Poster 1

April 29 (Monday) / 15:10 ~ 16:30 / Capri room

Cathodes

P1-5.1 / Thermionic Emission Mechanism of the Novel Y_2O_3-Gd_2O_3-HfO_2 Impregnated W base Direct-heated Cathode

Shikai Qi (Jiujiang University, China), Mingwei Hu (Xidian University, China), Wei Zeng (Jiujiang University, China)

In order to enhance the emission current, reduce the operating temperature and prolong the lifetime of the pure W filament cathode for application in high-ower (i.e., more than 10KW) continuous wave magnetron tube, a novel Y_2O_3-Gd_2O_3-HfO_2 impregnated W base direct-heated cathode (YGd-Hf-O impregnated cathode) has been developed. In this abstract, the thermionic emission mechanism of the Y-Gd-Hf-O impregnated cathode has been researched by SEM, EDS and AES.

P1-5.2 / Study on inhibition Of the M-Type Cathode edge emission in the high frequency vacuum electronic devices

Hui Wang (Beijing Vacuum Electronics Research Institute, China), Wensheng Shao (Beijing Vacuum Electronics Research Institute, China), Gaoyu Juan (Beijing Vacuum Electronics Research Institute, China), Pengyun Yang (Beijing Vacuum Electronics Research Institute, China), Ke Zhang (Beijing Vacuum Electronics Research Institute, China)

The ion beam film deposition technique has been introduced to inhibit the emission of the M-Type cathode edge in our research, by which the surface of the cathode is coated with a metal membrane, such as hafnium(Hf), zirconium(Zr) and tantalum (Ta). Below 900ºC, the effect of the inhibit membrane is all well, which the emission current density decreased to 0.3A/cm². With the best inhibitory of hafnium, it has been evidenced by XPS and XRD analysis that the inhibition mechanism of Hf film cathode, which was investigated by the interaction between barium and hafnium.

P1-5.3 / Dispenser M-type cathodes with alloy films made on the basis of osmium or rhenium for application in long life microwave devices

A.P. Makarov (JSC “RPC”Istok” named after Shokin, Russia), E.M. Zemchikhin (JSC “RPC”Istok” named after Shokin, Russia)

Results of investigation of emission properties, life time, elemental composition of the surface and change of these properties during the life of dispenser cathodes covered with films on basis of osmium and rhenium are presented. Dispenser cathodes covered with films (Re-Hf and Os-Hf)

can be used as effective sources of thermo and secondary electrons.

P1-5.4 / Pressed metal-alloy palladium-barium cathode

O.V. Polivnikova (FSUE "RPC "Istok", Fryazino, Moscow reg., Russia), I.P Li (OJSC "Pluton", Russia)

In filament-free magnetrons which are activated by electron emission from field-radiating cathodes its necessary level is provided by adsorption of active metal barium coming from the main palladium-barium cathode. The developed pressed palladium-barium cathode allows to change barium evaporation speed due to change of its porosity and hence barium Knudsen flow. It will lead to emission level control of field radiating cathodes.

P1-5.5 / HfC thermal field emitter: a brief study

Victor Katsap (NuFlare Technology America, Inc., USA)

In thermal field emission (TFE) technology, Schottky ZrO/W emitters reign supreme. We have tested a potential contender, HfC TFE.

P1-5.6 / A Study on the thermal emission properties of Y-Gd-Hf-O refractory rare earth oxides cathode

Xiqoqian Chen (Institute of Electronics, Chinese Academy of Sciences, China), Xiaoxia Wang (Institute of Electronics, Chinese Academy of Sciences, China), Zhaochuan Zhang (Institute of Electronics, Chinese Academy of Sciences, China), Yun Li (Institute of Electronics, Chinese Academy of Sciences, China), Qinglan Zhao (Institute of Electronics, Chinese Academy of Sciences, China), Qi Zhang (Institute of Electronics, Chinese Academy of Sciences, China)

Y_2O_3-Gd_2O_3-HfO_2 refractory rare earth oxide direct-heating cathode has the advantages of simple preparation process, high thermal emission current density, large secondary electron emission coefficient and long life, and has a good application potential in high-power continuous wave magnetrons. In order to further improve the thermal emission properties of the Y_2O_3-Gd_2O_3-HfO_2 cathode, the mitter active substance of the cathode was doped with different ratios of Sc_2O_3. The results show that the doping of Sc_2O_3 can effectively improve the thermal emission current density of Y_2O_3-Gd_2O_3-HfO_2 cathode. Among them, the thermal emission current density of Y_2O_3-Gd_2O_3-HfO_2 cathode doped with 10wt% Sc_2O_3 reached 5.3A/cm^2 at 1500°C, which was 35.5% higher than that of undoped.

