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The Publication of the International
EPR (ESR) Society

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Please feel free to contact us with items (news, notices, technical notes, and comments) or ideas for the *EPR newsletter*.

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TECHNION | PRINTING UNIT

The cover picture illustrates aspects of the research carried out by Jörg Wrachtrup, recipient of the Zavoisky Award 2021. It shows a diamond (square piece in the middle) with microwave coupling structure as well as electrodes to control qubits, which are implanted in middle of the diamond.

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The Publication of the International EPR (ESR) Society

volume 32 number 1 2022

Editorial

Dear colleagues,

In this issue, we introduce our new Patron of the International EPR(ESR) Society, CIQTEK, with an excerpt from the company profile: "CIQTEK is a high-tech enterprise with quantum precision measurement as the core technology. It is devoted to providing product and service to enterprises, governments, and research institutions around the world, including core devices represented by enhanced quantum sensors, advanced instruments and equipment for analysis and test, technical solutions for enabling industry applications, etc." You can find their ads on pp. 2, 10 and 11. In forthcoming issues, we plan to give you more detailed information on the company and an interview, the same as we will do with our new Major Sponsors Bridge12 Technologies and Signals.

If you know a company involved in magnetic resonance in any way, invite them to consider supporting our Society. This will help us to implement our numerous activities, while the company will have its own advertising and information box in each issue of the *EPR newsletter*. It will be seen by a targeted audience of thousands of specially selected scientists worldwide. Information on sponsoring our Society and advertising is shown on the web site: https://eprs.org/sponsors.

This issue starts volume 32 of our publication, the twentieth volume in hard color cover courtesy of Bruker BioSpin, our long-term Patron. Covers of the *EPR newsletter* are real masterpieces being an embodiment of the never-ceasing creativity of our technical editor, Sergei Akhmin.

This issue is a nice demonstration of the main tendency of our publication to feature diverse aspects of the life of magnetic resonance community and to keep balance between the material presented by different generations of the magnetic resonance researchers: Letter of the President by Songi Han (IES business, p. 3); Interviews with Michal Kern on the occasion of his IES Best Paper Award 2020/2021 and Jörg Wrachtrup on the occasion of his Zavoisky Award 2021 (Awards, pp. 4, 5); History of Electron Paramagnetic Resonance in Poland by Czesław Rudowicz and Piotr Pietrzyk (EPR newsletter Anecdotes, pp. 8. 9. 12. 13); International Conference "Modern Development of Magnetic Resonance" (MDMR2021) by Kev Salikhov and Violeta Voronkova; IES Virtual EPR Meeting by Michal Kern (Conference reports, pp. 16–18).

The cherry on the cake is the article "The Cello and Me: It's all Zoltan Kodaly's Fault" by Brian M. Hoffman (Another Passion, pp. 6, 7). This story is a perfect substantiation of a well-known saying that a talented man is talented in many things. Brian Hoffman (Bruker Prize 1997, IES Gold Medal 1999, Zavoisky Award 2007, Fellow of ISMAR 2009, Fellow of the IES, to name a few) tells us a story about his passion for playing cello, which was triggered by his attending a Kodaly celebration concert held on Caltech campus. Brian heard Kodaly's *Sonata for Solo Cello*. I have to confess that I was completely intrigued by Brian's story and I searched this sonata on the internet. It was really worth the effort.

Ending on a sad note, the In Memoriam column hosts a touching obituary to Shimon Vega, one of the pillars of magnetic resonance, the ISMAR Prize Awardee (2015) and the Awardee of the Gold Medal of the Israel Chemical Society (2018), a remarkable mentor and an exceptionally caring human being, prepared by Daniella Goldfarb (pp. 14, 15). We join Daniella in grieving on this loss and send heartfelt condolences to Shimon's family, collaborators and friends.

Laila Mosina

Letter of the President

Dear Friends, Colleagues and Students of the international EPR/ESR society (IES),

Here we are, we look to 2022 with hope and cautious anticipation. All of us are more determined than ever to take our lives back with the joy, complexity, imperfection and depth that come with in person human interaction because that is what makes us who we are.

I would like to announce that the IES designated meeting for 2022 is the 17th Spin Chemistry meeting, taking place at Northwestern University in Chicago, USA. Consider participating! The IES would like to foster existing, and generate new, connections with the spin chemistry, spintronics and quantum information science community. The IES is also excited to support young scientists at the 2022 RSC-EPR, RMC, Euromar, ICMRBS, MDMR and others in-person meetings, and witness impromptu hallway conversations that lead to collaborations, insight and friendship!

We have seen high quality nominations for the 2022 Silver Medal in Medicine/Biology, Silver Medal for Physics/Material, Fellow of the IES, as well as the 2022 YIA by the end of 2021. The various prize committees agonized about hard choices, but made their final award selection as follows. Congratulations!

- 2022 IES John Weil Young Investigator Award: Asif Equbal.
- 2022 IES Silver Medal in Medicine/Biology: jointly awarded to Bernard Gallez and David Cafiso for their seminal contribution to the field of EPR in Medicine and Biology, respectively.
- 2022 IES Silver Medal in Physics: Marina Bennati for her groundbreaking contribution to the field of EPR in Physics.
- 2022 IES Fellow: Asako Kawamori for her seminal contributions in the early days of modern pulsed EPR and its application to the study of photosynthesis systems.

Honoring accomplishments of junior and senior EPR scientists around the world is an important mission of the IES. The next IES award selection is an exciting one: *the IES Best Paper Award of 2022*, with deadline of March 31, 2022. The IES has now cemented in its bylaws that it will acknowledge each year up 2 publications as "best papers" in the field of EPR. The first author is recognized with this award and a monetary award. The expectation is that the first author be a young scientist. Nomination can be made by any active IES member. If self-nomination is made, it can be made only by the first author or the corresponding author. The nomination material should include the publication in PDF and a Letter by the advisor or collaborator explaining the role of the nominee in generating this paper, as well as the impact of this publication to the field of EPR, and be sent to ab359@technion.ac.il.

The IES is also actively discussing a proposal to support a shared EPR data base for our community. The IES concurs with the belief of many EPR researchers that sooner or later published EPR data will have to be deposited in its raw data format to a public data repository to ensure transparency and standardized best practice. In this context, a public data repository designed to support and share EPR data will require dedicated effort that the IES will be supporting. Your input is very welcome.

Last, but not least, we are most proud of the IVEMs, led by Zhongyu Yang and Thomas Schmidt together with Annalisa Pierro, Zhijie Li, Jana Eisermann, Jaideep Singh, Jing Jin, Julien Langley and Li Feng Li, and Nir Dayan. You are welcome to sign up to listen to and present at IVEMs, here: https://forms.gle/Usv8sbj3LUr7QvcE8. ALL IVEM speakers get the opportunity to submit synopsis and their photo to the *EPR newsletter* to be highlighted by Laila Mosina, Editor of the publication.

We would like to serve the community as best as possible. More than ever, we are aware of the critical importance of working towards supporting a much more diverse science community. A more diverse cohort of scientists, considering geography, ethnicity, gender and otherwise, will be the generator of more creative and innovative ideas. The IES is determined to diversify its leadership and membership. Help us get there. Help us nominate new names for the leadership in the future, awards and get involved with your ideas. We will be all ears.

With that, I look forward to seeing many of you in 2022, in person!

Songi Han

Interview with Dr. Michal Kern on the Occasion of His IES Best Paper Award 2020/2021

EPR newsletter: *Dear Dr. Kern, on behalf of the readers of the EPR newsletter we congratulate you on your IES Best paper Award 2020/2021. We are most appreciative that you agreed to answer the questions of this interview. Why did you start towards your career in science?*

Even though I was interested in astronomy and archaeology as a child, this interest mostly waned during my teenage years. When choosing a university after my high school studies, which predestined me for a career as a mechanical engineer, I spontaneously attended two public scientific talks, one about the research at the Large Hadron Collider and another about the supercomputer modeling of nanoscopic processes. These talks reignited my interested in science and spurred me to change my future university at the last minute, to the Brno University of Technology, Czech Republic, to the program Physical Engineering and Nanotechnology. This has proven to be an excellent choice, since I was welcomed by an incredibly positive, supporting and stimulating environment, both from my undergraduate colleagues and the faculty, which thoroughly intoxicated me with a deep love of experimental physics and the technology needed to perform it. This was further enhanced by my ERASMUS internship at the University of Stuttgart, Germany, where I had the luck to be working with Petr Neugebauer and Joris van Slageren, who both encouraged me to do a PhD in the group.

