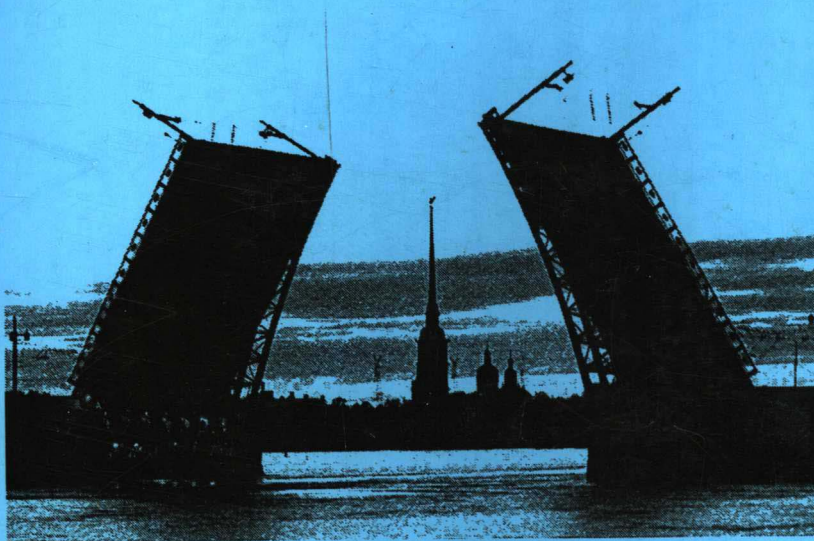


*Technical Digest*



**9th INTERNATIONAL  
VACUUM  
MICROELECTRONICS  
CONFERENCE**



**July 7-12, 1996  
St. Petersburg, Russia**



## **9th International Vacuum Microelectronics Conference**

**July 7-12, 1996**

**Saint-Petersburg, Russia**

**ORGANIZED BY THE**

**Russian Academy of Sciences**

**Academy of Natural Sciences**

**Institute of Radio Engineering and Electronics (Moscow)**

**Bonch-Bruевич University of Telecommunications (St. Petersburg)**

**Ioffe Physics-Technical Institute (St. Petersburg).**

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It gives me great pleasure and honor to greet the participants of the 9th International Vacuum Microelectronics Conference (IVMC'96) on behalf of the Russian Academy of Sciences and the Russian Popov Society. It is my special pleasure to greet the Conference also on behalf of the IEEE Russia Section and IEEE Electron Devices Society Russia Chapter which has been recently established in Russia.

There was a good idea of IEEE ED Society to convene this conference in Russia and in particular in Saint-Petersburg.

I consider this Conference as a part of arising interest of scientists and engineers of world vacuum microelectronics community to what is going on in the field in Russia and what social and market opportunities will appear there in the future.

The problems to be discussed during the conference sessions and roundtable discussions play an important and increasing role as they contribute much for widening and strengthening the relations and understanding as well as they serve information exchange and cooperation between countries and people.

It should be especially noted that this conference is the first one being held in Russia in cooperation and under the sponsorship of the IEEE Electron Devices Society as well as at the time when the IEEE ED Society Russia Chapter has been created.

The Conference owes much to the constant support and help of Dr. Henry F. Gray (USA) - Chairman, International Steering Committee, co-chairmen, National Organizing Committee Prof. George N. Fursey and Prof. Vladimir I. Makhov as well as to Dr. Dmitriy V. Glazanov, Secretary from Russia for their great efforts in preparing and convening the conference in Saint-Petersburg.

I am looking forward that this conference is just the first of many conferences and other technical events to be held in future in Russia in cooperation with the IEEE and ED society.

I wish the conference to be a success, creative fruitful work and pleasant visit to Saint-Petersburg for its participants. May we continue to work together and contribute to science, peace and understanding of mutual benefit!

Prof. Yuri Gulyaev,  
Chairman, IVMC'96 National Organizing Committee; President,  
Russian Popov Society;  
Member of the Presidium, Russian Academy of Sciences,  
Director, Institute of Radioengineering & Electronics, Russian  
Academy of Sciences;  
Chair, IEEE Russia Section

Dear Colleagues! Dear Guests!