P1-5.7 / Femtosecond laser direct writing fabricate single crystal LaB_6 FEA and their field emission

Zhang xin (Beijing University of Technology, China), Hongliang Liu (Beijing University of Technology, China), Zhang Wei (AVIC Beijing Research Institute of Aviation Engineering, China), Zhang Jiuxing (Beijing University of Technology / Hefei University of Technology, China)

In theory, single crystal LaB_6 as field emission materials have best comprehensive properties. At present, the single crystal LaB_6 field-emission tip arrays (FEA) is difficult to be effective produced using conventional micro machining method such as ion beam etching, electron beam lithography, chemical etching and mechanical micro machining due to its stable physicochemical properties, hard and brittleness properties, which limited the field emission application of single crystal LaB_6. The appearance of femtosecond (fs) laser technology and the application of stable and reliable commercial femtosecond laser equipment provide an effective tool for high quality processing of materials. Hence, it is very meaningful to reliability-accurate fabricate single crystal LaB_6 FEA by the femtosecond laser method and investigate their field emission. In this work, the femtosecond laser direct writing method been used to fabricate the single crystal LaB_6 FEA. The morphologies, structure phase as well as the field emission of the single crystal LaB_6 FEA are systematically studied. The nanostructures on the surface of tips with LaB_6 phase were formed, resulting in favor of improving field emission, particularly for samples with the nano-hill shaped bulges having the size of about 100nm. The produced single crystal LaB_6 FEA have uniform structure and a controllable curvature radius of about 0.5-3.0 μm. The FEA with a curvature radius of about 0.5 μm as field emitters have the best field emission performance, which the turn-on electric fields are as low as 2.2 with an emission current of 1.0 A/cm^2 at 8.0 V/μm and the emission current exhibits high stability. These indicating the processed LaB_6 FEA have a good prospect applied in vacuum microelectronic devices and the simple femtosecond laser direct writing method could lead to an approach for the development of electron sources.

P1-5.8 / Electron-Optical System with Planar-Arranged Coarse-Structured Field Emission Cathodes

Sergey Morev (JSC “RPE “Toriy”, Russia), Alexander Darmaev (JSC “RPE “Toriy”, Russia), Dmitry Komarov (JSC “RPE “Toriy”, Russia), Kirill Kuzmich (JSC “RPE “Toriy”, Russia), Eduard Muraviev (JSC “RPE “Toriy”, Russia), Sergey Maslennikov (National Research Nuclear University “MEPhI”, Russia), Victor Sablin (JSC “RPE “Toriy”, Russia)

The experimental study results of the coarse-structured field emission cathode cell with a tungsten emitter intended for millimeter range O-type device are presented. The propagation of an electron beam formed by a single-row nine-beam field emission cathode array in long rectangular (0.9 mm x 8.0 mm) beam channel is shown.

P1-5.9 / Measurement Method of the Distribution of Field Emission Current

Dmitry Ozol (Moscow Institute of Physics and Technology, Russia), Alexander Eliseevl (Moscow Institute of Physics and Technology, Russia), Maksim Garkushal (Moscow Institute of Physics and Technology, Russia), Anton Pavlenkol (Moscow Institute of Physics and Technology, Russia)

The density of field emission current is distributed over the anode in substantially nonhomogeneous way. A method that allows one to evaluate the degree of the nonhomogenuity and measure the current density using color variation cathode-ray-tube phosphors is proposed.