Who introduced you into magnetic resonance?

Petr Neugebauer and Joris van Slageren have introduced me to the wonders of high field EPR spectroscopy during my undergraduate ERASMUS internship in Stuttgart and gave me the opportunity to help develop the ultra-broadband spectrometer located there. I was immediately fascinated both by the instrumental complexity as well as the richness of physics that can be explored using EPR. I was also introduced to the field of molecular magnetism and was drawn by the highly interdisciplinary nature of the research. Joris helped me to understand the many facets of EPR and later, under his supervision, I could explore less traditional ways of detecting spin transitions, such as mechanical and electrical.

What are your main interests of work in magnetic resonance?

The focus of my PhD was to explore possibilities of reading out spin transitions in molecular quantum bits electrically, instead of microwave absorption. This very broad problem statement gave me the opportunity to explore many different fields, from solid-state physics, through semiconductor engineering and instrumental development all the way to polymer science. Through this exploration, I could recognize the potential of EPR as an important tool in modern technologies. For the last year and a half, I am exploring the possibilities provided by integration of EPR spectrometers on a single silicon chip, which I believe will revolutionize the field and bring magnetic resonance to a much wider community.

What is your message to your colleagues – the younger generation of magnetic resonance researchers?

As a tinkerer, I would always recommend everyone to try to understand the machines they are using, not to treat research equipment as black boxes. Only by understanding the measurement principles can one begin to truly take advantage of the possibilities modern equipment gives us and come up with novel applications and research ideas. Second recommendation would be to carefully study older literature. The original literature from the 1950s to the 1980s is truly remarkable, and one can gain not only better understanding of the spectroscopy itself, but find inspiration in pushing available technologies to the limits in the quest for answering interesting questions.

Joris van Slageren:

Michal came to us at the University of Stuttgart as an ERASMUS student from Brno University in the Czech Republic as part of his undergraduate studies. This was back in 2014, at a time where a lot of instrument development was going on in the group. With his background in Physical Engineering, he had a great deal of expertise in computer-aided design and this was instrumental in raising the level of sophistication of most of the spectrometers, which he then also operated himself. Returning to Brno, he started working on designing a spectrometer for torque-detected magnetic resonance for this MSc Thesis and returned to Stuttgart for the final months of the Thesis. Here he implemented and tested the setup, leading to his first publication with us. We were fortunate that Michal decided to stay in Stuttgart for his PhD thesis, which he started to work on in 2015. The topic was to be combining molecular quantum bits with semiconductor spintronics with the aim of implementing electrical readout of the qubits. His first task in this project was to develop a setup for low-temperature spintronic transport measurements, essentially starting from scratch. Many battles with electrical-noise sources later, the setup worked and measurements could be carried out reliably. In parallel, Michal started to consider further material platforms and hit upon the idea to use organic semiconductors. Rather than relying on spin-valve type measurements, he opted to use electrical detection of magnetic resonance instead, and developed the instrumentation to do so. The platform that proved to be most fruitful was that of hybrid materials consisting of thin films of conducting polymers with embedded molecular qubits. Here he had to optimize the thin-film deposition protocols, again essentially from scratch. He demonstrated that neither the electrical properties of the polymer, nor the coherent quantum properties of the qubits suffer from combining the two materials. In fact, Michal showed that quantum coherence survives at rather high temperatures, even in the presence of mobile charge carriers. This is a fundamental step in electrically addressing molecular qubits and as such the results were published in the high-impact journal Advanced Functional Materials leading to the IES Best paper award now being bestowed on Michal.

The extent and breadth of Michal's work in the group is truly bewildering. It can perhaps be expected in experimental physical sciences that PhD students develop, modfiy or optimize an experimental setup. However, Michal has developed no fewer than three setups entirely from scratch and helped develop at least three further ones. He also dealt with materials, such as conducting polymers, that no-one in the group had any experience with. In spite of having to trailblaze in many directions, he managed to achieve a fantastic amount of highly exciting scientific results. In addition, he helped out many members of the group, carried out measurements for collaborators and supervised many undergraduates. Currently, he is widening his expertise into the direction of EPR-on-a-Chip and I have no doubt he will continue to do exceedingly well.

Interview with Professor Jörg Wrachtrup on the Occasion of His Zavoisky Award 2021

EPR newsletter: *Dear Professor Wrachtrup, on behalf of the readers of the EPR newsletter we congratulate you on your Zavoisky Award 2021. We are most appreciative that you agreed to answer the questions of this interview. Why did you start towards your career in science?*

I have been interested in science from my very early child years on. My parents and teachers were fostering this interest very efficiently. I made my decision to study physics already before starting high school. Most importantly, I had an excellent physics teacher, like most students who pursue an active career in science. He understood how to teach physics in a lively and intellectually intriguing way. I had a couple of school mates who shared my passion in science and specifically physics and mathematics. They have a hard to underestimate share in my decision to study physics and pursue a career in science.

Who introduced you into magnetic resonance?

I started to work in the group of Prof. Klaus Möbius at the FU Berlin. It was the very open and friendly atmosphere in the group which dragged me in. I quickly learned that magnetic resonance is a subject in which theory and experiment go hand-in-hand. This was most fascinating to me and made me stay. In Klaus' group various application of magnetic resonance were pursued. He also had a series of exciting new developments, such as EPR at high frequencies, going on. One could clearly see the power of the technique but also the opportunities to work on, like enhancing the sensitivity. As a PhD candidate I came to the group of Prof. Stehlik and later Prof. V. Borczyskowski. Though also working on magnetic resonance, they had a different approach and also explored NMR and optics quite a bit. In the end, it was this mixture which made me work on single spins and later gave me a good start into quantum information processing, the field I'm currently working in the most.

What part of your research is most dear to your heart and why?

As already stated above, it is the model-building in combination with experiments which I find most interesting. Magnetic resonance follows Hamiltonians which can describe experiments quite well and at the same time cover a rich variety of physical phenomena. Multispin systems show dynamics which are far from trivial and nowadays can be controlled even a single spin level extremely well. We now try to extend the size of spin clusters atom by atom, use photons for entanglement of remote spin clusters and use them for various tasks in quantum science. Certainly, the use in quantum information science and the realization of quantum networks is what we are pursuing most actively at the moment.

What is your message to the young generation of magnetic resonance researchers?

For me, it was important to look for the right, i.e. active and open-minded scientific environment. Talking to people, i.e. try to exchange and also probe new ideas as often as possible turned out to be important. No only does it avoid mistakes but also it generates a solid scientific network.

In general, I see a pretty bright future of spins i.e., magnetic resonance in quantum physics and technology. A solid education in magnetic resonance is a head start into the field. Knowledge on precise spin control and complex spin dynamics will be indispensable in this field. I clearly see that researchers with this prior knowledge are the ones who understand and foster scientific progress these days. In addition, recent technical advances have lead to new systems for spin resonance, like e.g. silicon quantum dots and other engineered spin structures. This has generated a new field of activities for magnetic resonance in academia as well as industry.

The Cello and Me: It's all Zoltan Kodaly's Fault

Brian M. Hoffman

Northwestern University, Evanston, IL, USA

When I was a beginning graduate student at Caltech, Kodaly came to campus for a celebration of his 80th birthday. By that time I had made two especially close graduate school friends, one a Hungarian-born émigré, and the other, even more foreign to me, a native New Yorker. Both were deeply engaged in the arts, and, of course, planned to attend a Kodaly celebration concert held on campus, especially as Kodaly himself would be there. Although I had no particular involvement in 'culture' of any kind (I once took piano lessons for a few months, but then Spring arrived and baseballs started to fly), I accompanied them (was dragged by them?).

My entrapment by the cello began as the audience congregated outside the recital hall, waiting for the doors to open. As a grubby graduate student fresh from the laboratory, I was humbled *and* riveted by the Olympian visage of the tall, slender, and oh-so-elegant Kodaly, a long, gray overcoat gracefully draped over his shoulders and (I recall) casually wearing a matching broad-brimmed hat. I was probably more humbled – and captivated – by the gorgeous 22-year old blonde at his side. Aged elegance in combination with young beauty set a standard I instantly aspired to, while knowing it was beyond my reach, much less my grasp.

Then we went into the concert and I heard Kodaly's *Sonata for Solo Cello*.

