the experimental setup which enabled the measurements of tunneling current fluctuations took a few years. This setup was based on computer ISA-card analog-digital converter produced by Measurement Computing and gifted by dr. M. Kończykowski from École Polytechnique, Palaiseau and driven by Matlab© software. All low-noise amplifiers and preamplifiers, anti-aliasing filters and voltage- and current sources were designed and built by myself from special low-noise components looked up at the market. The electric signals were transferred by special low-noise cables to avoid the triboelectric effect and the microphoning. Because commonly available cryogenic cryostats for liquid helium were not properly screened and there were many non-controlled electric loops, first cryogenic measurements were performed in a specially designed sample-holders dipped inside the liquid helium cryogenic container without the possibility to change and stabilize the temperature in a controlled way - only by changing the extent of sample-holder dipped into the liquid helium. The dedicated continuous-flow cryostat for noise measurements which enabled the change and stabilization of temperature in the range 2 K - 300 K were designed and made in cooperation with dr. W. Plesiewicz from Institute of Physics, Polish Academy of Sciences in year 2011 and ran in 2012. In years 2008-2010 thanks to the grant No. 1925/B/H03/2008/34 *Current fluctuations in resonant tunneling diodes* which was initiated and originated by myself, we have bought commercial low-noise preamplifiers, filters and voltage sources which did not have the noise level as low as home-made ones, but enabled the automation of collecting the noise data, what for long-lasting measurement sessions was of great importance. However, still in the case of very demanding low-noise measurements, we used low-noise home-made battery-driven preamplifiers. In crosscorrelation method they enabled the measurement of current noise for currents at the level of few pA, i.e. of the current noise at the level of 10^{-30}A^2/Hz. Home-made voltage preamplifiers had the input-referred noise ca 1 (nV)^2/Hz. Home-made electronics have only one drawback: any change of configuration parameters like voltage, gain, etc. required the welding of elements as the mechanical jumpers introduced additional noise into the measuring system!

Tunneling current fluctuations in single-barrier GaAs/AlAs/GaAs structure

The subject of electron transport investigations in tunneling through the single tunneling barrier GaAs/AlAs/GaAs intentionally doped in the center of the barrier was started at the Faculty of Physics, University of Warsaw in year 1998. From the very beginning the leading idea of prof. M. Baj was to observe the resonant tunneling through single impurity/ defect inside the barrier. First samples of resonant tunneling diodes came from prof. L. Eaves from the University of Nottingham. We have started the investigations with measurements of tunneling current under hydrostatic pressure which became the part of MSc thesis of M. Gryglas [9, 10, 11]. The subject of electron tunneling through the single barrier was further continued in collaboration with CNRS-/Université Montpellier II without my participation. From this collaboration several papers came into being [12, 13, 14, 15, 16]. Taking advantage of existing samples, after my return to Warsaw I decided to perform the complementary measurements of tunneling current fluctuations, which should reflect the transport mechanism of electrons through the barrier. Because measurement of current fluctuations for currents lower then a few pA was not possible, we have chosen the samples with diameter of mesas large enough so the current was greater then few pA and simultanously we wanted to have this diameter as small as possible, to encompasse the smallest possible number of impurities inside the barrier. Following this algorithm we have chosen the mesas of diameters 50-100-200 μm. Therefore in $I-V$ characteristics at 4.2 K there were no distinct /sharp structures visible related to the tunneling through single impurities/defects, which in dc measurements were seen only at millikelvin temperatures for small mesas of diameters $< 1\mu$m and currents at the level of a few pA. Nevertheless, we expected that shot noise measurements will give more information about the system, not available from time-averaged current measurements. In particular, shot noise should reflect the discretization of electric charge and allow to reveal dynamics and inner energy scale of processes in charge transport [17]. For successive tunneling of noncorrelated and independent electrons low-frequency current power spectral density related to charge granulation was expected at the level of $S_I(f) = 2eI$, where e is the electron charge and I the current. This is the so-called poissonian noise. In order to characterize the shot noise one introduces *Fano factor* F: $S_I(f) = 2eFI$, which indicates if the process is subpoissonian ($F < 1$), or superpoissonian ($F > 1$). In our case electron transport occurs through the vertical tunneling structure of quite big horizontal size (ca 100 μm) but the thickness of the AlAs barrier equals 10 nm. The center of the barrier have been doped with the silicon impurities (ca 3×10^9 cm^{-2}) participating in resonant tunneling process (if the Fermi level of 2DEG approaches the energy of the impurity states). Since the tunneling diodes were vulnerable to electrostatic discharge damage and often during the measurement we noticed the breakdown of the sample, in order to save precious samples, we have started our experiment with small bias voltages $|U| < 1$ V. The results of these measurements were published in [H3, H4]. These results have been obtained in crosscorrelation configuration of two transimpedance amplifiers measuring the current fluctuations at both sample terminals biased by means of low-noise home-made voltage source through the virtual ground of amplifiers. Because of necessity to change the measurement parameters manually their voltage resolution was rather low (ca 25 - 30 mV). In these measurements we have measured at liquid helium temperature 4.2 K the fluctuations of the tunneling currents starting from 1 pA, i.e. from the power spectral density as low as 10^{-30}A^2/Hz, what in itself was quite an achievement. As a result of fluctuations measurements we have obtained following achievements:

1. at the lowest bias voltages we observe direct tunneling through the barrier without participation of any impurities inside the barrier. The Fano factor $F \to 1$, if $|U| \to 0$. Power spectral density of these fluctuations remained white in the whole frequency range, down to the lowest frequencies.

2. at increasing voltages in the range $|U| < 1$ V the Fano factor F decreased to the value 0.55 or 0.6, depending on the bias direction, and showed some regions of stabilizations at certain levels of F, whereas the determination of F was more and more difficult in the range of experimentally available frequencies < 10 kHz, because above $|U| > 0.4$ V the $1/f^\alpha$ noise superimposed on the white shot noise. The values of Fano factor between 0.55 and 1 mean that there are negative correlations of tunneling electrons inside the barrier. This agrees with theoretical predictions for tunneling through impurities inside the barrier [17, 18] and the change of stabilization level of Fano factor from 0.8 at $|U| < 0.4$ V to 0.55 - 0.6 at $|U| > 0.4$ V is caused by switching on the tunneling through the intentionally introduced impurities at the center of the barrier.

3. The origin of the $1/f^\alpha$ noise appearing at biases $|U| > 0.4$ V is probably similar as in 2DEG in working area of Hall sensors - there are traps/impurities inside the barrier in the

vicinity of 2DEG (formed in the emitter region under bias), which exchange the charge with 2DEG by tunneling mechanism. In that case we have not only the electron number fluctuations in 2DEG, but also, depending on the charge state of the trap inside the barrier, the changes in local conduction band edge, i.e. fluctuations of the local barrier hight/shape. It appears as a random telegraph signal (RTS) in tunneling current [19]. In this way the noise is created, whose dependence on current should be like $\propto I^2$ due to electron number dependence, but additional dependence on local barrier fluctuations gives this dependence only approximately. Because we also observe changes in the character of the $1/f^\alpha$ spectra (exponent α changes its value between 0.5 and 2, depending on the bias voltage), so we are probably dealing with nonuniform distribution of characteristic times od traps and/or non-homogenous distribution of traps itself - for uniform distribution we would observe only $1/f^\alpha$ with $\alpha = 1$ [20, 21]. We cannot also exclude the possibility that traps density modulating the tunneling current depends not only on tunneling exchange of traps' charges with 2DEG but could be also thermally activated - like it was shown in [H5], where we have measured the noise for thin (7nm) barrier asymmetrically δ-doped at 1 nm from one of the edges of the barrier. For barriers doped intentionally close to the edge from the substrate-side we were not able to measure the shot noise, which was dominated by $1/f$ noise (in the frequency range available in experiment) - probably δ-doped impurities propagated/diffused during the growth process over the whole barrier. The reason for this explanation is the fact that in the sample produced in the same technological process but δ-doped asymmetrically from the top side inside the barrier we have measured beautiful poissonian noise white down to the lowest frequencies. In the range where $1/f$ was observed we have observed also random telegraph noise (RTN), which allowed us to determine the thermal activation energy of one of the traps modulating the tunneling current through the barrier. Numerical analysis of the RTN signal and subtraction of the dominating RTN from the signal in time-domain revealed next two-level current fluctuations related to another remote fluctuating traps [H5].