P1-5.10 / Simulation Study of Compact Carbon Nanotube Cold-cathode Oscillator

Xiaotao Xu (University of Electronic Science and Technology of China, China), Yifan Zu (University of Electronic Science and Technology of China, China), Xusong Yuan (University of Electronic Science and Technology of China, China), Qingyun Chen (University of Electronic Science and Technology of China, China), Bin Wang (University of Electronic Science and Technology of China, China), Hailong Li (University of Electronic Science and Technology of China, China), Yang Yan (University of Electronic Science and Technology of China, China)

A compact carbon nanotube cold-cathode oscillator operating at terahertz band is designed by PIC simulation software in this paper. The cathode part is integrated with the high frequency structure. The field emission beam of the cold cathode is modulated by the high frequency field in the high frequency structure directly. The simulation results show that a peak output power of 3.4W is obtained at 140GHz, and the emission current modulation depth is 7.7% when the surface electric field strength of the cathode is 12V/μm.

P1-5.11 / Semiconductor-Free Field-Emission Nanoelectronics: Application in Air-Channel Transistors

Shruti Nirantar (RMIT University, Australia), Taimur Ahmed (RMIT University, Australia), Guanghui Ren (RMIT University, Australia), Philipp Gutruf (University of Arizona, USA) Chenglong Xu (RMIT University, Australia), Madhu Bhaskaran (RMIT University, Australia), Sumeet Walia (RMIT University, Australia), Sharath Sriram (RMIT University, Australia)

We introduce a nano-scale, metal-based, field emission air channel transistor. Comparative analysis of tungsten, gold, and platinum based devices is presented. Devices are fabricated with electron beam lithography, achieving channel lengths less than 35 nm. With this small channel length, vacuum-like carrier transport is possible in air under room temperature and pressure. Source and drain electrodes have planar, symmetric, and tapered-sharp geometry. Due to this, devices operate in bi-direction with voltages <2 V and current in nA range. The presented work enables a technology where metal-based switchable nanoelectronics can be created on any dielectric surface with low energy requirements.

P1-5.12 / Study on Electron Beam Bunching in a Gigahertz Oscillating Electric-Field Direct-Driven Cold-Cathode Electron Gun

Yang Xing (Sun Yat-Sen University, China), Yu Zhang (Sun Yat-Sen University, China), Ningsheng Xu (Sun Yat-Sen University, China), Yanlin Ke (Sun Yat-Sen University, China), Baohong Li (Sun Yat-Sen University, China), Shaozhi Deng (Sun Yat-Sen University, China)

The electron beam of an oscillating electric-field direct-driven cold-cathode electron gun in resonant structure is studied. Such electron gun is capable of providing modulated electron beam and has potential for novel vacuum electronic devices applications. However, the problem of electron beam divergence in the electron gun needs to be solved. By designing the position of cold-cathode and improving the electric field distribution on the cold-cathode surface, the

divergence of the electron beam is reduced and the transmission ratio of the electron gun is effectively improved from 75.90% to 94.78%. Further, by applying an axial magnetic field, the transmission ratio is optimized to 97.73%. The method for electron beam bunching optimization is simply and effective, it could find applications in microwave and terahertz vacuum electronic devices.

P1-5.13 / Development of microfabricated scandate dispenser cathode and electron gun for terahertz vacuum electron devices

Seong Lee (Agency for Defense Development, Korea), Jinwoo Shin (Agency for Defense Development, Korea), Joonho So (Agency for Defense Development, Korea), Jung hyo Park (Agency for Defense Development, Korea), Changgu Kim (Agency for Defense Development, Korea)

Scandate dispenser cathode with hundreds of ampere per square centimeter has been developed using metal injection molding (MIM) technique for terahertz vacuum electron devices. We have investigated scandate thermionic cathode surface by scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) before surface treatment. And then, scandate cathode was fabricated with 1 mm diameter. The performance was verified by beam transmission test after assembling electron gun using microfabricated scandate cathode. The beam transmission rate was 99.8% for 0.5 mm radius drift tube with 0.8 T magnetic field condition.

P1-5.14 / Numerical Analysis of Inter-Electrode Capacitance of Vacuum Micro-Electronics Devices

S Manna (The University of Burdwan, India), A K Singh (CSIR-CEERI, India), R K Sharma (CSIR-CEERI, India), Ranjan Barik (CSIR-CEERI, India)

In this paper, calculation of inter-electrode capacitance per unit length of vacuum micro-electronics devices is presented using finite difference method (FDM). A comparison of the analytical values with the simulation data of the same structure is also presented in this paper. The analytical results closely match with simulation results.