I reject any suggestion that the cellist was other than Janos Starker, the world-famous musician and teacher. Starker, like Kodaly a Hungarian, was only fifteen when he first played the *Sonata* for Kodaly, who later praised him as being but one correction away from the 'Bible performance'.

Regardless, the stunning Caltech performance of this marvelous piece, enveloped by the aura of the elegant composer (and the blonde), opened a door to the world of music – most especially to the cello. For decades afterwards, I attended chamber music performances of all kinds while collecting recordings by the great cellists – accumulating multiple recordings of the central literature and savoring the differences. But the only version of Kodaly's *Sonata* I have or need is Starker's.

As I progressed in my career at Northwestern University, I had the supreme good fortune to marry my wife, Janet, and helped her raise our two oldest daughters, Tara and Abby. Then the birth of twin baby girls, Alexandra and Julia, expanded that good fortune (notice, we specialize in girls). When Alex was about four, we decided that she should begin lessons on 'some' instrument. Of course, there was no question – it must be the cello! (Julia showed her independent spirit much later by taking up the saxophone!)

What type of program/teacher? We settled on the 'Suzuki Method'. In the description of this method on the website of the Suzuki Association of the Americas, the first subsection is headed "Parent involvement". Based on my experience, this 'involvement' is the equivalent of adopting a new and rigorously demanding religion. I was the 'Suzuki parent' and I took an oath (I don't remember whether or not blood was involved, but...) to go to the Saturday group and midweek private lessons, and to be present and guide Alex through every one of her daily practice sessions. I began those practices by performing all the 'motions' on her cello, to make sure I didn't mislead her, then sitting with her and guiding her through her practice. Now, remember, she started at age four (as recommended by the Suzuki folks), and therefore she used an 1/8 size cello. So picture this: me holding something about the size of a violin and pretending to play a cello tune (which I couldn't). And doing that every day.

Eventually, I concluded: This is crazy! If I'm going all-in to play at playing the cello, and doing so on a micro-cello, I might as well get a real cello and really learn how to really play. So I did. I acquired a 'real' cello and began lessons with a Suzuki teacher recommended to me by Alex's own teacher. The Suzuki method involves learning to play music before learning to read it, and the student proceeds through a series of increasingly complex (progressively less simple) tunes and small pieces collected in a series of 'Books'. I too started with 'Book 1', and began by learning to play the first tune in the progression: *Twinkle Twinkle Little Star*, the well-known children's song (based on an 18th century folk tune; classical music snobs might prefer to drop references to adaptations by Mozart and Haydn).

Alex was way ahead of me, but I dived in and, rather like Archimedes' tortoise, successively halved the gap (you know how unfortunately that process goes...). I had one advantage over Alex: I had spent decades learning how to learn, to focus, and to deeply concentrate. The problem was, she had ten advantages over me: five on one hand and five on the other. The music simply flowed into her ears and emerged from her fingers. A lesson in humility. But I persevered, and by the time she was about eight we were routinely playing simple cello duets together.

One feature of the Suzuki program is that to reward/incentivize the parents, the teacher regularly holds a recital in which each student performs and the parents bask in the glow. Alex's recitals started immediately on her entry into the program, so she became a seasoned performer long before the advanced age of eight. At my advanced age, on the other hand, I was not. So when the teacher first suggested we perform a duet at a recital I was apprehensive (terrified?). As my first recital began, there I was with Alex and the rest of us eight-year-olds, awaiting our turn in the spotlight. I can assure you that preparing to give a scientific lecture before almost a thousand experts is less anxiety-provoking (terrifying) than preparing to perform before a bunch of 8–10 year-olds and their parents. I make only one irrefutable claim about my performance: I survived. But high on my list of cherished possessions is a recital program listing the two of us in a duet, and a photo of us playing together.

Subsequently, my playing slowly progressed, and with the kindly and patient indulgence of several gifted teachers, reached the 'towering' heights of low-to-mid level mediocrity. But that's enough to allow me to play (at) great pieces of the cello repertoire: The Bach Suites (but not No. 6 – that's another story!); Vivaldi and Gabrielli sonatas; and ... Playing has had its ups and downs (pandemic isolation, without lessons to inspire, turns out to be especially trying), but still, there's nothing to drive away the day-to-day that compares to getting lost in my instrument.

History of Electron Paramagnetic Resonance in Poland. Part 1*

EDITORIAL INTRODUCTION

Shortly after E. K. Zavoisky's report (1945) of first observation of ESR absorption, Polish EPR research began (1954). The first commercial EPR spectrometers were acquired, e.g. Varian (1956), JEOL (1957). In this article, the history of EPR/EMR research in Poland is outlined. All major still active EPR/EMR research groups participated in this endeavour, under the auspices of the Polish EMR Group, which has reached maturity at the 10th Anniversary in 2020 (see C. Rudowicz, P. Pietrzyk, *EPR newsletter*, 31/2 (2021) p. 6). We provide a bird's eye view of development, key achievements, and current status of respective groups. The history of Poznań, Kraków, and Wrocław centers are covered in Part 1, whereas Wrocław, Warsaw, Szczecin, and Rzeszów centers – in Part 2*. Due to the space limitations, only selected information could be included. For information on the Polish EMR Group activities and the next Forum EMR-PL, please visit the websites: www.pgemr.org and www.emr6.zut.edu.pl, respectively. Note that the history of the Polish EPR Society and its successor, the Polish EMR Group, has been outlined in Ref. [1].

We are grateful to Laila Mosina, the *EPR newsletter* Editor, for her invitation, encouragement, and editorial guidance, and John Pilbrow, the former President, the International EPR/ESR Society, for his thoughtful comments on scientific matters.

Czesław Rudowicz, Chairman, Polish EMR Group
Piotr Pietrzyk, Chairman-Elect, Polish EMR Group

POZNAŃ CENTRE: Institute of Molecular Physics, Polish Academy of Sciences (IMP PAS) (Wojciech Kempiński, Zbigniew Trybuła, Andrzej B. Więckowski, Maria A. Augustyniak-Jabłokow, Stefan Waplak, Waldemar Bednarski), http://www.ifmpan.poznan.pl; **Adam Mickiewicz University (AMU)** (Ryszard Krzyminiewski), http://fizyka.home.amu.edu.pl/zaklady/en/zfmed_en.pdf; **Novilet** (Tomasz Czechowski), http://www.novilet.eu.

The history of EPR in Poznań is inextricably linked with the activity of two outstanding physicists: A. Piekara and his then student J. Stankowski, as well as two institutions: at first AMU and later IMP PAS. Soon after the Second World War, the then Department of Experimental Physics at AMU headed by A. Piekara was created. Here J. Stankowski was employed in 1956 and led a team working on the magnetic properties of chemical compounds using the EPR technique.

The history of IMP PAS goes back to the Ferromagnetics and Ferroelectrics Department established in Poznań in 1953 as a branch of the PAS Institute of Physics in Warsaw and led by S. Szczeniowski. Additionally, the Dielectrics Department headed by A. Piekara was established in 1956. J. Stankowski moved there from AMU in 1957, and, from 1966, led a new Department of Radiospectroscopy. During these early days close links existed between the staff employed at the two institutions. The current IMP PAS in Poznań was inaugurated in 1975 as an autonomous division of the PAS with the first director J. Stankowski (1975–1985).

Stankowski's team at PAS was initially involved in the construction of a gas maser, which was based on a quantum microwave generator, that used a beam of ammonia molecules (NH_3). Two-years spent on the optimization of the receiving system and modernization of the maser construction ended with success. On Jan. 2, 1964, J. Stankowski, J. Galica, and S. Smolińska-Gierszal observed the first signal of stimulated microwave emission in Poland, at 23.87014 GHz. Since 1964, Stankowski's team (A. Dezor, B. P. Sczaniecki, A. B. Więckowski, S. Waplak) also worked on construction of home-built X-band EPR spectrometers. Using this experience, the RADIOPAN company was established in 1975, and which produced quality spectrometers utilized until recently by many Polish and foreign researchers. In 1967, a commercial JEOL EPR spectrometer was obtained, the first in Poland, and, in 2007, a Bruker ELEXSYS spectrometer, which allowed us to extend our research capability.