We are glad to greet you here in St. Petersburg. We are happy that it is St. Petersburg that has been chosen to hold the 9th International Vacuum Microelectronics Conference. We will do our best to make your stay here and participation the Conference most productive.

St. Petersburg is a special city in this country. It was designed by Peter the Great as a gateway which would enable Russia to establish more effective political, cultural and trade relations with the West. It is situated at the crossroads of two great cultures -- Western and Eastern. St. Petersburg is a city in the creation of which many of great people of that time took part; not only great people of Russia, also eminent architects and artists of all the world. They are Pushkin and Rastrelly, Rossi and Falconet, Dostoevskii and Euler, Clodt and Voronikhin. It was here, in this city, that such prominent scientists as Vavilov, Pavlov and Bekhterev lived and worked, and also our contemporaries Fock, outstanding theoretical physicist and Lukirskii, who laid the basis to our national electronics, and many, many others. The city always remembers about creative deeds of those people. The city renders homage to everything created by them. Streets and squares were named after them. Quite recently one of the beautiful squares formed by the University building and those of the Library of the Academy of Sciences and the Optical Institute has been named after eminent human-rights activist academician A.D. Sakharov.

The city suffered from many hardships during the siege 1941-1944 in the World War II. The citizens of Leningrad-St. Petersburg did their utmost to save and preserve the greatest cultural values for the future generations. Thank to those people and to those who restored and reconstructed cultural heritage, that you will be able to see all the beauty of the city.

St. Petersburg is the birthplace of famous Russian physical schools: first, the Academy of Sciences created by Peter the Great, then St. Petersburg University, and, at last, a remarkable pleiad of outstanding scientists who got their start and grew up in the school of academician A.F. Ioffe at the Physics-Technical Institute. St. Petersburg State University and Polytechnics Institute (now called St. Petersburg Technical University) are the institutions that have always been raising specialists in the field of physics and technology. You will have a chance to be introduced to the system of finding capable young people and training them for their future scientific work, the system that starts with school-time. You will also have an opportunity to visit different laboratories in A.F. Ioffe Physics-Technical Institute, St. Petersburg State University, St. Petersburg University of Telecommunications and others research and educational institutions related to vacuum microelectronics.

You will have a chance to visit our theaters, museums, exhibitions, to go sightseeing in the city and of its beautiful suburbs. We hope that all this will help us in our work, will bring us closer together and will give us a better chance for cooperation.

We wish you good luck and success in the oncoming work!

On behalf of the citizens of St. Petersburg and the IVMC'96 Local Organizing Committee, Co-chairman of the IVMC'96 National Organizing Committee,  
Professor

*George N. Fursey*

Comment from the International Vacuum Microelectronics Conferences Steering Committee

As chairman of the International Steering Committee, I would like to take this opportunity to express my heartfelt thanks and appreciation to the general chairman of IVMC96, Academician Yuri V. Gulyaev, and co-chairmen Professors George N. Fursey and Vladimir I. Makhov. I congratulate them in a particularly strong manner because this year's conference is a very special one, being the first international conference of its kind in Russia. As we all know, it is no easy task to arrange and organize an international conference, particularly a conference which includes not only fundamental science but also applications and technology development. The international scientific community recognizes that Russia has great strengths in this field of vacuum microelectronics research; perhaps it is the strongest country in the world in this field. For that reason, the Electron Device Society (EDS) of the IEEE decided to sponsor IVMC96 in the same manner that it has sponsored conferences inside the US. This type of sponsorship by the EDS is the first of its kind in Russia. Furthermore, this year's EDS sponsorship exceeds all previous IVMC sponsorships in size and scope. Part of the reasoning is that this particular field of electronics is growing rapidly. But more importantly, the international community recognizes that much of the science and technology development resides inside Russian institutions. Indeed, major research in electron emission, notably field emission, is done in this country, and, in particular, in St. Petersburg. Furthermore, it is also recently been recognized that Russia has made great strides in low voltage phosphor research, perhaps the best in the world. Since the field of field emitter displays (FEDs) is part of vacuum microelectronics, and is the largest application of vacuum microelectronics at this time, it is indeed fitting that this conference be held in Russia. Vacuum physics and vacuum electronics is very strong in this country. And it has been our policy to hold IVMCs "where the action is". Governments both inside Russia and outside Russia also recognize the preeminence of Russian research and development in vacuum microelectronics, as have a number of industrial companies both inside and outside Russia. This acceptance of the excellence and strength of vacuum microelectronics research and development in Russia is measured by the amount and diversity of sponsorship and contribution support we have received from governments and companies throughout the world. The organizers of IVMC96 have certainly done an outstanding job in organizing and preparing for this year's conference, making it a most suitable forum for active research scientists.