The next stage of the investigations of tunneling current fluctuations in single barrier system has been opened when we have bought low-noise current- and voltage preamplifiers, filters and voltage sources with GPIB remote control and much better multi-channel analog-digital converter for signal acquisition. All these was possible thanks to the grant No 1925/B/H03/2008/34 which has been initiated and originated by myself. Automation of the measurements enabled higher biasing voltage resolution and more precise tracing of the tunneling current fluctuations as a function of the biasing voltage for barriers with different level of Si δ-doping in the center of the barrier. The results of these investigations were published in [H6]. The measurements of fluctuations were performed with small voltage step of 10 mV, what in energy scale corresponds to ca 1 meV (the so called leverage factor determines how much of the total voltage at the heterostructure is found in the center of the barrier - it depends on the structure, doping, and biasing voltage and has been determined by self-consistent solution of Schrödinger - Poisson equations for band edges profiles in the structure). Although this stage of investigations was dedicated to the influence of barrier doping on the current fluctuations, paradoxically the most interesting results were obtained for non-doped sample (reference sample) and for sample intermediately-doped at the level 5×10^9 cm^{-2}. Because it was possible to determine the Fano factor only for the smallest biasing voltages and for higher voltages the power spectrum density was dominated by $1/f^\alpha$, noise, were exponent α was in the range 0.5 - 2, the spectra have been integrated in the range 1 - 49 Hz and so obtained measure for current fluctuations as a function of the voltage have been presented in Figures 1 - 2 in [H6]. The main achievements from this investigations are following:

1. in dependency of integrated noise on biasing voltage we observed several distinct peaks of

the width in the range of a few meV $\gg k_B T$. In the same place in $I-V$ characteristics and its derivative there is nothing. It is a beautiful example when noise measurement reveal the existence of processes invisible in time-averaged measurements;

2. general dependency of integrated noise on current, ignoring the distinct structures, in all the samples up to ca 1 V is very similar - the integrated noise is proportional to the current and the average value of the noise is at the level corresponding to the Fano factor close to 1 or slightly below 1, what indicates the existence of negative correlations between tunneling electrons - similarly to described previously. This is mainly the region of direct tunneling and/or with participation of many resonant impurities;

3. above ca 1 V where starts the tunneling through localized states in the X-well in AlAs, and again ignoring the distinct structures, the integrated noise is proportional to current squared, likewise for dissipative processes involving phonons;

4. however, the most interesting distinct structures mentioned above, remained unexplored. In the first place because at that time we did not have the variable temperature cryostat for noise measurements, in the second place because of extremely low noise measured at the level of $10^{-30}\mathrm{A}^2/\mathrm{Hz}$, what correspond to currents of ca a few pA. It would be not possible to measure so low noise in a more complex experimental setup. The spectra of current fluctuations published by other researchers starts at the level of one order of magnitude higher [22, 23, 24]. Recently only one Japanese group approached to this limit, having however a specially designed cryogenic amplifier to their disposal [25].

   However, closer analysis of the data concerning these distinct structures/peaks (e.g. their small width of a few meV) allows for some speculations that we touch here the spectroscopy of the fundamental processes involved in tunneling through one impurity (and/or its excited states) or through several interacting impurities [26, 27, 28]. It could be also processes when Fermi level of two-dimensional electron gas from emitter equals the resonant level of single impurity in barrier which dynamically exchange electron with 2DEG in emitter - it would be strongly nonlinear process with not only electron number fluctuations in the emitter, but also with correlated change in the local coulomb potential of the impurity seen by the tunneling electron (it is fluctuation of the local barrier height). It is interesting also that in the case of some sharp integrated noise peaks when we approach the maximum, the $1/f^{\alpha}$-like power spectral density of the noise changes its exponent α in the range 0.5 - 2 and in maximum itself the fluctuations become a two-level random telegraph noise with lorentzian spectra $\propto 1/f^2$. The magnetic field and temperature investigations of this noise, strongly localized in energy scale, would allow to recognize the nature of this noise.

5. the broad structures in the integrated noise dependency on biasing voltage for voltages higher then 1 V are undoubtedly related to the impurities in the center of the AlAs barrier (which simultaneously is a confining well for X-electrons) and could reflect the $\Gamma \rightarrow X$ scattering, nonelastic tunneling with participation of phonons and/or fluctuating charge of impurities in the barrier, and/or fluctuating charge accumulated inside the barrier. The charge accumulated in the barrier (due to asymmetry in the time-rates of the entering and quiting processes, e.g. as a result of interband scattering) will hinder the tunneling process and this kind of positive feedback will cause the increase of the noise [17, 29].

The building of the experimental setup for the measurements of extremely low low-frequency current fluctuations opened wide range of possibilities in investigations of the charge dynamics in nano- and mesoscopic systems. This subject is very important not only for standard semiconductor devices (where e.g. the noise of the leakage current substantially influences the parameters of the devices) but also for new nano- and mesoscopic quantum logic devices based on the trapped charge of the qubits, where $1/f$ noise is the main source of decoherence of signal in such a system [1].

4.4.3 Investigations of electric fluctuations in $La_{1-x}Ca_xMnO_3$ - LCMO - the materials exhibiting the CMR effect

Since the 1950s manganite $La_{1-x}Ca_xMnO_3$, belonging to the perovskite group, thanks to the very unique combination of electronic, magnetic, and structural properties is a veritable field of fundamental research in condensed matter physics and one of the most fascinating material of interest to the physicists. The colossal magnetoresistance effect (CMR) and half-metallic properties make this class of materials of great importance in electronic and spintronic applications and in technology of magnetic memories. Doping with divalent Ca results in mixed-valence material where the manganese atoms occur simultaneously in Mn^{3+} and Mn^{4+} valence states. With $x < 0.5$ the holes are introduced into the material at the doping level close to the calcium doping level x. Electrons in partially filled $3d$-shells couple strongly the electronic and magnetic (spin) degrees of freedom. Additionally strong coupling to the orbital and lattice degrees of freedom (by Jahn-Teller and polaronic effect) results in a system of strongly correlated electrons/holes. Competition between different degrees of freedom is the origin of very complex phase diagram with many phases of different order parameters (spin, orbital, and electron) which additionally are strongly coupled to the lattice [30]. Local competition of different ordering parameters at the nano- and submicrometer scale is the origin also for the so-called phase separation, which is not a chemical separation, but the separation of different orderings and different electron and magnetic properties. Low hole-doped manganites for $0.125 < x < 0.225$ at low temperatures are ferromagnetic insulators. Therefore we have chosen and grown for investigations the crystals with $x = 0.14$ and $x = 0.18$. In the case of $x = 0.18$, between paramagnetic phase and ferromagnetic insulated one, there is a small region of ferromagnetic metallic phase which is absent in the case of $x = 0.14$. For $x > 0.225$, i.e. above the percolation threshold, the material is ferromagnetic metal (in the ground state and below T_c) [30].

In crystals with $x = 0.14$ and $x = 0.18$ the ferromagnetic metallic and ferromagnetic insulated phases coexist, which probably is responsible for the strong CMR effect and percolative character of the charge transport [31, 32]. The strong fluctuations of the short-range/local charge order in manganites are reflected in conductivity fluctuations. Despite intensive research, the image of electronic properties and mechanisms of charge transport in hole-low-doped manganites ($0 < x < 0.2$) is not quite clear and investigations of conductivity fluctuations are essential.

In following items the results are described which constitute the essential achievements in explaining the mechanisms of electron transport and conductivity fluctuations in hole-low-doped $La_{1-x}Ca_xMnO_3$.

