Symposium Applications and New Trends of Plasmatechnology – An Overview (SYPT)

jointly organized by
Short Time-scale Physics and Applied Laser Physics Division (K),
the Plasma Physics Division (P) and
the Deutsche Gesellschaft für Plasmatechnolgie (DGPT)

Klaus Frank
Physics Department, University of Erlangen
Erwin-Rommel-Straße 1
D-91058 Erlangen
k.frank@fau.de

Andreas Görtler
Peutinger Gymnasium Augsburg and
Justus-von-Liebig Gymnasium Neusäß
Landrat-Dr.-Frey-Straße 4
863565 Neusäß
agoertler@gmx.de

Generally in plasma technology gas discharges are widely used for plasma generation. Discharges are classified as dc discharges, ac discharges, RF, microwave, or pulsed discharges on the basis of the temporal behavior of the sustaining electric field. The spatial and temporal characteristics of the plasma depend to a large degree on the particular application for which the plasma will be used. The venue of the meeting offers an unique opportunity to remember to the submission of the first paper about a novel low-pressure gas discharge, called pseudospark. This paper was submitted to Zeitschrift für Physik A in October 1978. Over the last four decades the pseudospark spread from Erlangen world-wide with a variety of applications in the field of plasma technology.

The term "pseudospark" is the heading for this more general symposium on vacuum and gas discharges and their applications in accelerators, considering the phenomena of arc-electrode interaction, and novel applications in medicine. Therefore, this symposium circles back from the historic development of pseudospark to the current state of the art of pseudospark research and application. The first three talks present an overview on past and recent research activities on pseudospark in the United States, Russia, and South Korea. The next talk considers different applications of plasmas in accelerator facilities. Subsequently, three contributions highlight fundamental processes with the arc-electrode interaction in high-pressure lamps, in vacuum interrupters, and in gas-filled HVDC circuit breakers. The symposium closes with a talk about novel uses of non-thermal plasmas in medicine and related fields of activity.

Overview of Invited Talks and Sessions

(Lecture room M 00.910)

Invited Talks

SYPT 1.1	Thu	10:30–11:00	M 00.910	**Pseudospark Research in Southern California** — •Martin Gundersen
SYPT 1.2	Thu	11:00–11:30	M 00.910	**Features of a hollow-cathode discharge in pseudospark switches** — •Yuri Korolev
SYPT 1.3	Thu	11:30–12:00	M 00.910	**Overview of R&D Activities on Vacuum and Gas Discharges and Their Applications in South Korea** — •Sang Hoon Nam
SYPT 1.4	Thu	12:00–12:30	M 00.910	**Plasma Stripper, Plasma Window, Plasma Gun as Applications of Discharge Plasmas** — •Joachim Jacoby
SYPT 2.1	Thu	14:00–14:30	M 00.910	**Plasmaphysical Basics of Vacuum Switching Devices for High Currents and Voltages** — •Norbert Wenzel
SYPT 2.2	Thu	14:30–15:00	M 00.910	**Discharge inception and breakdown in weakly and strongly electronegative gas in HV switchgear applications** — •Martin Seeger
SYPT 2.3	Thu	15:00–15:30	M 00.910	**Plasma Technological Research for Electrical Engineering and Medicine** — •Dirk Uhrlandt
SYPT 2.4	Thu	15:30–16:00	M 00.910	**Progress in Understanding Arc-Electrode Interaction** — •Jürgen Mentel

Sessions

SYPT 1.1–1.4	Thu	10:30–12:30	M 00.910	**Application and New Trends of Plasmatechnology - Part I**
SYPT 2.1–2.4	Thu	14:00–16:00	M 00.910	**Application and New Trends of Plasmatechnology - Part II**

SYPT 1: Application and New Trends of Plasmatechnology - Part I

Time: Thursday 10:30–12:30 Location: M 00.910

Invited Talk SYPT 1.1 Thu 10:30 M 00.910
Pseudospark Research in Southern California — •Martin Gundersen — Dep. of Physics, and Materials Science Seaver Science Center 421, MC 0483 University of Southern California Los Angeles CA 90089-0483

A historical account of pseudospark research both at the University of Southern California (USC), and in collaboration with U. Erlangen, will be presented. The remarkable properties of pseudosparks, including the super emissive cathode, will be reviewed. Comparison of pseudosparks with traditional thyratrons, which have analogous hold off voltage design and properties, and similar plasma physics for their conductive phase, will be briefly reviewed. The distinction in cathodes will be discussed. More recent work at USC in the development of mini-Back-Lighted Thyratron (BLT switches), which have high voltage hold off advantages and are very compact, will be presented. Areas for further research will be discussed, including the mini-BLTs, cathode issues, and other applications.

