

43rd International Field Emission Symposium (Moscow, July 14–19, 1996)

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The International Field Emission Symposium is annual meeting which has been held since 1952 with only two cuts during the entire period. The location of each of the 42 previous Symposium was invariably a western country, and only the 43rd Symposium was organized in Moscow, Russia.

The International Field Emission Symposia are prestigious meetings which as a rule bring together leading scientists from practically all developed countries.

The Moscow Symposium was organized by the Russian State Research Center “Institute of Theoretical and Experimental Physics” (ITEP) and the Association “Ultramicroscopy in Science and Technology” established jointly by ITEP and several other institutions. The Local Organizing Committee was co-chaired by Prof. R Z Bakhtizin (Bashkir State University, Ufa) and Prof. A L Suvorov (ITEP, Moscow). The Organizing Committee included Prof. I V Chuvilo, director of ITEP; Prof. Yu V Gulyaev, member of the Presidium of the Russian Academy of Sciences (RAS), and director of the Institute of Radio and Electronic Engineering, RAS; Prof. G N Fursey, State University of Telecommunications, St.-Petersburg; Prof. V N Shrednik, A F Ioffe Physico-Technical Institute, RAS, St.-Petersburg; Prof. E I Givargizov, Institute of Crystallography, RAS, Moscow; Dr. E P Sheshin, Moscow Institute of Physics and Technology; Prof. N N Syutkin and Prof. V A Ivchenko, Institute of Electrophysics, Urals Division, RAS, Ekaterinburg.

The venue of the 43rd Symposium was the “Uzkoye” hotel in the beautiful outskirts of Moscow.

Major sponsors of the Symposium were the Moscow Government (Yu M Luzhkov, Mayor of Moscow, extended a cordial message of welcome to the participants) and the Russian Fund for Fundamental Research. The sponsoring institutions also included the Moscow Physics Society and the Center for Analysis of Substance. The Symposium was held under the aegis of the International Field Emission Society (President: Dr. M Miller, Oak Ridge National Laboratory, USA).

The Symposium was attended by 120 scientists from 16 countries including 55 participants from Russia. Its scientific programme included 12 invited lectures, 40 oral (plenary) talks and over 100 poster presentations.

The International Field Emission Symposium used first and foremost to be focused on the physical aspects of the following four quantum-mechanical processes known to occur in electric fields of $10^6 - 10^9 \text{ V cm}^{-1}$:

- field electron emission (electron tunneling from electroconductive materials over a field-modulated potential barrier);

- field ionization of neutral atoms and molecules in gases (also realized via tunneling);

- field desorption (the removal of foreign substances from solid surfaces mediated through atom and ion tunneling mechanisms);

- field evaporation (the removal of atoms contained in surface layers of solids following their ionization without previous thermal activation).

These processes provided the basis for the development of various original devices and methods such as:

- the field electron microscope (developed by E Muller in 1937 to study surface emission properties, adsorption and desorption of foreign particles and their surface migration, and to measure the electron work function both surface-adjusted and at selected crystallographic facets);

- the field ion microscope (developed by E Muller in 1951) which allowed individual atoms to be seen for the first time and proved an excellent tool for investigating a variety of surface effects at the atomic level, and the formation and behavior of defects in crystal structures);

- the atom probe (developed by E Muller in 1968 as an arrangement of a field ion microscope and a highly sensitive mass-spectrometer to identify the chemical nature of individual particles and small aggregations selected on microscopic images);

- the scanning tunneling microscope (developed in 1982 by G Binnig and H Rohrer, the 1986 Nobel Prize winners in physics) which provides atomic resolution indispensable in microtechnology, construction of desired compositions from individual atoms, etc.).

Further improvement and application of the above instruments and techniques for ultramicroscopy along with the design and development of new ‘field’ electron and ion sources constitute another important topic of the International Field Emission Symposium.

By virtue of the relatively small number of participants normally attending such meetings, only plenary sessions were planned, each dealing with a specific topic. A total of 25 sessions were held encompassing 10 topics.

One session was concerned with “Field Emission: Theory and Processes”. Original papers presented by its participants

discussed the extension of the field electron emission theory to a number of specific practical problems such as field emission from a diamond (P Cutler et al., Pennsylvania State University, USA) and the use of a pulsed laser to generate this process (M Hagmann et al., Florida International University, USA). The session showed special interest in the presentation by F I Dalidchik et al. (N N Semenov Institute of Chemical Physics, RAS) which considered the probability and specific features of two-electron effects in tunneling.