H7 Nano- and mesoscopic inhomogeneity of the ground state and dynamic coexistence of different phases in $La_{1-x}Ca_xMnO_3$ causes that metastability is an intrinsic property of this material. External stimulation by thermal cycles, electric field/current, magnetic field or pressure may transform the system to the metastable state of specific properties. In crystals with higher Ca-doping ($x = 0.18$, 0.20, and 0.22) it was possible to transform the sample to the metastable state by means of electric pulses in a controlled way. In the case of investigated material this procedure didn't succeed but as a result of several thermal cycles (during electric transport measurements) and related voltage - current cycles, the sample evolved towards the metastable state of low resistivity (LRS - Low Resistance State) [H7]. In the initial high-resistivity state of the sample we observed in conductivity fluctuations measurements only $1/f$-like power spectral density, whereas in metastable low-resistivity state the $1/f$-noise was observed only at temperatures above T_c. As we lower the temperature the lorentzian noise emerged and superimposed on the $1/f$ noise. These noise spectra, measured in low-resistivity metastable state, constituted signatures of different metastable states of different resistivity states which were created spontaneously or under influence of the electric current [H7]. At the metastable state we observed transformations of the sample between the states of different resistivities and we noticed that the state of definite resistivity is related to the specific noise spectra - this is the noise signature of the given metastable state. The occurrence of different metastable states is probably related to different landscapes/distributions of localized charges interacting with current carriers and freezing of these metastable states to the electron glass.

H8 Coexistence of ferromagnetic insulating and ferromagnetic metallic phases and in $La_{1-x}Ca_xMnO_3$ for $0.125 < x < 0.225$ and hypothetic existence of electron glass state in this material is the subject of intensive investigations. Therefore rarely observed high-frequency cutoff of the conduction fluctuations spectrum described in [H8] has been compared to existing model of hopping transport in electron glass presented in [33]. Arguments for the hypothesis that the electron glass exists in this material are as follows:

- the difference between measured magnetization during cooling the sample down in magnetic field and without magnetic field shows that below T_c magnetic moments freeze into glassy clusters; simultaneously long-range coulomb interaction in the system opens the coulomb gap and the carrier transport is possible only via hopping mechanism;
- the temperature dependence of the sample resistivity agrees (in certain temperature range) with Efros-Shklovskii law $R(T) = R_0 exp[(T_{ES}/T)^{1/2}]$ for variable-range hopping in the system of strongly localized electrons [34].
- we observed the strong power law dependency of the Hooge factor on temperature.

Nonexpected observation of the high-frequency cutoff in conduction fluctuation spectra in sample with $x = 0.18$ gave an exceptional possibility to compare this behavior to existing models of the $1/f$ noise proposed in [33, 35, 36], which predict such a cutoff. These models describe the carries transport based on variable-range hopping mechanism and for the noise generation they need two-level fluctuators which influence the percolative transport while changing its state. According to these theories in the system should exist the shortest time of fluctuator relaxation related to the fastest hopping process, i.e. the conductivity noise spectrum should be cut from the high-frequency side and the character of this cutoff should be like $1/f^2$. The dependence of the cutoff frequency on the model parameters [36, 33] fitted to the experimental data in certain temperature range below T_c enabled to the determination of such parameters like Efros-Shklovskii temperature, factor describing the electron-phonon interaction, the localization radius of the electron states participating in the hopping transport and the average hopping length. Unfortunately there is no other data to compare these parameters to. Studies of agreement of the model with experimental data is of great importance for description of the nature of the two-level fluctuators. In the last of above mentioned papers [33] there was an assumption that the fluctuator has the many-particle nature and consist of cluster of strongly correlated traps. This is close to the picture of hypothetical electron glass in low-hole-doped ferromagnetic insulator. This is surely a problem which is seeking the solution and our observation is an essential contribution in this discussion.

H9 Telegraph noise occurs usually in mesoscopic systems containing one or a few two-level fluctuators like electron traps in barrier of the tunneling junction [37]. However, in many macroscopic strong correlated systems like high-T_c superconductors or CMR manganites there are macroscopic fluctuations observed, where one two-level fluctuator can influence the resistance of the whole sample. Usually single macroscopic fluctuators are observed in a very narrow temperature range, often around the phase transition temperature, and the life times of the telegraphic states depend on current, bias voltage and magnetic field. In paper H9 for the first time in bulk manganite LCMO in its low-resistance metastable state the robust random telegraph noise was observed and investigated, which occurs in wide temperature range 130 K - 180 K, including T_c. The switching times are thermally activated and independent of magnetic and electric field. With increasing current the amplitude of RTN decreases in exactly the same way as the resistance of the sample increases. The conclusion was that the two-level fluctuator responsible for RTN has macroscopic character and changes the resistance of the whole sample. On the basis of the magnetic and magnetic resonance investigations (ferromagnetic resonance, EMR and electron paramagnetic resonance, EPR) we have stated that in temperature range 130 K - 185 K there exist two phases in this material: ferromagnetic insulating (FMI) and ferromagnetic metallic (FMM), whereas FMM phase as superparamgnetic one exist already below T = 240 K and the EMR-line related to the FMI phase appears below T = 185 K, splits by further lowering the temperature and one of them disappears at 130 K. Emerging of long-range magnetic ordering below 185 K and big difference between magnetic irreversibility temperature T_{irr} = 160 K and freezing of the spin-glass temperature T_g = 80 K suggested the appearance of the clusters of different resistances in this percolating system. Emerging of these clusters is related to the strong inhomogeneity of this material at the nano- and mesoscopic level. Authors of the paper [H9] proposes the mechanism of dynamic current redistribution between percolating paths as an origin of two-level random telegraph noise. The key element of this dynamic current redistribution mechanism (DCR) is specific dependency of the electric resistivity on the current. The current flowing through the percolating net find always the path of lowest resistivity and when this path is found, its resistivity increases and the current comes back to the previous path, thus generating RTN. Because of the wide temperature range of the RTN and its independence of the magnetic field, we have excluded the magnetic, orbital or charge ordering as the origin of these fluctuations. These fluctuations exist in the sample even if they do not develop into full RTN - in the same temperature range 130 K - 150 K instead of RTN the increased intensity of second spectrum (i.e. the normed fluctuations of the consecutive octaves of the first conductivity spectrum) is observed. The second spectrum and nongaussianity of occuring processes are in the course of investigations - the results was not yet published [H9]. This topical subject has been assigned to the oral presentation at the *24th International Conference on Noise and Fluctuations ICNF 2017* in Vilnius (June, 2017).

Because of the potential application of manganites in spintronic/magnetic devices for information processing and storing, the investigations of $1/f$ noise and its origins have not only the fundamental significance but also may be of great importance for optimization of noise-generating processes in devices where the extraordinary properties of manganites will be used.

5 Discussion of other research achievements

5.1 Point defects

Starting with my MSc thesis I was engaged in a point defects research in GaAs. At that time GaAs was very intensively investigated material for fast electronics (the carriers mobility in this semiconductor is much higher then in commonly used Si). Point defects were very often electrically active and electric activity of these centers substantially influenced the properties of semiconductors important from the point of view of applications. Research on antisite defects in GaAs (e.g. EL2) and in mixed crystal $GaAs_{1-x}P_x$ and on DX-like defects in different materials (like GaAs, GaAlAs, Cd(Mn)Te) in Department of Solid State Physics at Faculty of Physics, University of Warsaw, belonged to the world's leading. These research used various experimental techniques like absorption of light, photocurrent, Hall effect, capacitance measurements (DLTS) and EPR, usually in extreme conditions of hydrostatic pressure up to 1.5 GPa and at cryogenic temperatures. Investigations was very often made in collaboration with Unipress, Institute of Physics, Polish Academy of Sciences, and Institute of Electronic Materials Technology. In years 1989-1997 I was engaged in the following investigations:

1. evidencing that antimony atoms in gallium arsenide create similar antisite defects as arsenic atoms and famous EL2-defect. This defect has been observed and investigated in grown in-house bulk GaAs:Sb crystals as well as in thin films grown by MOCVD method [39], [JP1].