Invited Talk SYPT 1.2 Thu 11:00 M 00.910
Features of a hollow-cathode discharge in pseudospark switches — •Yuri Korolev — Institute of High Current Electronics, Siberian Branch, Russian Academy of Sciences (IHCE SB RAS) 2/3 Akademichesky Avenue Tomsk 634055

This paper presents an interpretation of the regimes of the hollow-cathode discharge sustaining in pseudospark switches. As applied to the main gap of the pseudospark switch, the discharge burns at a high-current density in the regimes of dense and superdense glow. In the trigger unit of the switch, we deal with a low-current density discharge with a hollow cathode. For both regimes, the discharge is treated as a self-organizing system that is able to rearrange itself to provide the current requested by external electric circuit. The principal discharge regions in the glow stages are the hollow-cathode plasma, the positive column plasma, and the double electric layer that separates these plasma regions. A model that allows some quantitative estimates when applied to the hollow-cathode plasma is developed. In this model, a generalized secondary emission coefficient that considers an external emission current is introduced. The abrupt transition from dense glow stage to superdense glow stage occurs because of microexplosions at the cathode surface and appearing the metal vapor plasma. In terms of the model, it becomes possible to interpret the main discharge phenomena in a wide range of current density.

Invited Talk SYPT 1.3 Thu 11:30 M 00.910
Overview of R&D Activities on Vacuum and Gas Discharges and Their Applications in South Korea — •Sang Hoon Nam — Pohang Accelerator Laboratory 80 Jigokro 127 Beon-gil, Namgu, Pohang, Gyeongbuk 37673, South Korea

The Pohang Accelerator Laboratory (PAL) is operating the Pohang light source II (PLS-II) and the PAL-XFEL. The PLS-II is a 3rd generation synchrotron light source, which was upgraded from the 15 year-old PLS in 2011. It is consisted of a 3 GeV linac and a 3GeV storage ring (SR). The PAL XFEL is a facility to produce 0.1 nm hard x-ray free electron laser with tens of femto-second pulse-width by using a 10 GeV electron linear accelerator. These facilities use many discharge devices, such as electron guns, thyratrons, klystrons, etc. Thus there have been various vacuum and gas discharge related R&D activities in the PAL; such as pseudospark switches, spark gap switches, triggered vacuum switches, thyratron switch auto-ranging system, pseudospark electron beam source, micro-hollow cathode discharge UV source, related pulse power circuits, etc. Historical and current activities on vacuum and gas discharges and their application in the PAL will be emphasized. In addition, related R&D activities in other institutions in South Korea will also be presented and discussed.

Invited Talk SYPT 1.4 Thu 12:00 M 00.910
Plasma Stripper, Plasma Window, Plasma Gun as Applications of Discharge Plasmas — •Joachim Jacoby — Institut für Angewandte Physik Goethe-Universität Frankfurt Max-von-Laue-Str. 1 60438 Frankfurt am Main

High current, high voltage discharges provide the opportunity to produce a variety of plasmas. We are using e.g. discharges powered from a capacitor bank for our plasma gun to initiate a plasma in a coaxial electrode system near the Paschen-minimum of a gas. By the jxB-forces of this discharge a He-plasma can be accelerated to velocities up to 70 km/s. By directing these accelerated plasma clouds into a glass cone a compression from initial electron densities of 1015 cm-3 to about 1018 cm-3 is achieved. A coil discharge is used to initiate a hydrogen plasma in a glass vessel. The discharge is caused by the inductive coupling of the coil to the gas in the vessel. At these conditions hydrogen may be fully ionized, which is favorable for beam-plasma interaction experiments, because at full ionization the recombination of electrons into projectile particles is reduces and a high beam charge state may be produced. Theoretical and experimental results for these interaction experiments are presented. The possible application of this discharge as a plasma stripper is discussed. A plasma window is an arc discharge inside a small electrode system. This discharge plasma is used to enhance the pressure difference between the cathode and the anode of the discharge. First results demonstrate the expected pressure difference caused by the discharge. Together with a moderate pumping a pressure reduction of about a factor 100 could be demonstrated yet.