Other important EPR activities that originated in Poznań are as follows. On the initiative of A. Piekara, the first nationwide conference Radiospectroscopy and Quantum Electronics was organized in 1964. Subsequent conferences took place every two years and the last (fifth), organized by J. Stankowski and his team, was held in 1972. As the Radiospectroscopy and Quantum Electronics contributions were presented separately, J. Stankowski decided in 1975 to organize the sixth, then international conference, as Radio and Microwave Spectroscopy – RAMIS-75, to be held every two years.

Solid State Radiospectroscopy (SSR) Laboratory and **Superconductivity and Phase Transitions (SPT) Laboratory, IMP PAS**

Up to 1986, the SSR Laboratory was headed by J. Stankowski, then till 2013 by S. K. Hoffmann and after his retirement by W. Bednarski. The interests of the SSR Laboratory evolved over the years. Initially, a lot of effort at IMP was paid to the development of EPR spectrometers as described above. During the last reorganization, EPR staff employed in previous Laboratories had a choice to move between the SSR and SPT Laboratories. Since for this reason, it is impossible to separate their contributions, we present them jointly below.

Initially, we studied doped or irradiated ferroelectrics, e.g. TGS, KDP, leading to the discovery of the basic relations between local EPR parameters (zero-field splitting, line intensities, and their phases) and bulk properties (polarization, order parameter, domains, etc.) [2]. Subsequently, with the better equipment, and due to the international RAMIS Conferences, we started cooperation with Russian researchers, who provided us with modern samples, as well as with USA-based laboratories. Collaboration with Laboratory

* Part 2 to be published in the *EPR newsletter* 32/2 (2022).

of Solid State Physics of the Russian Academy of Sciences (Institute of Crystallography in Moscow) earned S. Waplak and J. Stankowski an Award for results of joint research from the Polish and Russian Academies of Sciences. Research visits to Montana State University during 1988/89 resulted in a joint publication on fracton relaxation times in proton glasses [3]. It allowed us to join the mainstream of EPR applications in modern physics of materials at that time. This included, e.g. EPR studies of ferroics, incommensurate phases, spin and proton glasses, and fast proton conductors, as well as other materials [4].

M. Krupski developed systems for high-pressure and low-temperature EPR studies [5]. P. B. Sczaniecki cooperated with J. S. Hyde (USA) and W. Froncisz (USA and Kraków) in developing continuous-wave multi-quantum EPR spectroscopy. Attention was paid to the EPR properties of transition ions, especially Cu(II). Experimental and theoretical studies of copper-doped compounds revealed the impact of tetrahedral distortion of Cu(II) complexes on their electronic structure and proved that the weak superexchange interactions in Cu-compounds can be studied by EPR [6]. New possibilities for EPR studies opened with the purchase of a pulse Bruker X-band EPR ESP380E FT/CW spectrometer in 1991. S. K. Hoffman, W. Hilczer, and J. Goslar formed the core of a group specializing in pulse EPR spectroscopy. The first results were obtained for the SeO_3^- radical in $(NH_4)_3H(SeO_4)_2$ [7]. Subsequent studies concerned the impact of the Jahn-Teller effect on Cu(II) spin relaxation. The pulse EPR study was complemented by CW EPR studies under ambient and high hydrostatic pressure [8].

The EPR studies of coals samples, initiated by A. B. Więckowski, were continued in the SPT Laboratory by M. Augustyniak-Jabłokow and co-workers who broadened their research topics to include graphene [9] and, since 2014, to physical and biological aspects of carbon nanomaterials [10].

Department of Low Temperature Physics (LTP), IMP PAS

This department, located on the premises of the liquid helium plant in Odolanów, for a long time closely cooperated with J. Stankowski. The interests of this group were mainly related to the wide class of carbon materials, from the classic allotropes such as diamond and graphite to the more modern forms such as fullerenes (C_{60} and C_{70}), carbon nanotubes (single- and multiwalled), graphene, and various modifications of them. The most important forms include graphite intercalation compounds, fullerites (crystalline and powdered), fullerides, onion-like structures (obtained from a diamond), island graphene and graphene oxide, carbon nanotubes also decorated with metal oxide nanoparticles and various forms of active carbons, with the most important Activated Carbon Fibers in the pure form and doped as a host-guest system.

The EPR technique has proved very useful for fullerene materials, as it allows one to trace the evolution of radical centres in the sample. The formation of A_1C_{60} (octahedral voids occupied) and A_3C_{60} (octa- and tetrahedral voids occupied) phases is accompanied by appearance of $C_{60}{}^{1-}$ and $C_{60}{}^{3-}$, both easily registered with EPR [11]. We also applied a modified EPR technique: Magnetically Modulated Microwave Absorption (MMMA), e.g. to study superconducting materials [12]. Correlated with regular EPR, this method supported a coherent picture of the formation of various structural phases in the A_xC_{60} systems, as well as superconducting ones [11].

In total 22 publications were published in the carbon-related series concern the research on the host-guest interactions in carbon matrices with adsorbed dipolar and non-dipolar molecules. Two papers [13] were selected in 2006–2008 by the American Inst. of Physics & the American Phys. Soc. (together with other societies and publishers) for presentation in Virtual J. Nanoscale Sci. Technol. amongst publications described as *covering a focused area of frontier research*. Studies of various graphene materials are being continued [14].

Medical Physics and Radiospectroscopy Laboratory, AMU

In addition to the introductory remarks concerning the development of EPR research in Poznań, there is the further history of independent EPR research at AMU dating back to the late 1960s. In the group of J. Pietrzak and J. Kubiak, the first EPR spectrometer working at K-band was constructed, which was used mainly for studying magnetic compounds, e.g. ferrites and garnets. During the early 1970s, Z. Kruczyński, together with J. Kubiak and R. Krzyminiewski, constructed several EPR spectrometers operating at X-band. They were used for studying inorganic and organic magnetic compounds and as well were employed in the coal industry, in coal mines, and at other universities. Most of the work was focused on the study of molecular dynamics, electronic structure and phase transitions, etc. A large part of the research concerned free radicals, including those generated in biological systems under the influence of ionizing radiation. Beginning in 1979, further development of EPR equipment expanded the existing facilities with ENDOR functionality. The first measurements of ENDOR signals in Poland were achieved by R. Krzyminiewski using a home-built spectrometer [15]. In 2000, a modern Bruker X-band CW-EPR/ENDOR EMX-10/12 spectrometer was purchased, which currently is mainly used for investigations

Electron Paramagnetic Resonance Spectrometer

国仪量子
CIQTEK

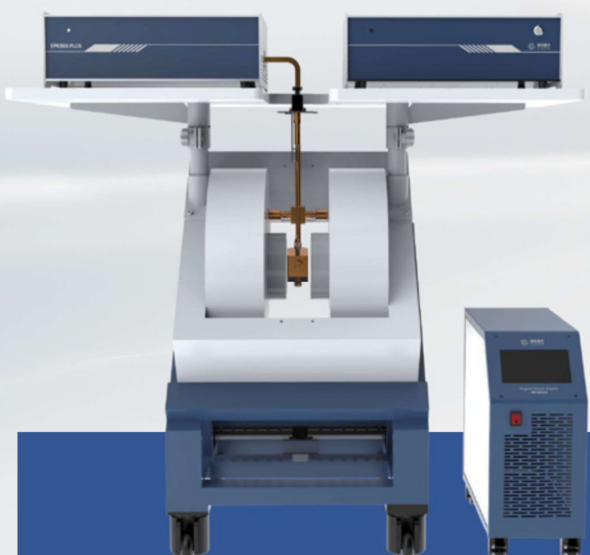
EPR100/EPR200-Plus

EPR100

- Equipped with all CW mode functions of EPR200-Plus
- Echo / FID measurement
- Relaxation time measurement
- Sweep echo detection
- DEER experiment
- ENDOR experiment

X-Band Pulse / Continuous Wave Electron Paramagnetic Resonance Spectrometer

EPR100



EPR200-Plus

- 1D magnetic field scanning
- 2D magnetic field-microwave power scanning
- 2D magnetic field-modulation amplitude sweep
- 2D magnetic field-time scanning
- Variable temperature experiment
- Irradiation experiment

X-Band Continuous Wave
Electron Paramagnetic Resonance Spectrometer

EPR200-Plus

CIQTEK is a high-tech enterprise with quantum precision measurement as the core technology that is originated from CAS Key Laboratory of Microscale Magnetic Resonance (since 2000) in University of Science and Technology of China. This laboratory focuses on the research of spin quantum control and its applications in novel quantum technologies, with various experimental routes including nuclear magnetic resonance (NMR), electron spin resonance (ESR), optically-detected magnetic resonance (ODMR), magnetic resonance force microscopy (MRFM), and electrically-detected magnetic resonance (EDMR).