2. evidencing that antisite defect in GaAs related to arsenic atom in the place of Ga: As_{Ga}, i.e. the EL2-defect under hydrostatic pressure or in mixed material increasing the gap (GaAsP), capturing electron from the conduction band stabilizes itself in its distorted configuration - As_i, which becomes the fundamental state of the defect, whereas the nondistorted configuration, which is fundamental without pressure, becomes metastable [40], [JP4, JP11]. In other words under hydrostatic pressure the energy of electrons in conduction band increases so much that the transformation of the EL2-defect to its distorted configuration with simultaneous electron capture is more favourable for the system - the role of fundamental and metastable states becomes inverted [JP4].

3. investigations of substitutional DX-like defects similar to EL2-defect. These defects are associated with a strong lattice relaxation and occur not only in III-V but also in II-VI materials. At the beginning of 1990s one of the most exciting topics was the problem how many electrons captures the DX-defect in its fundamental state. The so-called negative-U systems capture two electrons, where U is the coulomb interaction energy of two on-site electrons. Using the idea of an additional doping (codoping) of the material with sufficiently high lying in the conduction band tellurium-impurities it has been shown in paper [41] that by means of high hydrostatic pressure the resonant germanium-related DX-level enters the gap and captures two electrons from the conduction band. Hence it is the negative-U system. The aim of papers [JP5, JP6, JP8] was to investigate if DX-like centers in II-VI materials have also negative-U.

4. copying the idea od codoping from the experiment [41] we have studied the role of the Ge_{Ga} $A_1^{0/+}$-level in the Fermi level pinning in GaAs:Ge,Te [JP2].

5. the possibility of arbitrary filling of the DX-center in pressure-temperature cycle allowed us to investigate the dependence of carrier mobility on carrier concentration and we have shown that the pressure-temperature cycle leads to spatial correlation of scattering charges

and to the increase of mobility comparing the situation when the same carrier concentration is obtained by means of annealing of the carriers from DX-centers filled with electrons in pressure freeze-out procedure. The observation of spatial charge correlations enabled the discussion whether the DX-center is negativ- or posistive-U system. It seemed that the more likely situation is the negative-U one [JP7, JP9].

6. In paper [JP12] we have precisely measured the splitting energies of the DX-centers due to different statistically allowable neighbourhood of this defect in GaAlAs:Si.

5.2 Resonant tunneling under hydrostatic pressure [JP15, JP17]

In addition to the subject of point defects in semiconductors I was engaged in years 1998-2000 in high-pressure investigations of resonant tunneling through impurity states in single GaAs/AlAs/GaAs barrier. The results have been published in [JP15, JP17] and were a part of the master thesis of Ms Marta Gryglas [9]. In next years this subject transformed to the PhD thesis of Ms Marta Gryglas [42].

5.3 Investigations of InN and (Ga,Mn)As materials

After returning from my post-doc fellowship in addition to the building the experimental setup for noise measurements and the noise investigations, I was engaged in electron transport investigations in a new material InN [JP22] and in semimagnetic semiconductor material (Ga,Mn)As [JP23, JP26, JP30, JP31, JP32]. InN was the least explored semiconductor in III-N group. It excited an interest at the beginning of 2000s when it turned out that the forbidden gap has the value of 0.7 eV what enabled to cover with III-N compounds a wide spectral range between 0.7 eV (InN) and 6.2 eV (AlN). Hence the interest in p-doping of this material with magnesium Mg. The difficulty lies in the fact that in spite of heavy Mg doping the material in Hall effect measurements demonstrated the conductivity of n-type. This problem has been explored in article [JP22] by means of impedance- and thermopower- measurements. These studies revealed that on the surface of InN the n-type inversion layer is created which covers the interior of p-type. Great interest in results of this paper manifest itself in a big number of citations - 19.

Although the peak interest in (Ga,Mn)As has already passed, thanks to the unique set of available experimental techniques, our group is still occupied with some unsolved problems. One of such a problems is e.g. the pressure coefficient of the Curie temperature in this material. The value of this coefficient and its sign is an important parameter of the theory explaining the origin of ferromagnetism in this material [JP23], [43]. The experimental determination of this parameter is not easy. The methods of Curie temperature determination developed during these studies have been described in [JP30]. We are preparing the next publication about this subject.

5.4 Development of scientific instruments and research methods in Solid State Division:

- development of experimental setup for Hall effect measurement under high hydrostatic pressure with an access of monochromatic light (1997);
- building of the experimental setup for capacitance measurements; intensively used since the creation in 1998;
- year 2000 - building of the electrometer for tunneling current measurements with remote control;

- creation of the laboratory for noise measurement (in the new location of the Faculty of Physics there is a specially screened room for the experimental setup enabling the measurement low-frequency electric fluctuations at temperatures 2 K - 300 K).

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6 Scientific activities

6.1 Bibliometric data

6.1.1 Summarized *impact factor* according to Journal Citation Reports (JCR): 35.934

6.1.2 Citation number according to Web of Science (WoS)

Sum of the Times Cited: 98
Sum of Times Cited without self-citations: 77
Citing Articles: 81
Citing Articles without self-citations: 68
Average Citations per Item: 3.16

6.1.3 H-index according to Web of Science (WoS): 6

6.2 Participation in scientific projects

- executor in project of National Science Centre No 2012/05/B/ST3/03157 *Transport noise and metastable resistance states in manganites*
- executor in project of National Science Centre No 2011/03/B/ST3/03287 *(Ga,Mn)As under high hydrostatic pressure*
- author and executor in project of Ministry of Science and Higher Education No N N202 192534 *Current fluctuations in resonant tunneling diodes*, (2008-2010)
- executor in grant of Scientific Research Committee No 2 P03B 052 15 *Physical phenomena responsible for limiting the electrical conductivity of two-dimensional electron gas in II-VI heterostructures on the basis of CdTe*, (1998 -2000)
- executor in grant of Scientific Research Committee No 2P03B 138 10 *Investigations of the distorted configuration of the arsenic-antisite defect in thermodynamic equilibrium in mixed GaAsP crystals* (1997)
- executor in grant of Scientific Research Committee No 2P30201707 *Stabilization of metastable defects in GaAs* (1994-1996)

6.3 Participation in conferences (poster or oral presentation)

- 23$^{\mathrm{rd}}$ International Conference on The Physics of Semiconductors, Berlin, 1996, *Pressure investigations of the distorted configuration of the EL2 defect stabilized by free electron capture in* $GaAs_{1-x}P_x$, J. Przybytek, M. Baj, T. Słupiński, J. Mikucki - oral presentation;
- XXIX International School on the Physics of Semiconducting Compounds, Jaszowiec 1999, *Resonant tunnelling through X-minimum-related states in a single barrier GaAs/AlAs/GaAs heterostructure*, M. Gryglas, J. Przybytek, M. Baj L. Eaves;
- XXX International School on the Physics of Semiconducting Compounds, Jaszowiec 2001, *High-pressure magnetotransport measurements of resonant tunnelling via X-minimum related states in AlAs barrier*, M. Gryglas, J. Przybytek, M. Baj, L. Eaves, M. Henini - oral presentation;