Albeit that IVMC96 is expected to be the best of all IVMCs, it must be remembered that it follows a history of successful and noteworthy conferences: IVMC88 in Williamsburg, Virginia, USA; IVMC89 in Bath, England, UK; IVMC90 in Monterey, California, USA; IVMC91 in Nagahama, Japan; IVMC92 in Vienna, Austria; IVMC93 in Newport, Rhode Island, USA; IVMC94 in Grenoble, France; and IVMC95 in Portland, Oregon, USA. And next year IVMC97 will be in Kyongju, Korea, where I am assured that we will have a most unique and special experience.

Lastly, I would like to thank in a very special and sincere way, my thanks and appreciation to Dr. Dmitriy V. Glazanov, secretary/treasurer of IVMC96, whose untiring efforts and constant work made this conference a success. Dr. Glazanov has become a world expert in email, western cultures including their differences, master of administering details when the "going-gets-rough", a remarkable person who was observed working very late at night on IVMC96 issues, even at 4AM, for months. Many of us in the West do not understand these things. We on the Steering Committee thank you and congratulate you.

Henry F. Gray, Chairman  
International Steering Committee

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## Vacuum Microelectronics 1996: Where We Are and Where We are Going

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### Abstract

In 1948, Bardeen and Brattain published their historic paper titled "The Transistor, A Semiconductor Triode", ushering in a new era of electronics, a transition from vacuum devices to solid-state devices. Note the term "triode", a term and concept which dominated transistor papers for many years. The transition from vacuum devices to solid-state took a long time; the first devices were fragile, not reproducible, and they failed easily and frequently. Furthermore, the semiconducting material and processing technology had to be invented and developed. After much hard work and much funding, those first transistor ideas were superseded by a large variety of different structures, made from different semiconductor material systems. However, the solid-state industry blossomed only after the inventions of planar processing and the integrated circuit.

At about the same time that the transistor was developed, Kenneth Shoulders at MIT conceived of a transistor-size vacuum device which was totally electrostatic, had a non-linear current-voltage characteristic similar to the transistor, and was not too dissimilar to the first transistor concept in structure, i.e., the electron transport was unidirectional from cathode to anode. The concept was a miniature vacuum triode. One fundamental device difference between Shoulders' device and the transistor was that in Shoulders' device, the charge transport occurred in vacuum, whereas in the transistor the charge transport occurred in the solid. Unfortunately for Shoulders, research and development funding and excitement went to the development of the transistor, not his miniature vacuum device. Shoulders moved to SRI International where he put together a creative team which fabricated and demonstrated the first Thin-Film Field Emission Cathode (TF FEC) (1968) based on an ebeam evaporation scheme of Charles Spindt, who was assisted by other members of the group who developed the required microfabrication techniques. Because the TF FEC contained only two of the three electrodes required to make a vacuum transistor, development of the device was concentrated on making a thermionic cathode replacement for traveling wave tubes. Researchers at the Naval Research Laboratory believed that an electron collector could be integrated with the field emitter and extraction gate, all on the same surface of a silicon wafer, using standard silicon MOS microfabrication techniques and materials, thereby making a truly planar vacuum transistor. This first vacuum transistor (1986) promised radiation hard and temperature insensitive microelectronics, as well as high voltage tolerant integrated circuits. Furthermore, due to the lack of charge scattering from emitter to collector, high frequency power amplifiers were envisioned. Interest in the development of this first vacuum transistor for all three of these reasons was the beginning of Vacuum Microelectronics (1988).