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Desktop EPR

Electron Paramagnetic Resonance Spectrometer **EPR200M**

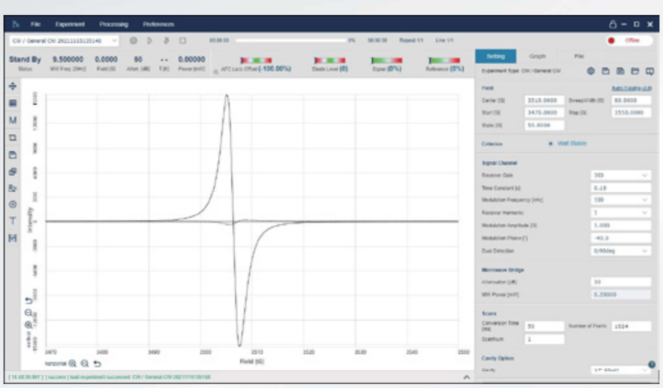
国仪量子 CIQTEK

Product Parameter

Parameter	Value
Frequency Range	9.2-9.9GHz
Modulation Field Amplitude	10 Gauss
Magnetic Field Range	6500 Gauss (Max)
Uniformity of magnetic field in sample area	Better than 50mG
Detection SN ratio in continuous wave mode	Better than 600:1
Absolute spin number sensitivity	5×10^{9} spins/(G√Hz)

Applications

Environment Science | Chemistry | Physics & Material | Biomedical | Food Science | Industry



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of nanoparticles of biological and medical importance, such as liposomes, nanoparticles with a magnetic core, micelles, etc. Not only the basic properties of such nanomaterials are investigated, but also their interactions with health and cancer cells [16]. After retirement of R. Krzyminiewski, the research is continued by B. Dobosz.

Novilet – EPR instrumentation company

In 2008 K. Jurga from AMU, J. Jurga from Poznań University of Technology (PUT) and T. Czechowski established EPR laboratory in 2009 at PUT as a self-funding unit to develop prototypes of the rapid EPR tomograph and novel EPR imaging instrumentation. This interdisciplinary team produced the prototype of the EPR imager. To develop novel solutions for EPR spectroscopy and tomography Novilet was set up in 2014. Supported by an investor and several EU grants, Novilet expanded. Our first EPR tomograph (ERI TM 600) allows examining living mouse-sized objects with time to take the 3D images only a few seconds [17]. Ten innovative technological solutions have resulted, including a multiharmonic analyzer.

KRAKÓW CENTRE: Jagiellonian University (JU) (Tadeusz Sarna, Krystyna Dyrek, Zbigniew Sojka, Piotr Pietrzyk)

The EPR research with a focus on biological applications was initiated at JU in Kraków by S. Łukiewicz in 1968 using a modern EPR spectrometer acquired for the then-formed Department of Biophysics (DB, within the Institute of Molecular Biology since 1970). The team initially included also W. Froncisz, T. Sarna, and W. K. Subczynski. The research scope was soon extended to the general use of EPR in a biochemical context. The first EPR study at DB concerned magnetic properties of tissue samples excised from mice brains, which were later attributed to paramagnetic or ferromagnetic states of iron ions. In the 1970s and 1980s, the quality of EPR resonators was improved. More comprehensive work on EPR instrumentation, commenced by W. Froncisz during his postdoc with J. S. Hyde in National Biomedical EPR Center, Medical College of Wisconsin, resulted in an S-band microwave bridge equipped with a special resonant cavity. Later developments included a loop-gap cavity operating at various frequencies. Biophysical studies of melanin initiated by T. Sarna in 1980s are continued by P. Plonka, A. Żądło, and G. Szewczyk.

Another EPR laboratory, located in the Institute (Faculty since 1981) of Chemistry, was oriented towards EPR applications in solid-state chemistry, catalysis, and interfacial phenomena. Magnetic studies initiated by A. Bielański (then Chair of Inorganic Chemistry) concerned the electronic theory of chemisorption and catalysis of, e.g. oxide nonstoichiometric materials, in collaboration with the Wrocław Center where the first quality EPR spectrometer was manufactured in the early 1970s. In 1972, the Environmental Laboratory of Physicochemical Analyses and Structural Research was funded at FC, which included the EPR group headed by K. Dyrek. Her group published numerous EPR-based articles and developed into a strong EPR laboratory collaborating with foreign researchers, e.g. M. Che, University P. & M. Curie, Paris (oxides and surface forms of oxygen), Elio Giamello, University of Turin (surface species), S. Schlick, University Detroit Mercy (polymers and EPR imaging). EPR activities in FC focused within research group of Catalysis and Physicochemistry of Solid State (headed by Z. Sojka), were extended to new fields, e.g. catalysis and photocatalysis, electron transfer processes at gas/solid and liquid/solid interfaces, inorganic and polymer materials (P. Pietrzyk, K. Kruczała, A. Adamski, Z. Sojka), biological systems (M. Łabanowska, E. Bidzińska, M. Kurdziel). Nowadays, this laboratory is equipped with two Bruker spectrometers (X-band, CW and FT), a bench-top EPR, liquid nitrogen variable temperature set-up, helium cryostat, and in situ irradiation setups.

Faculty of Biochemistry, Biophysics and Biotechnology (FBBB), JU https://wbbib.uj.edu.pl/wydzial/zaklady-i-pracownie/zaklad-biofizyki, https://bm.wbbib.uj.edu.pl

Important developments of EPR instrumentation led by W. Froncisz (see above) enabled enhancing spectral resolution of hyperfine lines of Cu(II) complexes in powder samples leading to a strong correlation amongst spectral parameters. Froncisz's successful collaboration with J. S. Hyde led to the establishment of a dedicated laboratory at FBBB, which contributed greatly to achievements in molecular biophysics and EPR techniques – noticeably construction of a unique pulse EPR spectrometer for saturation recovery studies [18].

Achievements of Sarna's group since the 1970s in the biochemistry of melanin include, e.g., EPR measurements of living cells and embryos of amphibians with the use of specially designed flat cells; assigning the free radical signal to melanin pigmentation and elucidating the mechanism of this phenomenon; EPR studies of the metal-melanin interaction proving the existence of several types of metal-binding sites. The physicochemical studies enabled, e.g., understanding the nature of the interaction of melanin with molecular oxygen; analysis of melanin's ability to reduce oxygen in the dark and also during visible light irradiation [19]; using EPR oximetry to study chemical and photochemical processes mediated by a biological pigment. Melanin research was expanded by other group members to include electrochemical EPR (K. Reszka, Z. Matuszak); oxygen diffusion in model or biological membranes, and effect of cholesterol on the polarity of membranes and phospholipid mobility (W. K. Subczyński) – in collaboration with Hyde's group [20].

Nowadays biomedical EPR research is continued by S. Łukiewicz's successors in the FBBB. In the Department of Biophysics, headed by M. Elas, the focus is on in vivo EPR spectroscopy and EPR imaging, e.g. tumor oximetry, biology, and treatment [21]. In the Department of Molecular Biophysics, headed by A. Osyczka, advanced EPR methodologies are used extensively for the examination of structure, mechanisms, and dynamics of proteins involved in bioenergetic systems, i.e. bioenergetic enzymes of respiration and photosynthesis. These studies exploit paramagnetic centres in proteins, e.g. semiquinone radicals or metallic cofactors, and spin labels introduced via SDSL [22], thus allowing detection of transient paramagnetic states during enzymatic turnover.

Faculty of Chemistry (FC), JU https://chemia.uj.edu.pl

Early EPR studies in the Group of Catalysis and Physicochemistry of Solids, then headed by K. Dyrek (now succeeded by Z. Sojka), concerned magnetic and electronic properties of transition-metal oxides, and later evolved to explore the processes occurring upon the adsorption of gas molecules on oxide surfaces. In the 1970s and 1980s EPR was extensively utilized to investigate, e.g. redox processes occurring in the bulk and on the surface of oxide catalysts or solid solutions; kinetic processes, identification of adsorbed species and their electronic structure; mechanistic insights into the activation processes of small non-innocent (O_2, NO, NO_2) and innocent (CO, N_2O, N_2, PR_3, CH_3OH) molecules with various transition-metal ions (TMI) [23]. EPR also served as a tool to study interfacial chemistry of TMI on oxide surfaces, metallozeolites, homogeneous complexes, and minerals [24]. From 2000, experimental studies were corroborated by advanced quantum chemical modelling of the spin Hamiltonian parameters [25]. Dedicated software (EPRsim32 and ACON) was developed for the analysis of complex powder spectra and reconstruction of concentration profiles obtained by EPR imaging [26].