- 9èmes Journées Nationales de Microélectronique et Optoélectronique, (JNMO), St Aygulf, France, du 29 septembre au 02 octobre 2002, *Hétérostructures III-V micromagnétométrie*, Mosser V., Adam D., Lee M., Konczykowski M., Ocio M., Przybytek J., Boero G., Contreras S. (invited);
- XXXII International School on the Physics of Semiconducting Compounds, Jaszowiec 2003, *Simple capacitance measurements as a useful tool for characterization of semiconductor heterostructures containing 2DEG*, M. Gryglas, M. Sakowicz, J. Przybytek, J. Siwiec-Matuszyk, L. Dmowski, M. Baj;
- SPIE International Symposium Fluctuations and Noise (FaNo 2003, Santa Fe, New Mexico USA), *LF noise in cross Hall effect devices - geometrical study*, J. Przybytek, V. Mosser, Y. Haddab;
- SPIE International Symposium Fluctuations and Noise (FaNo 2003, Santa Fe, New Mexico USA) *Low-frequency noise in AlGaAs/InGaAs/GaAs Hall micromagnetometers*, V. Mosser, G. Jung, J. Przybytek, M. Ocio and Y. Haddab - oral presentation;
- XXXIII International School on the Physics of Semiconducting Compounds, Jaszowiec 2004, *Electronic noise measurements as a tool for characterisation of physical processes in semiconductor heterostructures*, J. Przybytek;
- XXXIV International School on the Physics of Semiconducting Compounds, Jaszowiec 2005, *Shot noise suppresion in tunnelling through a single GaAs/AlAs/GaAs Si δ–doped barrier measured by crosscorrelation technique*, J. Przybytek;
- XXXV International School on the Physics of Semiconducting Compounds, Jaszowiec 2006, *How to measure extremely low current noise in single barrier tunneling devices*, J. Przybytek, J. Kowalewski, M. Baj;
- XXXVI International School of Semiconducting Compounds, Jaszowiec 2007, *Low-Frequency Resistance Noise in (Ga,Mn)As with embedded MnAs magnetic nanoclusters*, J. Przybytek, A. Kwiatkowski, M. Baj, D. Wasik, J. Sadowski;
- XXXVI International School of Semiconducting Compounds, Jaszowiec 2007, *Current fluctuations in single barrier vertical GaAs/AlAs/GaAs tunneling devices*, J. Przybytek, M. Baj;
- XXXVII International School of Semiconducting Compounds, Jaszowiec 2008: *Current fluctuations in Si δ-doped double-barrier resonant tunneling device*, J. Przybytek, M. Baj, Z. Wasilewski;
- "20^{th} International Conference on Noise and Fluctuations" (ICNF 2009, Pisa), *Low-Frequency Noise Measurements of the Tunneling Current in Single Barrier GaAs/AlAs/GaAs Devices*, J. Przybytek and M. Baj;
- XXXVIII International School and Conference on the Physics of Semiconductors, "Jaszowiec" 2009, *Interplay between surface inversion layer and Mg-acceptor doped interior in InN:Mg*, L.H. Dmowski, M. Baj, T. Suski, J. Przybytek, R. Czernecki, S.B. Che, A. Yoshikawa, H. Lu, W. J. Schaff, D. Muto, and Y. Nanishi - oral presentation;
- XXXIX "Jaszowiec" 2010 International School and Conference on the Physics of Semiconductors, *Transport in GaAs/AlAs/GaAs [111] Tunnel Junctions*, S. Lewinska, M. Gryglas-Borysiewicz, J. Przybytek, M. Baj, B. Jouault, U. Gennser, A. Ouerghi;

- XXXIX "Jaszowiec" 2010 International School and Conference on the Physics of Semiconductors, *Observation of thermally-activated electron traps in GaAs/AlAs/GaAs heterostructures in low-frequency noise measurements*, R. Stankiewicz, J. Przybytek, M. Gryglas-Borysiewicz and M. Baj;
- 40$^{\text{th}}$ "Jaszowiec" 2011 International School and Conference on the Physics of Semiconductors, *Impurity-Related Noise in Si δ-doped Single-Barrier GaAs/AlAs/GaAs Resonant Tunneling Devices*, J. Przybytek, M. Gryglas-Borysiewicz, M. Baj;
- 41$^{\text{st}}$ "Jaszowiec" 2012 International School and Conference on the Physics of Semiconductors, *Influence of epitaxial strain on magnetic anisotropy in (Ga,Mn)As*, P. Juszyński, D. Wasik, M. Gryglas-Borysiewicz, J. Przybytek, J. Szczytko, A. Twardowski, J. Sadowski;
- 41$^{\text{st}}$ "Jaszowiec" 2012 International School and Conference on the Physics of Semiconductors, *QHE in low carrier density epitaxial graphene grown by CVD on SiC (0001)*, R. Stankiewicz, M. Gryglas-Borysiewicz, L. Dobrzański, J. Przybytek, A. Kwiatkowski, A. Wysmołek, J. M. Baranowski, W. Strupiński, R. Stępniewski;
- Sixth International Conference on the Fundamental Science of Graphene and Applications of Graphene-Based Devices, Graphene Week 2012 (Delft), *QHE in low carrier density epitaxial graphene grown by CVD on SiC (0001)*, R. Stankiewicz, M. Gryglas-Borysiewicz, L. Dobrzański, J. Przybytek, A. Kwiatkowski, A. Wysmołek, J. M. Baranowski, W. Strupiński, R. Stępniewski;
- Graphene Week 2013, Chemnitz, *Magnetotransport properties of epitaxial grpahene grown on SiC*, M. Gryglas-Borysiewicz, A. Kwiatkowski, J. Przybytek, S. Bütün, E. Ozbay, W. Strupiński, R.Stępniewski, M. Baj;
- Graphene Week 2013, Chemnitz, *Weak localization in epitaxial graphene layers grown on (0001) SiC*, M. Gryglas-Borysiewicz, A. Kwiatkowski, J. Przybytek, K. Zieleniewski, S. Bütün, E. Ozbay, W. Strupiński, R.Stępniewski, M. Baj;
- 42$^{\text{nd}}$ "Jaszowiec" 2013 International School and Conference on the Physics of Semiconductors, *Electronic Transport of Graphene Grown by CVD on SiC(0001)*, K. Zieleniewski, A. Kwiatkowski, K. Grodecki, S. Bütün, E. Ozbay, J. Przybytek, R. Bożek, W. Strupiński, A. Wysmołek, M. Borysiewicz, M. Baj, R. Stępniewski;
- MSS 2013 Wrocław, *Magnetotransport properties of epitaxial graphene grown on SiC*, M. Gryglas-Borysiewicz, A. Kwiatkowski, J. Przybytek, S. Bütün, E. Ozbay, W. Strupiński, R. Stępniewski, M. Baj;
- MSS 2013 Wrocław, *Weak localization in epitaxial graphene layers grown on (0001) SiC*, M. Gryglas-Borysiewicz, A. Kwiatkowski, J. Przybytek, K. Zieleniewski, S. Bütün, E. Ozbay, W. Strupiński, R. Stępniewski, M. Baj;
- MSS 2013 Wrocław, *High mobility 2D electrons in undoped InN epitaxial layers grown on N-polarity GaN buffer*, L.H. Dmowski, M. Baj, L. Kończewicz, A. Kwiatkowski, J. Przybytek, T. Suski, X. Q. Wang;
- ICNF 2013, Montpellier, *Impurity-Related Noise in Si δ-doped Single-Barrier GaAs/AlAs/GaAs Resonant Tunneling Devices*, J. Przybytek, M. Gryglas-Borysiewicz, M. Baj, A. Cavanna, G. Faini, U. Gennser, A. Ouerghi;