P1-5.15 / Defect-enhanced field electron emission from WO_{3-x} nanowires

Zufang Lin (Sun Yat-sen University, China), Paibin Xie (Sun Yat-sen University, China), Jun Chen (Sun Yat-sen University, China)

Field emission properties of WO_{3-x} nanowires prepared on glass substrate were studied. Current up to 3 mA were achieved from an effective area of 0.25 cm^2, corresponding to a current density of 12 mA/cm^2. Field emission from individual WO_{3-x} nanowires was also studied in order to understand the high current emission mechanism. Based on the experimental results on field emission behavior of individual WO_{3-x} nanowires with different defect concentrations, it is proposed that the high current relates to the defect-induced transportation in the nanowire.

The results were supported by theoretical calculation using a model considering the defect-related electric transport and Joule heating in the field emission process. Our results are important for exploring a large area high brightness X-ray flat panel source.

P1-5.16 / Hydrothermally prepared reduced graphene oxide free standing film as high current field emitter

Dongpyo Hong (Seoul National University, Korea), Muhammad Mohsin Hossain (Seoul National University, Korea), Matlabjon Sattorov (Seoul-Teracom, Inc / Seoul National University, Korea), Seontae Kim (Seoul National University, Korea), Sun-Hong Min (Korea Institute of Radiological and Medical Sciences, Korea), Gun-Sik Park (Seoul National University, Korea)

Uniform, highly conductive, thin film field emitters are in immense need for future development of high power compact terahertz(THz) vacuum electronic devices(VED). Reduced graphene oxide(rGO) based free standing film as high current sheet beam cathode is fabricated by hydrothermal method. This hydrothermal method facilitates highly conductive, thin, compact film. We achieved to get few micrometers to sub-micrometer thick film which is much thinner than conventional vacuum filtered film resulting in higher field enhancement factor, current density, and current. This approach can successfully establish a fabrication method for uniform, thin high current field emitter for high power THz VEDs.

P1-5.17 / Planar Graphene Edge Field Emitter Design with Improved Emission Current

Jonathan L Shaw (U.S. Naval Research Laboratory, USA), John B Boos (KeyW Corporation, USA), Byoung Don Kong (POSTECH, Korea), J. Mittereder (U.S. Naval Research Lab, USA)

We demonstrate field emission from planar graphene edges fabricated using a new method. The device uses narrow cantilevered metal beams to support the graphene. To date we have measured emission currents over 10μA from edges less than 50μm long, three orders of magnitude improvement over previous results. Millikan-Lauritsen plots result in straight lines. The electron energy spectra demonstrate field emission but are sometimes broadened on the low energy side relative to standard field emission theory, suggesting the Fermi energy was shifted by up to several eV along the edge. The cause of the shift may be adsorbed fluorine atoms which reduce the electron density in graphene.

P1-5.18 / Field emission properties of polyacrylonitrile(PAN) carbon fibers of various processing temperatures

Htet Win Aung (Moscow Institute of Physics and Technology, Russia), E. P. Sheshin (Moscow Institute of Physics and Technology, Russia), Wai Zin Hlaing (Moscow Institute of Physics and Technology, Russia), Nyein Chan Kyaw (Moscow Institute of Physics and Technology, Russia)

All carbon materials used as auto electronic cathodes are nanostructured materials. Field emission of such materials occurs from micro beams having characteristic sizes from 0.1 to 100 nm. Polyacrylonitrile (PAN) carbon fiber consists of closely intertwined filamentous fibrils, the

length of which can reach 1 μm, diameter 1-5 nm.

P1-5.19 / Field emission properties thin foils based on carbon materials

Wai Zin Hlaing (Moscow Institute of Physics and Technology, Russia), Evgeny P. Sheshin (Moscow Institute of Physics and Technology, Russia), Htet Win Aung (Moscow Institute of Physics and Technology, Russia), Nyein Chan Kyaw (Moscow Institute of Physics and Technology, Russia)

All Carbon materials used as field cathodes belong to nanostructured materials. Field electron emission of such materials occurs from micro-protrusions having characteristic dimensions of 0.1-100 nm. Since carbon has a finite amount of compound (and all life on the planet Earth is based on this), all properties of carbon materials, including field emission materials, should be sought in their structure.