Panel Discussion II
"Is there anything fundamentally new in our field?"

Schedule:

1. Stage is set by prepared statements of Panelist
2. Open discussion
3. If we have time: Discuss ISDEIV publications
4. Closing, perhaps some Action Recommendations

Panelists:

Jia Shenli, China

Alexander Batrakov, Russia

Raymond Boxman, Israel

Hans Schellekens, France

Osamu Yamamoto, Japan

Andre Anders, USA

Panel Discussion II
"Is there anything fundamentally new in our field?"

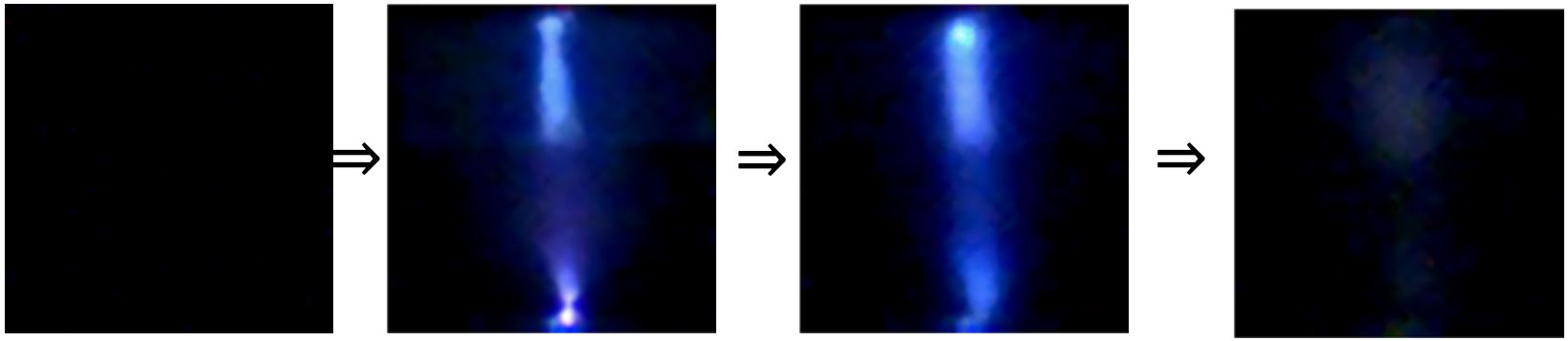
(O. Yamamoto)
Sub-field of expertise: **Charging and Flashover Mechanisms**

The greatest progress I have seen in my professional live:

/From the engineering point of view/

1. Charging mechanism and its formulation relying on SEEA (in ***1963!***)
2. Formulation of flashover voltage taking SEEA charge accumulation and desorption of gas molecules into account (in ***1982!***)

(SEEA ; Secondary Electron Emission Avalanche)