Group members worked also on protocols for quantitative EPR measurements and the development of standards for the determination of spin concentration in various materials. In collaboration with S. Schlick using EPR and EPR imaging, K. Kruczała studied the interaction of TMI with polymer matrices and their thermal/photo-degradation. Since 2004 M. Łabanowska, E. Bidzińska, M. Kurdziel, and K. Dyrek have studied native and modified plant products subjected to thermal and chemical processes and radicals generated therein by oxidative stress [27].

Taking advantage of equipment developments, from 2008 the research topics evolved into new areas using e.g. the HYSCORE technique (in collaboration with M. Chiesa, University of Turin). At present, EPR spectroscopy is mainly used in FC together with other spectroscopic and microscopic techniques, combined with kinetic studies, for comprehensive investigations of the radical, catalytic, and related photo- and electro-catalytic processes.

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Shimon Vega (1943–2021)

Professor Shimon Vega, a member of the department of Chemical and Biological Physics, Weizmann Institute of Science in Israel passed away on November 16th 2021, two days after his 78th birthday. Shimon was one of the pillars of Magnetic Resonance, a close collaborator and a dear friend for many decades. In this short obituary I will describe his long scientific career and major contributions to Magnetic Resonance along with his special, open hearted personality, which made him a very special and beloved human being. It is reproduced mostly from the obituary appearing on our Department webpage written by Lucio Frydman and myself (https://www.weizmann.ac.il/chembiophys/memoriam) with a few personal remarks highlighting also his contributions to EPR spectrscopy.

Shimon Vega was born in Amsterdam on November 14, 1943. As he would later say: "This was not a good time and place for a Jewish child to be born, and led to what perhaps was the most 'interesting' part of my life". At the age of 6 weeks he was sent to a hideout with a Dutch family until the end of the war, thus surviving the Holocaust. He grew up in Ouderkerk aan de Amstel, a small village south of Amsterdam. After obtaining both his B.Sc. and M.Sc. in Physics in Holland he moved to Israel with his wife Margrit, and completed his PhD with Prof. Zeev Luz at the Weizmann Institute on Nuclear Quadrupole Resonance. Shimon stood out already during his PhD, where he published his thesis papers as a sole author with the full encouragement of his advisor. This work was the beginning of a long and remarkable scientific career with the unique trademark of joint theoretical and experimental efforts to uncover the chemical physics underlying magnetic resonance. After PhD graduation Shimon became Alex Pines' first postdoc at Berkeley, where they made pioneering discoveries in the new field of multiple-quantum NMR. This work would eventually lead to setting the basis for the fictitious-spin-1/2 formalism, nowadays a primary tool for understanding NMR in solids and liquids and gaining recognition in EPR and quantum optics.

Upon completing his postdoc Shimon returned as a tenure-track faculty to the Weizmann Institute, where he expanded these studies to half-integer quadrupolar nuclei. This work, along with the multi-quantum concept, served as basis for additional future developments in the field that resulted in a wide variety of materials-oriented research. Shimon continued to focus mostly on solids NMR and developed new decoupling and recoupling methods, as well as new kinds of pulses and new structural determination schemes –most often while relying on magic angle spinning (MAS). In those late-1970/early-1980 days, MAS was largely viewed from a continuous-wave perspective; i.e., as an averaging process leading to the cancelation of second-rank anisotropies and hence sharp spin-1/2 lines. Drawing from the time-domain perspective that had led to multiple-quantum NMR, Shimon departed from this outlook, and was among the first to recognize the complex time-dependencies that underlie MAS as an averaging process. Starting at Weizmann and furthering these ideas during sabbaticals at MIT with R. G. Griffin and at Washington University with J. Schaefer in the 1980s, Shimon thus developed sophisticated theories –many of them based on the Floquet formalism – to advance the understanding of MAS NMR. These efforts allowed exact computation of MAS spectra under a variety of scenarios, while leading to a deeper understanding and to new pulse sequences. They also lead to new methods to evaluate dynamic processes in MAS NMR, and to the design and interpretation of a variety of discrete multipulse recoupling experiments. The latter included homo- and hetero-nuclear dipolar decoupling/recoupling schemes like SEDRA, TEDOR, RFDR and REAPDOR, that have since become common tools in the biomolecular and materials NMR arsenal. They also included sensitivity enhancement schemes, such as the FAM sequence for semi integer quadrupolar nuclei. During a subsequent stage of Shimon's solids NMR research he extended Floquet's sophisticated formalism to a multimodal format, capable of accounting for the coherent evolution of a density matrix subject to multiple, non-commensurate time-dependent processes simultaneously. Numerous experiments he designed were on the basis of multi-modal Floquet theories, in particular the high resolution single- and multidimensional proton NMR phase-modulated Lee-Goldburg sequences (PMLGn).

During the last decade Shimon embarked on yet another venture: understanding the mechanism of dynamic nuclear polarization (DNP) at high magnetic fields. He realized the limitation of traditional steady-state descriptions of DNP, and developed instead quantum mechanical models which could reproduce and predict important experimental features – helping to bring about static DNP and MAS DNP renaissance.

Shimon's exceptional understanding of spin physics was not limited to nuclei in diamagnetic systems; he had a clear picture of all spins, including nuclei coupled to electron spins and electron spins. Our offices were on the same floor since I have joined the Weizmann Institute as a graduate student, the 2nd floor of the Perlman building, the strong hole of magnetic resonance at Weizmann. Whenever I got lost in the often dark forest of the electron and nuclear spins, I was lucky to have Shimon around to turn on the lights and show me the way. Our formal collaboration started with the set-up of X-band pulse ENDOR (electron-electron double resonance) in my lab (late 1990's) with the vison of having a spectrometer capable of multi-resonance and multi-dimensional spectroscopy like in NMR. Whenever we had new and interesting observations or developed new experiments which required theoretical foundations me and my lab members were highly fortunate to attract Shimon's curiosity, interest and kindness in sharing his knowledge and time. This led to several of our significant collaboration, which expanded Shimon's contributions also to the field of EPR, particularly hyperfine spectroscopy. This includes two-dimensional ENDOR-ESEEM correlation spectroscopy, understanding the effect of spin relaxation on ENDOR spectra recorded at high magnetic fields and low temperatures, resolving the unusual behavior of the ENDOR signals of ligand protons in a frozen solution of copper histidine as explained by T1e-driven three-spin relaxation and population transfer for signal enhancement in pulsed EPR experiments on half integer high spin systems by adiabatic field sweep. This than evolved into our collaboration on DNP, together with Dr. Akiva Feintuch. Here Shimon understood that the electron spin dynamics, which play a central role in DNP, has to be experimentally followed and theoretically understood in order to decipher the DNP mechanism. Focusing on static DNP he used ELDOR (electron-electron double resonance) spectroscopy to account for electron spectral diffusions within the EPR line shape, integrated it into the DNP mechanism and coined the indirect-cross effect DNP mechanism. Shimon continued to be highly active and productive years after his “formal” retirement, working mainly on DNP, thinking about magnetic resonance till the day he was hospitalized.

Shimon was truly exceptional as an educator and scholar, that molded and enriched the lives of those he met and interacted with. He was an engaging lecturer that would capture audiences, despite – and perhaps because of – his relentless refusal to escape from equations and meaningful concepts. Shimon taught at many international schools, including two EPR schools and his contribution to the EPR community also includes an extensive and highly educational chapter in “EPR spectroscopy: Fundamentals and Methods” on spin dynamics where he provides a comprehensive summary of the theoretical tools that are presently used to design and analyze microwave (MW) and radiofrequency (RF) pulse experiments in magnetic resonance spectroscopy.