Four sessions were devoted to “Field Electron Emission and Microscopy”. Two invited lectures presented during these sessions deserve special attention. One was by A Tonomura (Hitachi Ltd, Saitama, Japan) and reported unique experimental findings obtained with a holography electron microscope designed by this author and his group. The use of a totally novel approach allowed images of individual vortices (in fact, ‘clusters’ of magnetic lines of force) in superconducting niobium films to be obtained for the first time, and their dynamics to be studied. The other lecture by A G Naumovets (Institute of Physics, NASU, Kiev, Ukraine) illustrated further prospects for using field electron and ion microscopy following their successful extensive application to the description of surface diffusion processes. Equally interesting was a review of experimental and theoretical studies on field electron emission from liquid metal surfaces supplemented with original results obtained by the authors (G N Fursey et al.). One more presentation (A N Stepanova et al., Institute of Crystallography, RAS, Moscow) is worth mentioning for the description of original methods for preparing and testing field electron emitters from diamond particles deposited on sharpened silicon tips.

One of the sessions was designed to discuss research of surface phenomena, e.g. adsorption and desorption of individual atoms (O Nishikawa et al., Kanazawa Institute of Technology, Japan), dynamics of film formation (T Tsong and T -Y Fu, Institute of Physics, Taipei, Taiwan), and surface ionization (R Forbes, University of Surrey, UK). Much attention was given to the presentation of J Jia et al. (Tohoku University, Sendai, Japan) who used a field ion scanning tunneling microscope to examine the formation and behavior of a gold overlayer on a copper substrate.

A large number of presentations considered the atom probe field ion technique and its application to the solution of current problems in material science. Original results obtained by this method in high-temperature superconductor studies were analysed in the invited lecture of H -O Andren (Chalmers University of Technology, Goteborg, Sweden). Another invited lecture (K Hono et al., National Research Institute for Metals, Tsukuba, Japan) was devoted to studies of nanocrystallization and the supercooled liquid state of selected amorphous alloys. Other reports in the context of this topic were focused on purely methodological problems (e.g. A Cerezo et al., Oxford University, UK, and P Camus, University of Wisconsin, Madison, USA). It appears that highly promising atom probe field ion microscopy continues to be successfully used to study the structure and phase transitions in constructional alloys and steels (a very informative invited lecture by D Blavette, Universite de Rouen, France; reports of V A Ivchenko and S I Paramonov, Institute of Electrophysics, Urals Division, RAS, Ekaterinburg, Russia; R Thomson et al., Loughborough University, UK, etc.).

The Symposium showed special interest in scanning tunneling microscopy. This technique, although a relatively new one, is currently very popular all over the world and used

to be considered at a variety of different international meetings including the well-known International Conferences on Scanning Tunneling Microscopy, International Conferences on Nanotechnology “Nano”, etc. This poses a problem for organizers of Field Emission Symposia. On the one hand, they cannot avoid including such an ‘intrinsically field technique’ in the programme, but on the other hand it seems illogical to lay special emphasis on it. The 43rd Symposium invited three lecturers to discuss consecutively the theory of electronic and atomic processes in scanning probe microscopy (M Tsukada, University of Tokyo, Japan), the extraordinary growth of carbon-60 films on a specially oriented gallium arsenide surface (T Sakurai et al., Tohoku University), and the specific design and performance of an original scanning tunneling microscope (Y Kuk, Seoul National University, South Korea). Analysis of reports on these lines brings the reviewer to the conclusion that the main area of research using scanning tunneling microscopy remains atomic structure and surface layer dynamics in crystals including those of one-atom films of certain substances on crystallized surfaces of different substrates (D Jeon et al., Myong Ji University, Seoul, South Korea; V Yu Yurov et al., Institute of General Physics, RAS, Moscow, Russia; O Takaoka et al., Tohoku University, Sendai, Japan).

The Symposium featured three special sessions in memory of Prof. J Block (Fritz-Haber-Institute, Berlin, Germany) who died in 1995. Professor Block made an immeasurable contribution to the solution of surface problems by the immense body of work that he did to explore physico-chemical properties of structured surfaces. Also, he founded a world-renowned scientific school and very effectively participated in the activities of the International Field Emission Society, doing a lot to enhance its prestige. Many young scientists from the former Soviet Union and CIS countries had a chance to work in the laboratory headed by Prof. J Block at the Fritz-Haber-Institute and receive excellent training there. Many presentations at this Symposium are in some way or other related to the studies carried out or initiated by Prof. Block, and they were delivered either by his pupils from different countries (N Ernst and V Drachsel, Fritz-Haber-Institute; N Kruse, Universite Libre de Bruxelles, Belgium; F Rollgen, University of Bonn, Germany; V V Gorodetskiĭ and others, Institute of Catalysis, Novosibirsk, Russia; V K Medvedev, Institute of Physics, NASU, Kiev, Ukraine) or friends and colleagues (R Forbes, University of Surrey, UK; T Tsong, Institute of Physics, Taipei, Taiwan, V N Shrednik, A F Ioffe Physico-Technical Institute, St.-Petersburg, Russia).