- Graphene Week 2014 (Gothenburg), *Resistivity fluctuations in microhallbars on CVD QFS-bilayer graphene*, M. Gryglas-Borysiewicz, T. Ciuk, J. Przybytek, A. Kwiatkowski, S. Cakmakyapan, E. Ozbay, W. Strupiński, M. Baj;
- 43$^{\text{rd}}$ "Jaszowiec" 2014 International School and Conference on the Physics of Semiconductors, *Low - Frequency Resistance Fluctuations in (Ga,Mn)As*, J. Przybytek, A. Kwiatkowski, P. Juszyński, M. Gryglas-Borysiewicz, D. Wasik, M. Baj, and J. Sadowski;
- 44$^{\text{th}}$ "Jaszowiec" 2015 International School and Conference on the Physics of Semiconductors, Jaszowiec 2015, *Tunneling Magnetoresistance of (Ga,Mn)As / GaAs Esaki Diodes*, M. Gryglas-Borysiewicz, A. Kwiatkowski, A. Lemaître, J. Przybytek, M. Sawicki, M. Baj, D. Wasik;
- 44$^{\text{th}}$ International School and Conference on the Physics of Semiconductors, Jaszowiec 2015, *Pressure Induced Decrease of the Curie Temperature in (Ga,Mn)As Nonmetallic Sample*, A. Kwiatkowski, M. Gryglas-Borysiewicz, J. Przybytek, M. Baj, D. Wasik, J. Sadowski;
- HPSP 2016, Tokyo, *Pressure study of ferromagnetic - paramagnetic phase transition in (Ga,Mn)As*, A. Kwiatkowski, M. Gryglas-Borysiewicz, P. Juszyński, J. Przybytek, M. Baj, J. Sadowski, D. Wasik;
- ICPS 2016, Beijing, China, *Determination of Curie temperature in (Ga,Mn)As non-metallic samples by means of electrical transport measurements*, A. Kwiatkowski, M. Gryglas-Borysiewicz, P. Juszyński, J. Przybytek, M. Sawicki, J. Sadowski, D. Wasik, M. Baj;
- 45$^{\text{th}}$ "Jaszowiec" 2016 International School and Conference on the Physics of Semiconductors, *Random Telegraph Noise in $La_{1-x}Ca_xMnO_3$ single crystals*, J. Przybytek, J. Fink-Finowicki, G. Jung;
- 45$^{\text{th}}$ "Jaszowiec" 2016 International School and Conference on the Physics of Semiconductors, *Galvanomagnetic methods of Curie Temperature determination in low-T_C (Ga,Mn)As samples*, A. Kwiatkowski, M. Gryglas-Borysiewicz, P. Juszyński, J. Przybytek, M. Sawicki, J. Sadowski, D. Wasik, M. Baj;
- 45$^{\text{th}}$ "Jaszowiec" 2016 International School and Conference on the Physics of Semiconductors, *Capacitance Studies of GaMnAs/GaAs Esaki diodes*, Z. Ogorzałek, K. Filipiuk, M. Gryglas-Borysiewicz, A. Kwiatkowski, J. Przybytek, A. Lemaitre, M. Sawicki, M. Baj, D. Wasik.

6.4 Referee in international and domestic journals

- Acta Physica Polonica A (1 - 2016)
- IEEE Journal of the Electron Devices Society (1 - 2015)
- The European Physical Journal B (1 - 2007)
- Solid State Communications (1 - 2006)

6.5 Awards

- 2011 - Individual Award of 2nd-degree of the Rector of the University of Warsaw for contributions to the maintenance of operation of cryogenic infrastructure at Solid State Division of Institute of Experimental Physics.
- 2014 - Award of the Dean of the Faculty of Physics for outstanding classroom teaching.
- 2015 - Individual Award of the Rector of the University of Warsaw on the occasion of the Feast of the University of Warsaw on November 19th, 2015 (for the care of cryogenic facilities of the Solid State Division).

7 Teaching and organizational activities

7.1 Scientific care

- care for 2 master thesis
- care for 4 bachelor's degree thesis

7.2 Teaching activities - list of regular activities

- counselor of the year
- Computer programming I
- demonstrations to the lecture *Introduction to Physics I*
- classroom teaching and demonstrations to the lectures on physics (mechanics, electricity and magnetism, vibrations, waves, thermodynamics) for Teacher Training College of Physics;
- The first laboratory of physics;
- The introductory laboratory of physics;
- The introductory laboratory of physics for individual studies;
- Laboratory of measurement techniques;
- The physical laboratory for chemists;
- Advanced physics laboratory;
- revision course for compensatory semester (lecture, classes and demostrations);
- classroom teaching and demonstrations to the lecture ”Introduction to Physics II” (Electricity and Magnetism);
- classroom teaching and demonstrations to the lecture ”Fundamentals of Physics II” (Electricity and Magnetism);
- classroom teaching and demonstrations to the lecture ”Physics III” (Waves);
- demonstrations to the lecture ”Vibrations and waves”;
- classroom teaching to the lecture ”Introduction to Optics and Solid State Physics”;
- classroom teaching to the lecture ”Introduction to the Atomic, Molecular and Solid State Physics”;
- classroom teaching and demonstrations to the lecture ”Physics V & VI” (Introduction to modern physics);
- pro-seminar - caring for students;
- training in the field of Health&Safety for students using cryogenic liquids.

7.3 Organizational activities

- **2003-2006 coordination of the Center of Excellence CEMOS** - project of the European Commission in the framework of 5^{th} Framework Programme, Competitive and Sustainable Growth (Center of Excellence CEMOS Physics and Technology of Semiconductor Materials and Structures for Optoelectronics and Spintronics). The whole Solid State Physics Division benefited greatly from this programme, which encompassed the organization of workshops, conferences (e.g. "Jaszowiec" International School on the Physics of Semiconducting Compounds conferences in years 2003, 2004, and 2005), foreign internship of the members of the Solid State Division and stays of foreign academic and researchers in our Division. The activities of the Center of Excellence CEMOS have contributed significantly to the development of our contacts with researchers from foreign centres and directly to the development of the research carried out in collaboration with our partners. The web page of the project: `http://www.fuw.edu.pl/~cemos/`. Project CEMOS grand total amounted to ca 1.5 million PLN and has been positively evaluated by European Commission; in the framework of this project we have organized three "Jaszowiec" conferences, *International Workshop on Optical Properties of 2D Systems with Interacting Carriers*, Symposium C of *E-MRS 2004 Fall Meeting*, many seminars of the Warsaw semiconductor physics community, annual workshops for students and PhD students in Obory, a few hundred of arrivals and travels from/to European academic and research centers (especially Université Joseph Fourier - Grenoble, Grenoble High Magnetic Field Laboratory and Université Montpellier II); from the indirect costs of the CEMOS project we have financed and organized many works to the benefit of the university's infrastructure (e.g. renovation of the helium liquefier room and air conditioning in the main faculty building at Hoża 69);

- **2003-2007 secretary/a delegate of the Rector for recruitment to the College of Inter-Faculty Individual Studies in Mathematics and Natural Sciences (K MISMaP)** - responsible not only for recruitment but also for event promotion and advertising.

- **2006-2017 care of cryogenic plant of the Solid State Division** (and of technical workshop up to 2012). I was associated with the cryogenic plat from the time of my PhD studies when I participated in installation of the first helium liquefier as an interpreter (1993-1994). Next, I organized the building of an access road to the back of the cryogenic plant and I organized the construction of the foundations for the liquid nitrogen container (5000 liters) (1998). When I officially took the responsibility to care for cryogenic plant in 2006, the throughput of the plant was at the level of several thousand litres of liquid helium per year. In years 2006-2007 due to adaptation of the polish law to the directives of the European Union, we have bought a liquid helium container authorized for the public road transport. In years 2006-2011 I was many times concerned with the repair of the old helium liquefier, which very often went off. In June 2011 the main liquefier compressor underwent the serious breakdown which suspended majority of the research carried out at the Solid State Division. Organization of the repair in USA took several months and in April 2012 the refurbished compressor came back to Warsaw. In 2010 I have organized the public tender and purchase of the new helium liquefying system - the investment project of key importance for the whole Solid State Division (contract No 371/FNiTP/115/2009 MNiSW). Preparations for the installation of the new liquefier (preparing the room, new electrical installation, gas installations, connecting the helium reservoir, etc.) and the installation of the liquefier itself took almost two years. We started the operation of the new liquefier on April, 23^{rd}, 2012. In the period August 2012 - April 2013 I have organized two serious warranty repairs of the liquefier. In August 2014 I have personally conducted the serious repair of the liquefying compressor on site in Warsaw, what substantially shorted the helium liquefying-off period. During the movement of the Faculty of Physics to the new location at Pasteura 5 I was responsible for a planning of the new rooms for cryogenic plant, cryogenic installations and helium recovery system (2008-2014). I repeatedly corrected the plans and verified its execution. In 2015 I was occupied with the movement of the cryogenic plant to the new location and its renewed installation (2015). On the occasion of the renewed installation of the cryogenic plant I have organized the installation of two new liquid nitrogen containers (2 × 9000 l, 2012 year), the installation of the cryogenic vacuum insulated cryogenic pipeline for liquefier precooling, the purchase of a new compressor for helium recovery system, the purchase and installation of the new reservoir for gaseous helium. After the movement and renewed installation, the cryogenic plant started its operation in November 2015. Nowadays the throughput of the plant is at the level of several thousand litres of liquid helium per month. For many years I was also responsible for the organization of the public tenders for the supply of cryogenic liquids (helium, nitrogen). For the care of the cryogenic facilities of the Solid State Division I have obtained Individual Award of the Rector of the University of Warsaw on the occasion of the Feast of the University of Warsaw on November 19$^{\text{th}}$, 2015.