Shimon was a sought-after teacher that in addition to regular courses at the Weizmann Institute devoted ample time lecturing at high schools, guiding local kids in visits through the Weizmann labs, and sharing his science with his community –much before outreach activities became “fashionable”. Shimon was a remarkable mentor, who trained graduate students and postdoctoral fellows that are now leaders in the forefront of magnetic resonance worldwide. But more than anything else, Shimon was an exceptionally caring human being, who inspired with his generosity in sharing his knowledge and wisdom, his patience, his unusual capability to listen, and his modesty. When he received the ISMAR prize 2015 and I congratulated him he asked “but why me?”. At the Israel Chemical Society 2018 meeting, which endowed Shimon with its highest Gold Medal award, Shimon summed up some of these traits in a way that reflected his personality: “I wish to share with you, my love. Above all my love for my wife Margrit, who in addition to all the rest, made it possible for me to dedicate much of my time to science. And for our children who knew what it meant to have a dad in the lab or abroad or in miluim (army reserve). Let me tell you about my other love… Magnetic Resonance… I wish to thank the ICS Prize Committee. I assume that if I had been a member of that committee, I would not have voted in favor of myself. Why? Because I know what I know and I also know what I don’t know, but they don’t realize how much I don’t know. It is a great honor for me to join the incredible list of ICS Gold Medalists.”

I and many of the people who crossed paths with Shimon have been fortunate to be touched by his warmth and intellect, he will be missed by many.

Daniella Goldfarb

International Conference "Modern Development of Magnetic Resonance" (MDMR2021)
November 1–5, 2021, Kazan, Russia

The annual International Conference "Modern Development of Magnetic Resonance" was held from 1 November till 5 November 2021 in Kazan. The conference was organized by the Kazan Zavoisky Physical-Technical Institute of the Federal Research Center "Kazan Scientific Center Russian Academy of Sciences" and the Kazan Federal University under the auspices of the AMPERE Society. The conference also included the ceremony of the International Zavoisky Award 2021 and the celebration of the 85th birthday of Prof. Kev M. Salikhov. All events were organized in a mixed format: face-to-face and online participation.

The conference topics were extremely diverse and included reports in the following fields:
– Perspectives of magnetic resonance in science and spin technology
– Chemical and biological systems
– Low-dimensional, nanosized and strongly correlated electronic systems
– Magnetic resonance instrumentation
– Electron spin-based methods for electronic and spatial structure determination in physics, chemistry and biology
– Modern methods of magnetic resonance
– Molecular magnets and liquid crystals
– Other applications of magnetic resonance and related phenomena
– New trends in spin chemistry

The participants of the conference were leading scientists and experts in the field of magnetic resonance from Australia, Belgium, Canada, Czech Republic, Germany, Israel, Italy, Japan, Moldova, Poland, Russia, Sweden, Switzerland, Tajikistan, Turkey, United Kingdom and USA. The total number of participants was 181, who presented 146 reports (7 plenary lectures, 79 invited and oral talks, and 67 posters). The program of the conference and abstracts can be found at Program_MDMR-2021.pdf (knc.ru) and Book of abstracts_MDMR.2021 .pdf (knc.ru), respectively.

The opening ceremony and the first scientific session of the conference took place on November 1, 2021 and were chaired by Alexey Kalachev, Director of the Federal Research Center. The Zavoisky Prize ceremony was held before the opening of the conference. Kev Salikhov, Chairman of the International Zavoisky Award Selection Committee, announced the names of the Zavoisky Awardees 2021: Professor Sergei Demishev (Prokhorov General Physics Institute of Russian Academy of Sciences, Russia) and Jörg Wrachtrup (University of Stuttgart, 3rd Institute of Physics and Center for Applied Quantum Technology, Stuttgart, Germany). Sergei Demishev was distinguished for his achievements in the field of application of EPR methods to the study of quantum materials including strongly correlated metals and quantum critical systems. Jörg Wrachtrup was distinguished for his achievements in the field of application of EPR methods to the study of quantum materials including single-spin systems and materials for spin technology. Leila Fazleeva, Deputy Prime Minister of the Republic of Tatarstan, Myakzyum Salakhov, President of the Tatarstan Academy of Sciences, Dmitry Tayursky, Deputy Rector of the Kazan Federal University congratulated heartily Sergei Demishev and Jörg Wrachtrup on their highly deserved awards. The laureates also received congratulations from Songi Han, IES President, Anja Böckmann, President of the AMPERE Society, Robert Tycko, ISMAR President, and Akash Chakraborty, Publishing Editor, Springer-Verlag. Traditionally, the laureates gave Zavoisky Award lectures: Magnetic Resonance One Spin at a Time (Jörg Wrachtrup) and EPR Adventures in the Strongly Correlated World: Quantum Materials and Quantum Critical System (Sergei Demishev).

The first plenary session included the following plenary lectures: Adventures and Advances with Compact Magnetic Resonance by Bernhard Blümich (ITMC, RWTH Aachen University, Aachen, Germany) and CW and Pulsed EPR of Radicals in Solutions Undergoing Exchange by Michael Bowman (Novosibirsk Institute of Organic Chemistry, Novosibirsk, Russia; Chemistry & Biochemistry Dept., University of Alabama, Tuscaloosa, USA).

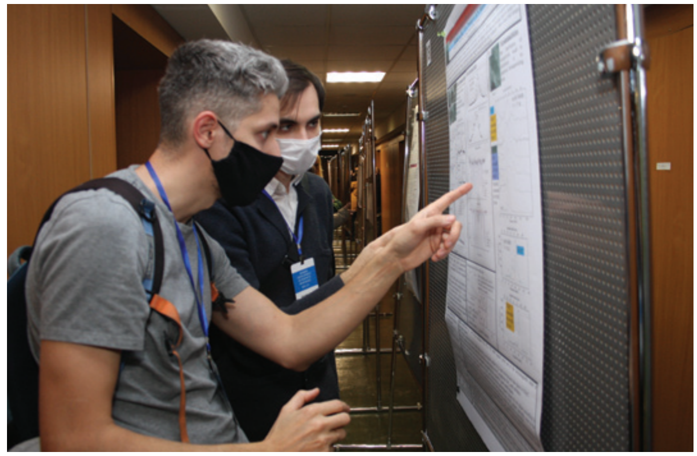
A number of topical fundamental problems were discussed at the conference. These include: search for promising applications of magnetic resonance in science and spin technology; the recent development of magnetic resonance method, study of the properties of new materials with specified functional properties; a new trends in spin chemistry; recent developments in the application of solid-state NMR of quadrupolar nuclei to understand inorganic materials; etc.

On November 3, the celebration of Kev Salikhov's 85th birthday was held, when the hero of the day presented a report on his ambitious scientific plans. Kev Salikhov was congratulated by leaders of the Republic of Tatarstan, the city of Kazan, the Academy of Sciences of the Republic of Tatarstan, Federal Research Center "Kazan Scientific Center of Russian Academy", Kazan Federal University, colleagues and friends. Farid Mukhametshin, Chairman of the State Council of the Republic of Tatarstan, awarded Kev Salikhov the Order of Friendship of the People of the Republic of Tatarstan. Ilsur Khadiullin, Minister of Education of the Republic of Tatarstan, presented him Insignia "Honorary mentor". Many congratulations were received online, including those from the Physics Department of the Russian Academy of Sciences and Songi Han, IES President.

Two IES Student Poster Awards were granted at the MDMR2021. The IES Student Poster Award Selection Committee consisted of Kev Salikhov (Chairman, Zavoisky Physical-Technical Institute, Kazan, Russia) and members:

Leila Fazleeva presents the Zavoisky Award diploma to Sergei Demishev (from left to right: Leila Fazleeva, Sergei Demishev, Kev Salikhov).

The first plenary lecture is given by Bernhard Blümich.



At the poster session.

Farid Mukhametshin (left) presents the Order of Friendship of the People of the Republic of Tatarstan to Kev Salikhov (right).

Kev Salikhov presents the IES Student Poster Award diploma to Arina Tarasova (right).

Michael Bowman (Chemistry & Biochemistry Dept., University of Alabama, Tuscaloosa, USA), Sergei Demishev (Prokhorov General Physics Institute of RAS, Moscow, Russia), Marat Gafurov (Kazan Federal University, Kazan, Russia) and Dmitri Stass (Voevodsky Institute of Chemical Kinetics and Combustion, Novosibirsk, Russia). Arina Tarasova (Moscow State University, Moscow, Russia) and Bogdan Rodin (International Tomography Center SB RAS, Novosibirsk, Russia, PSL University, Sorbonne Université, Paris, France) were chosen as the awardees.