Professor E Muller, the first man to see the atom using field electron and ion microscopes he designed and created himself died in 1977. A year later, the first E Muller Outstanding Young Scientist Medal Competition was held in the framework of the 1978 International Field Emission Symposium. Since then, the competition of best studies performed by young scientists has become traditional. Two special sessions at the Moscow Symposium were assigned to presentations by competitors for this award. The winner of the 1996 E Muller Medal was L Li of the Institute of Materials Research, Tohoku University, Sendai, Japan, who studied the reconstruction of a 6H-SiC surface under Si-rich conditions using a field ion scanning tunneling microscope. A similar study was conducted by O Shue in the same laboratory and with the same instrument. One more report by a young scientist worthy of citing was devoted to the field

electron emission spectroscopy of Y-Ba-Cu-O single crystals at temperatures above and below the superconducting transition temperature (S N Ivanov, Institute of Electrophysics, Urals Division, RAS, Ekaterinburg, Russia).

The scientific programme of the Symposium included three poster sessions. Actually, the poster presentations were open for informal discussion throughout the entire period of the meeting, from the very first to the last day. Even a brief review of these reports is beyond the scope of the present communication. Suffice it to say that they reflected tendencies apparent from oral presentations and invited lectures. As before, field ion microscopy (with or without an atom probe) was largely applied to material studies. Likewise, scanning tunneling microscopy remains a major tool in the physics (or rather, the structural and dynamical investigations) of solid surfaces. A series of interesting reports concerned the development of mono and multi-tip electron sources based on the field electron emission properties of different materials. Novel technologies were proposed for this purpose. A number of reports described the parameters and potentialities of new devices and methods. Another group of presentations considered theoretical aspects of both quantum-mechanical processes in strong electric fields and instruments and techniques taking advantage of these processes. Finally, a few authors suggested computer simulation of these processes. By tradition, a special prize was awarded to the authors of the best poster presentation. The steering Committee of the International Field Emission Society declared N Ernst and co-workers (Fritz-Haber-Institute, Berlin, Germany) to be the winners of the 1996 prize. Their report was devoted to the use of microprobe analysis (the so-called probe hole technique) in field electron and ion microscopy for surface reaction studies.

The last session of the Symposium passed under the heading "Challenges in the Realization of Russian High-Technology and Analytical Services" and aroused great interest among the participants. A B Danilin (Center for Analysis of Substance, Moscow, Russia) presented a vivid discussion of the differences between the socio-psychological motivation of scientific activity in Russia and in the West and offered a rather unexpected explanation of their causes and effects. A Thurman (Denver, USA) summarized the experience of Denver–Moscow Associates Inc. both in Russia and USA to illustrate the hard route from technical idea to commercial market.

Two new members for the Steering Committee of the International Field Emission Society were elected at a Symposium business meeting (Dr. R Forbes, University of Surrey, UK, and Prof. A L Suvorov, ITEP, Moscow, Russia). Also, Dr. R Forbes will be at the head of the Committee next year as the newly-elected President of the International Field Emission Society. Simultaneously, Dr. M Miller (Oak Ridge National Laboratory, USA) was elected Vice-President. According to the Statute of the Steering Committee, it comprises eight members each serving for a period of 4 years.

The proceedings of the 43rd Symposium have been published in a special issue of *J. de Physique* **6** (5), Suppl JP III (9) (1996) (France). The 44th International Field Emission Symposium will be organized by Dr. K Hono in Tsukuba City, Japan, during the week of July 7–11, 1997. The Steering Committee decided that the 45th Symposium be held in Al-Karak, Jordan, in the summer of 1998; the chairman of the Organizing Committee will be Dr. M Mousa.

In conclusion, it is appropriate to note that it has recently become traditional to hold the International Field Emission Symposium and the annual International Vacuum Microelectronics Conference as parallel meetings. Notwithstanding the similarity of topics discussed by the participants of the two meetings, the Symposia appear to be largely concerned with basic physical problems whereas the Conferences tend to focus on applied matters. Many scientists and specialists prefer to attend both meetings. For this reason, they are normally held in one country. The 9th International Conference on Vacuum Microelectronics was organized by Prof. Yu V Gulyaev in St.-Petersburg in July 1996.