- **2007-2012 member of the Committee on the Accommodation in Researcher's Home of the University of Warsaw**

- **2009-2011 organization of the new laboratory for the investigations of low-temperature coherent quantum phenomena in semiconductor nanostructures:**

  1. preparing and carrying out the renovation of the room designed to the dilution refrigerator laboratory - specific grant MNiSW (Ministry of Science and Higher Education) No 6120/IB/115/2011;
  2. reorganization of the old laboratory for the reception of the new VTI (variable temperature insert) cryostat;
  3. negotiations, public tender and purchase of the VTI and dilution refrigerator (2010)
  4. installation and launching of the VTI cryostat and dilution refrigerator (November - December 2011).

  Both experimental setups open a new experimental possibilities of the research of electron transport in semiconductors thanks to the capability to obtain the temperature as low as ca 20 mK and high magnetic field up to 18 T in dilution refrigerator and the temperatures spanning the range 1.5 K - 300 K and high magnetic field up to 14 T in VTI cryostat. This purchase was financed by the project CEZAMAT and opened the possibility to investigate experimentally a coherent phenomena in electron transport in nano- and mesoscopic structures.

- **2007-2015 Occupations related to the movement of the Faculty of Physics to the new location at Pasteura 5.** Preparing the conception and systematic inspection of a new cryogenic facilities and several laboratories of the Solid State Division at the location of the faculty. Supervising the movement of the cryogenic plant, VTI and dilution refrigerator laboratories, noise measurement setup and renewed installation of these setups.

7.4 Popularization activities

Popular science lecture with demonstrations *At the origins of the modern physics* for the Creative Group Quark from Palace of Youth, Katowice (2006-2007).

8 Full list of scientific publications

JP1 A. Babiński, J. Przybytek, M. Baj, P. Omling, L. Samuelson, T. Słupiński, *Hydrostatic-pressure deep level transient spectroscopy study of the heteroantisite antimony level in GaAs*, Acta Physica Polonica A **82**, 841-844 (1992).
My contribution to this work consisted in formulation of the problem, performing the DLTS measurements under high hydrostatic pressure with access of monochromatic light, studying, discussing and interpreting the results (in the framework of my MSc thesis). I estimate this contribution at 50%.

JP2 T. Słupiński, G. Nowak, J. Przybytek, R. Stępniewski, *On the pinning of the Fermi level by germanium $A_1^{o/+}$ deep donor state in GaAs codoped with Ge and Te*, Acta Physica Polonica A **84**, 807 (1993).
My contribution to this work consisted in performing measurements of Hall effect under high hydrostatic pressure with access of monochromatic light, studying, discussing and interpreting the results and participating in preparation of the publication. I estimate this contribution at 35%.

JP3 T. Słupiński, J. Przybytek, A. Wysmołek, M. Leszczyński, A. Babiński, J. Borysiuk, A. Kurpiewski, A. Barcz, R. Stępniewski, *Single crystals of $GaAs_{1-x}P_x$ $0 < x < 0.15$ grown by the Czochralski technology*, Proceedings of the 8th Conference on Semi-insulating III-V Materials, Warsaw 1994, ed. by M. Godlewski, World Scientific, Singapore, 1994, pp. 39-42.
My contribution to this work consisted in performing measurements of Hall effect under high hydrostatic pressure with access of monochromatic light, studying, discussing and interpreting the results and participating in preparation of the publication. I estimate this contribution at 35%.

JP4 J. Przybytek, M. Baj, T. Słupiński, *Stabilization of the distorted configuration of the EL2 defect induced by free electron capture in GaAsP*, Acta Physica Polonica A **88**, 881 (1995).
My contribution to this work consisted in performing measurements, studying, discussing and interpreting the results and preparing the publication (these rusults constitute part of my PhD thesis). I estimate this contribution at 75%.

JP5 D. Wasik, J. Przybytek, M. Baj, G. Karczewski, T. Wojtowicz, A. Zakrzewski and J. Kossut, *Indium DX-like centers in MBE CdTe layers*, Materials Science Forum, Vols **182-184**, p. 247-250 (1995) Trans Tech Publications, Switzerland.
My contribution to this work consisted in participating the experiment, studying and interpreting the results and making the figures for publication. I estimate this contribution at 20%.

JP6 J. Szczytko, D. Wasik, J. Przybytek, M. Baj and A. Waag, *Hydrostatic pressure study of MBE CdMnTe doped with Bromine*, Acta Physica Polonica A **88**, 933-936 (1995).
My contribution to this work consisted in participating the experiment, studying and interpreting the results. I estimate this contribution at 15%.

JP7 T. Suski, P. Wiśniewski, E. Litwin-Staszewska, D. Wasik, J. Przybytek, M. Baj, G. Karczewski, T. Wojtowicz, A. Zakrzewski, and J. Kossut, *Spatial correlations of donor charges in MBE CdTe*, Acta Physica Polonica A **88**, 929-932 (1995).
My contribution to this work consisted in participating the experiment. I estimate this contribution at 15%.

JP8 D. Wasik, J. Przybytek, M. Baj, G. Karczewski, T. Wojtowicz and J. Kossut *Hydrostatic pressure study of indium DX-like centers in MBE CdTe and CdMnTe layers* - Journal of Crystal Growth **159**, 392 (1996), Elsevier.
My contribution to this work consisted in participating the experiment. I estimate this contribution at 15%.

JP9 T. Suski, P. Wiśniewski, E. Litwin-Staszewska, D. Wasik, J. Przybytek, M. Baj, G. Karczewski, T. Wojtowicz, A. Zakrzewski, and J. Kossut - *Spatial correlations of In-donor charges in CdTe layer* - Journal of Crystal Growth **159**, 380 (1996), Elsevier.
My contribution to this work consisted in participating the experiment. I estimate this contribution at 15%.

JP10 J. Przybytek, M. Baj, T. Słupiński, J. Mikucki - *Pressure investigations of the distorted configuration of the EL2 defect stabilized by free electron capture in* $GaAs_{1-x}P_x$ - Proceedings of the 23rd International Conference on The Physics of Semiconductors ed. by M. Scheffler and R. Zimmermann (World Scientific, Singapore 1996), pp. 2749-2752.
My contribution to this work consisted in performing measurements, studying, discussing and interpreting the results and preparing the publication (these rusults constitute part of my PhD thesis). I estimate this contribution at 75%.

JP11 J. Przybytek, M. Baj, T. Słupiński, Ming-Fu Li - *DLTS investigations of the distorted configuration of the EL2 defect stabilized under high hydrostatic pressure in* $GaAs_{1-x}\ P_x$ - Physica Status Solidi (b), Vol. **198**, No. 1, 193-198 (1996) as Proceedings of the HPSP VII, Akademie Verlag.
My contribution to this work consisted in performing measurements, studying, discussing and interpreting the results. I estimate this contribution at 75%.

JP12 R. Piotrzkowski, E. Litwin-Staszewska, J. Przybytek - *Photo-ionization of Si-DX center in AlGaAs: the effects of pressure and local configuration* - Physica Status Solidi (b), Vol. **198**, No. 1, 205-210 (1996) as Proceedings of the HPSP VII, Akademie Verlag.
My contribution to this work consisted in preparing and participating the experiment, participation in studying, discussion and interpretation of results. I estimate this contribution at 40%.