The conference favored the exchange of ideas and recent achievements and its participants received a good impetus for their further research, which was especially important in the pandemic we all live through.

The organizers of the conference are sincerely grateful to the Government of the Republic of Tatarstan, Federal Research Center "Kazan Scientific Center of the Russian Academy of Sciences", and the Russian Science Foundation for the financial support.

Kev Salikhov
Chairman of the Organizing Committee MDMR2021
Violeta Voronkova
Scientific Secretary MDMR2021

IES Virtual EPR Meeting
October 7, 2021

Hybrid Spintronic Materials from Conducting Polymers with Molecular Quantum Bits

Michal Kern

University of Stuttgart, Stuttgart, Germany

Quantum technologies have the potential to fundamentally change many technological fields, such as simulation, computation, sensing and metrology among others. Quantum sensing uses quantum objects and their properties to improve the sensitivity or precision of measurement, beyond what is possible classically [1]. At the heart of all quantum technologies are quantum bits or qubits. Qubits are two- or more-level systems that can be prepared in a coherent superposition. Spin qubits based on paramagnetic molecules (molecular quantum bits, MQBs), are one of the prime candidates for quantum sensing and in fact, have long been used for determination of protein structures in the form of spin labels [2]. One of the main advantages of MQBs compared to other spin qubits is that their chemical tailorability may be used to, e.g., add additional functionality, such as optical addressability, or enhance chemical selectivity by integration of a specific binding site. An important figure of merit for qubits is the phase memory time T_m. While MQBs were shown to possess relatively long coherence times of hundreds of microseconds at low temperatures and a few microseconds at room temperature, all the measurements were performed on bulk samples using standard electron paramagnetic resonance (EPR) techniques. Since quantum devices will require a readout of individual qubits, conventional EPR based on measurements of microwave absorption is fundamentally unsuitable for this purpose, due to the limited energy content of microwave photons. Techniques that convert the low-energy spin transitions into higher energy transitions, such as optical [3] or charge transitions [4], have been shown to possess single qubit detection capabilities. Charge transitions can be detected purely electrically, and therefore have the advantage of easier integration into electrical control and readout system. Electrical readout of MQBs has been shown to work on a single-molecule level, however, only at millikelvin temperatures [5]. For the purposes of practical quantum sensing, higher temperature operation is critical. In this work [6], we focused on the fabrication and characterization of a hybrid material composed of a conducting polymer and a MQB, with the goal of creating a material in which both conductivity and quantum coherence of the MQB is present at the same temperature, thus having the potential to use the interaction between mobile charge carriers and MQBs to read out the quantum state of the MQBs using electrically detected magnetic resonance (EDMR).

The hybrid material was manufactured by combining the semiconducting polymer poly(3-hexylthiophene) (P3HT) with the MQB [Cu(dbm)$_2$](Hdbm=dibenzoylmethane). To separate the effects of inclusion of the MQB in a foreign matrix from the effect of nearby charge carriers, we investigated the hybrid semiconductor in nominally undoped as well as a doped state by sequential chemical doping with the electron acceptor 2,3,5,6-tetrafluoro-tetracyanoquinodimethane (F$_4$TCNQ). Through a combination of UV-VIS-NIR spectroscopy and field-effect transistor measurements at room temperature, we have established that the inclusion of MQBs has no detrimental effects on the electrical performance of the semiconducting polymer, both in doped and undoped state. Low-temperature transport measurements have revealed the presence of mobile charge carriers in the doped hybrid material already at 15 K, which move through variable range hopping. Pulsed Electron Paramagnetic Resonance (EPR) was used to study the MQB at low temperatures. Hahn-echo-detected spectra have shown no change in the static spin Hamiltonian of the MQB in the hybrid material compared to MQB incorporated in its diamagnetic analog [Pd(dbm)$_2$], proving the intactness of the molecule after incorporation into the semiconducting matrix. Spin dynamics investigations revealed that the spin-lattice relaxation time wasn't significantly affected at intermediate temperatures between 10 K and 20 K, after which a sharp decay could be observed, with the highest temperature with an observable spin echo being 40 K. The T_m of [Cu(dbm)$_2$] in the hybrid material was approximately halved compared to the one in [Pd(dbm)$_2$], even though in [Pd(dbm)$_2$] the concentration of [Cu(dbm)$_2$] was more than 1000 times lower. The value of T_m was essentially constant up to 15 K, after which it started to moderately decrease. Upon introduction of charge carriers via chemical doping, T_1 wasn't significantly affected. However, spin echoes were observable only up to 30 K, with the T_m times approximately halved compared to the undoped hybrid material. Crucially, in the temperature range between 15 and 30 K, we have observed a system with both conductivity and quantum phase coherence. These results pave the way to addressing MQBs by means of electric currents and thus to using hybrid polymer/molecular qubit materials as a novel platform for quantum spintronics. Next steps will include tailoring and optimization of the material, the search for signatures of qubit-charge carrier interaction in transport measurements, and appropriate modeling to understand the interaction mechanism between the qubit and the charge carriers.

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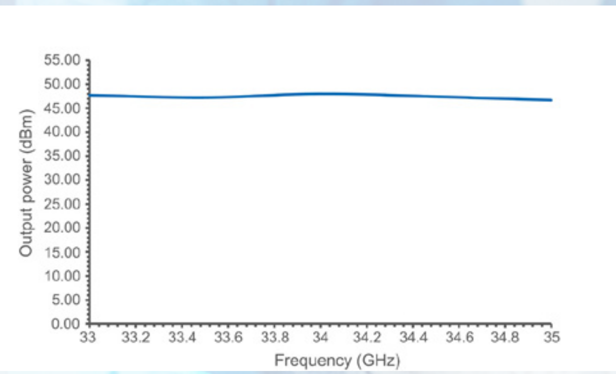

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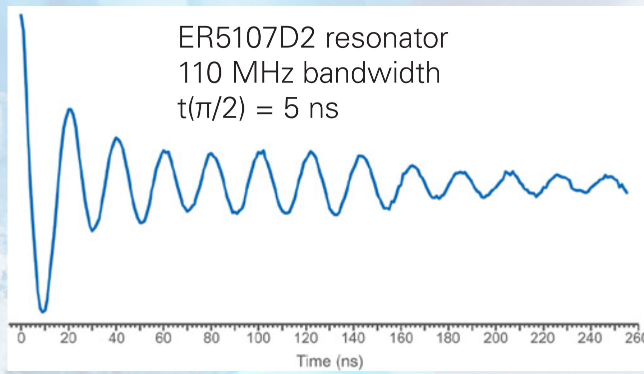

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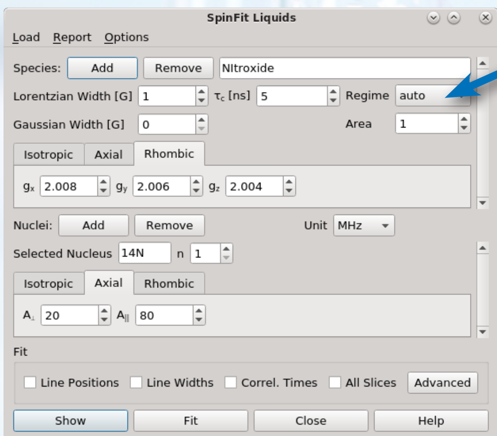

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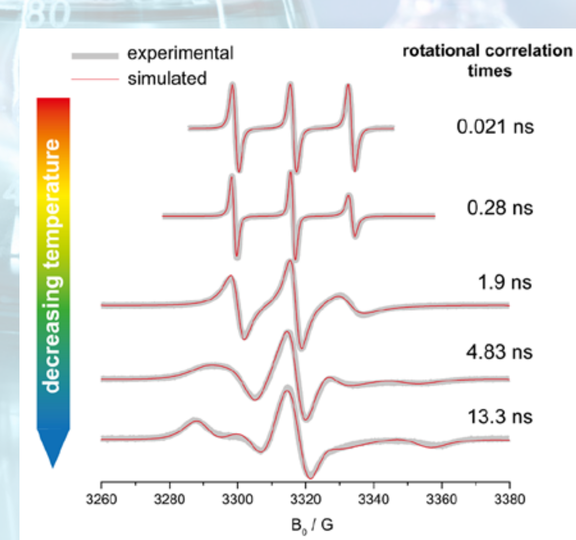

Rotational correlation times of nitroxide spectra in water/glycerol mixture obtained from SpinFit Liquids