SYPT 2: Application and New Trends of Plasmatechnology - Part II

Time: Thursday 14:00–16:00 Location: M 00.910

Invited Talk SYPT 2.1 Thu 14:00 M 00.910
Plasmaphysical Basics of Vacuum Switching Devices for High Currents and Voltages — •Norbert Wenzel — Siemens AG, Corporate Technology Research In Energy and Electronics Switching and Power Grid, Günther-Scharowsky-Str. 1 91058 Erlangen

The technology of vacuum arc plasmas is being applied successfully to the development of high-current and high-voltage switching devices. Advances in the design of vacuum interrupters have been accompanied by a deeper understanding of the physical processes in the arc column and in the arc attachment zone on the cathode that comprises the cathode spots feeding the arc with metal vapor. This contribution starts with an introduction to the spatiotemporal characteristics of a vacuum arc during short-circuit current breaking. It describes methods to control the arc by magnetic fields forcing the arc to burn in a diffuse or a rotating constricted mode in order to distribute the energetic stress of the arc homogeneously over the contact surface. It reports on experiments with high-speed video cameras and fast magnetic probes. And it presents a physical model of the plasma together with numerical simulation results. The combination of experimental and theoretical studies delivers quantitative key parameters of the arc under practical operation conditions and thus allows a purposeful improvement of the performance of industrial high-power circuit breakers. The contribution concludes with challenging switching applications in vacuum: a generator circuit breaker ($>$ 70kA) and a large-gap interrupter operated at high voltages ($>$ 72kV).

Invited Talk SYPT 2.2 Thu 14:30 M 00.910
Discharge inception and breakdown in weakly and strongly electronegative gas in HV switchgear applications — •Martin Seeger — Senior principal scientist ABB Schweiz AG RD-P1 Segelhofstrasse 1K 5405, Baden-Dättwil, Aargau, SWITZERLAND

The control of gaseous insulation capability in HV switchgear and insulation applications is important for reliable operation of HV transmission and distribution systems. This is not only important for gaseous insulation at ambient temperatures (e.g. 300 K) but also for the insulation at elevated temperatures as they occur for example in HV circuit breakers (e.g. up to 3000 K) and switches after switching operations. Typically HV switchgear and insulation systems are operated at pressures in the range of 100 kPa to 1 MPa, which defines the main pressure range of interest. The present paper will addresses the most important physical processes, like streamer and leader transition for discharge inception and breakdown on the example of weakly and strongly electronegative gases, like CO2 and SF6, respectively. An overview of experimental investigations and simple predictive models will be given.

Invited Talk SYPT 2.3 Thu 15:00 M 00.910

Plasma Technological Research for Electrical Engineering and Medicine — •Dirk Uhrlandt — INP Greifswald Felix-Hausdorff-Str. 2 17489 Greifswald

The Leibniz Institute for Plasma Research and Technology (INP) in Greifswald carries out application oriented and fundamental research in a broad area from materials and technologies for renewable energy and resource-efficiency up to applications in medicine and hygiene. The potential of current research will be illustrated by means of two examples: The deeper understanding of arcs and other discharges in power distribution systems supports new solution approaches for the challenges of the German Energiewende. Use of environmentally friendly materials and energy efficient solutions for the mobility sector and the long-distance power transfer are in the focus. Recent developments in the technology of cold atmospheric pressure plasma sources enable a variety of new applications in life science e.g. therapeutic treatment of chronic wounds in human and veterinary medicine. This becomes possible by the strongly interdisciplinary research from the detailed diagnostics of plasma sources, the explanation of the plasma-chemical, biochemical and cell-biological mechanisms up to the responsible clinical trials. The strategy to carry out interdisciplinary and transdisciplinary research under one roof has led to meanwhile four spin off companies in the fields of diagnostics and plasma medicine and surface modification.

Invited Talk SYPT 2.4 Thu 15:30 M 00.910

Progress in Understanding Arc-Electrode Interaction — •Jürgen Mentel — Ruhr-University Bochum, Electrical Engineering and Plasma Technology, 44780 Bochum, Germany

Within the last years a model of a microscopically thin boundary layer covering the cathode surface was developed managing the current transfer between arc plasma and cathode. An extremely high local electrical power input into the layer effects that the local power- and current-transfer from the arc plasma to the cathode surface are only determined by the local electrode surface temperature and the global cathode fall so that the solution of the cathodic power balance is decoupled from the bulk plasma. For a given arc current generally several solutions are found: always a diffuse mode and mostly several spot modes of arc attachment. The properties of the diffuse mode and of low voltage spot mode are confirmed by measurements at tungsten electrodes. The arc attachment at anodes is determined by the mass flow in front of it and on the anode temperature. In front of cold anodes an electric field reversal and arc constriction occurs, which may need being stabilized by a mass flow. In front of hot, electron emitting anodes the field reversal disappears and the arc attachment becomes diffuse and stable.