JP13 D. Wasik, M. Baj, J. Przybytek, T. Słupiński, K. Kudyk - *Coexistence of DX and* A_1 *states in highly doped GaAs:Ge,Te and GaAs:Si,Te* - Physica Status Solidi (b), Vol. **198**, No. 1, 181-186 (1996) as Proceedings of the HPSP VII, Akademie Verlag.
My contribution to this work consisted in preparing and participating the experiment, participation in discussion and interpretation of results. I estimate this contribution at 20%.

JP14 L. H. Dmowski, J. Przybytek, E. Litwin-Staszewska, *Manganin sensors as low temperature pressure gauges*, High Pressure Research, **19**, 743 (2000).
My contribution to this work consisted in preparing and participating the experiment, writing the measurement software, participation in discussion and interpretation of results and writing the publication. I estimate this contribution at 50%.

JP15 M. Gryglas, J. Przybytek, M. Baj, M. Henini, L. Eaves, *Hydrostatic pressure investigations of resonant tunnelling through X-minimum-related states in a single barrier GaAs/AlAs/GaAs heterostructure*, High Pressure Research, **18**, 63 (2000).
My contribution to this work consisted in planning and supervising the experiment, writing the measurement software, participation in discussion and interpretation of results and writing the publication. I estimate this contribution at 40%.

JP16 D. Wasik, M. Baj, L. Dmowski, J. Siwiec-Matuszyk, J. Przybytek, E. Janik, T. Wojtowicz, G. Karczewski, *Effect of buffer layer thickness on improvement of modulation doped CdTe/CdMgTe heterostructures grown on GaAs substrate*, Proceedings of the 25th International Conference on the Physics of Semiconductors, Osaka, Springer Proceedings in Physics (Eds. N. Miura, T. Ando), Vol. **87**, p. 811 (2001).
My contribution to this work consisted in designing and making the experimental setup and writing the measurement software. I estimate this contribution at 15%.

JP17 M. Gryglas, J. Przybytek, M. Baj, L. Eaves, M. Henini, *High-pressure magnetotransport measurements of resonant tunnelling via X-minimum related states in AlAs barrier*, Acta Physica Polonica A **100**, 403 (2001).
My contribution to this work consisted in planning and supervising the experiment, writing the measurement software, participation in discussion and interpretation of results and writing the publication. I estimate this contribution at 40%.

JP18 **H1** V. Mosser, G. Jung, J. Przybytek, M. Ocio and Y. Haddab, *Low-frequency noise in AlGaAs/InGaAs/GaAs Hall micromagnetometers*, Fluctuations & Noise 2003, Noise and Information in Nanoelectronics, Sensors, and Standards, L. B. Kish, F. Green, G. Iannaccone, J. R. Vig, Editors, Proc. SPIE Vol. **5115** (2003), 183-195.
.

JP19 **H2** J. Przybytek, V. Mosser and Y. Haddab, *LF noise in cross Hall effect devices - geometrical study*, Fluctuations and Noise 2003, Noise in Devices and Circuits, M. Jamal Deen, Zeynep Celik-Butler, Michael E. Levinshtein, Editors, Proc. SPIE Vol. **5113** (2003), p. 475-483.
.

JP20 **H3** J. Przybytek, M.Baj, *Current Fluctuations in Single Barrier Vertical GaAs/AlAs/GaAs Tunneling Devices*, Acta Physica Polonica A, **112**, 221 (2007).
.

JP21 **H4** J. Przybytek and M. Baj, *Low-Frequency Noise Measurements of the Tunneling Current in Single Barrier GaAs/AlAs/GaAs Devices*, American Institute of Physics CP**1129** (2009), Noise and Fluctuations, 20th International Conference (ICNF 2009) edited by M. Macucci and G. Basso.
.

JP22 L. H. Dmowski, M. Baj, T. Suski, J. Przybytek, R. Czernecki, X. Wang, A. Yoshikawa, H. Lu, Schaff, W. J. Schaff, D. Muto, Y. Nanishi, *Search for free holes in InN:Mg-interplay between surface layer and Mg-acceptor doped interior*, Journal of Applied Physics **105**, 123713 (2009).
My contribution to this work consisted in programming the experimental setup, participation in measurements and preparing the publication. I estimate this contribution at 15%.

JP23 M. Gryglas-Borysiewicz, A. Kwiatkowski, M. Baj, D. Wasik, J. Przybytek, J. Sadowski, *Hydrostatic pressure study of the paramagnetic-ferromagnetic phase transition in (Ga,Mn)As*, Physical Review B **82**, 153204 (2010).
My contribution to this work consisted in maintaining the experimental setup, participation in discussion of results and writing the publication. I estimate this contribution at 15%.

JP24 S. Lewińska, M. Gryglas-Borysiewicz, J. Przybytek, M. Baj, B. Jouault, U. Gennser and A. Ouerghi, *Transport in GaAs/AlAs/GaAs [111] Tunnel Junctions*, Acta Physica Polonica

A **119**, 606 (2011).
My contribution to this work consisted in performing and interpreting the noise measurements and participation in discussion of results and in preparation of publication. I estimate this contribution at 15%.

JP25 **H5** J. Przybytek, R. Stankiewicz, M. Gryglas-Borysiewicz, M. Baj, A. Cavanna and G. Faini, *Observation of Thermally-Activated Electron Traps in GaAs/AlAs/GaAs Heterostructures in Low-Frequency Noise Measurements*, Acta Physica Polonica A **119**, 723 (2011).
.

JP26 P. Juszyński, D. Wasik, M. Gryglas-Borysiewicz, J. Przybytek, J. Szczytko, A. Twardowski, J. Sadowski, *Influence of Epitaxial Strain on Magnetic Anisotropy in (Ga,Mn)As*, Acta Physica Polonica A **122**, 1004-1006 (2012)
My contribution to this work consisted in maintaining the experimental setup and in discussion of experimental results. I estimate this contribution at 5%.

JP27 **H6** J. Przybytek, M. Gryglas-Borysiewicz, M. Baj, A. Cavanna, G. Faini, U. Gennser, A. Ouerghi, *Impurity-related noise in single-barrier GaAs/AlAs/GaAs resonant tunneling devices*, Proceedings of 22nd International Conference on Noise and Fluctuations ICNF 2013, IEEE 2013.
.

JP28 **H7** J. Przybytek, J. Fink-Finowicki, R. Puźniak, V. Markovich, G. Jung, *Noise signatures of metastable resistivity states in ferromagnetic insulating manganite*, Journal of Applied Physics **118** , 043903 (2015).
.

JP29 **H8** J. Przybytek, J. Fink-Finowicki, R. Puźniak, G. Jung, *High frequency cut-off in* $1/f$ *conductivity noise of hole-doped* $La_{1-x}Ca_xMnO_3$ *manganite single crystals*, Journal of Statistical Mechanics: Theory and Experiment 054024 (2016).
.

JP30 A. Kwiatkowski, M. Gryglas-Borysiewicz, P. Juszyński, J. Przybytek, M. Sawicki, J. Sadowski, D. Wasik, M. Baj, *Determining Curie temperature of (Ga,Mn)As samples based on electrical transport measurements: Low Curie temperature case*, Applied Physics Letters **108**, 242103 (2016)
My contribution to this work consisted in the installation of VTI, participation in discussion and writing the publication. I estimate this contribution at 5%.

JP31 M. Gryglas-Borysiewicz, A. Kwiatkowski, A. Lemaître, J. Przybytek, K. Budzik, Ł. Balcerzak, M. Sawicki, D. Wasik, *Magnetotransport investigations of (Ga,Mn)As/GaAs Esaki diodes under hydrostatic pressure*, Applied Surface Science **396** 1875–1879 (2017).
My contribution to this work consisted in the installation of VTI, performing and interpreting the noise measurements and participation in discussion and writing the publication. I estimate this contribution at 5%.

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