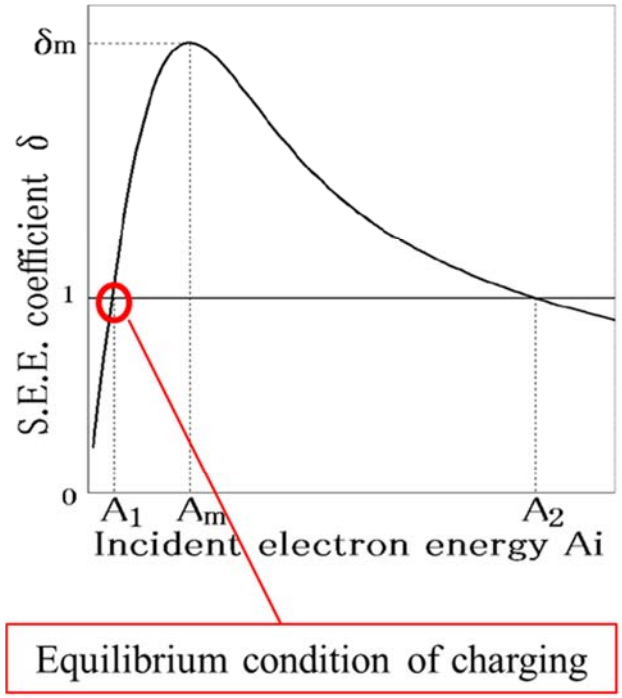


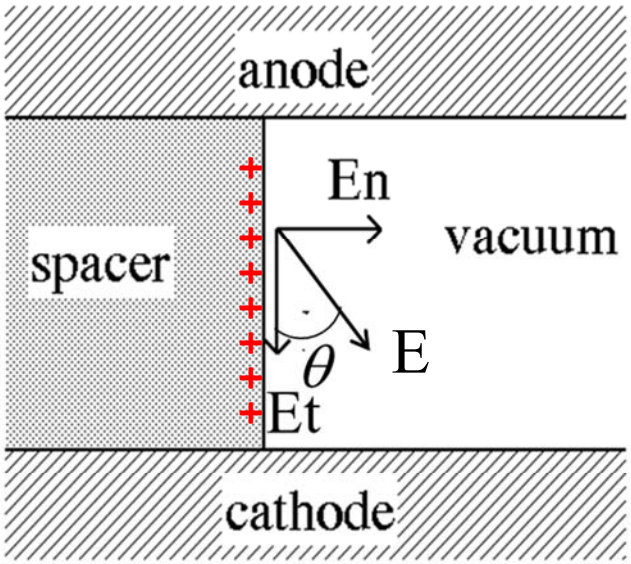
t = -3 μs t = 0 μs t = 3 μs t = 6 μs

<High speed video camera, FASTCAM SA1.1, Photron. @360,000 Frame/second>

Panel Discussion II
"Is there anything fundamentally new in our field?"

(O. Yamamoto)
Sub-field of expertise: **Charging and Flashover Mechanisms**





@ equilibrium state

$$\begin{cases} E_t : E_n = \sqrt{k} : 1 \\ k = \frac{1}{2}\left(\frac{A_1}{A_s} - 1\right) \end{cases} \quad (1)$$

<H. Boersch et. al (1963)>

<A_1; e-energy when the yield equal to unity>
<A_s; Initial energy of secondary electrons.>

By using (1) as a boundary condition, numerical calculation of charge due to SEEA is available. .

Panel Discussion II
"Is there anything fundamentally new in our field?"

(O. Yamamoto)
Sub-field of expertise: : **Charging and Flashover Mechanisms**

The greatest lack of progress / unmet need in my subfield:

$$\begin{cases} E_t : E_n = \sqrt{k} : 1 \\ k = \dfrac{1}{2}\left(\dfrac{A_1}{A_s} - 1\right) \end{cases} \qquad (1)$$

<H. Boersch et. Al (1963)>

The problems are:

A_1; Difficult to obtain reliable data. $A_1 \leq 100$ eV
A_s; Should be taken as its mean value?

Furthermore:

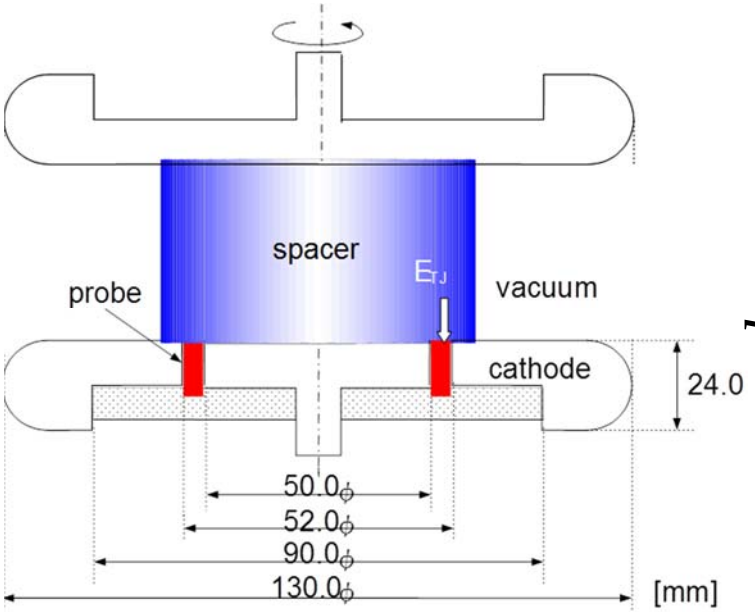
A_1 and A_s depend on the material of insulator, its surface condition like roughness etc.

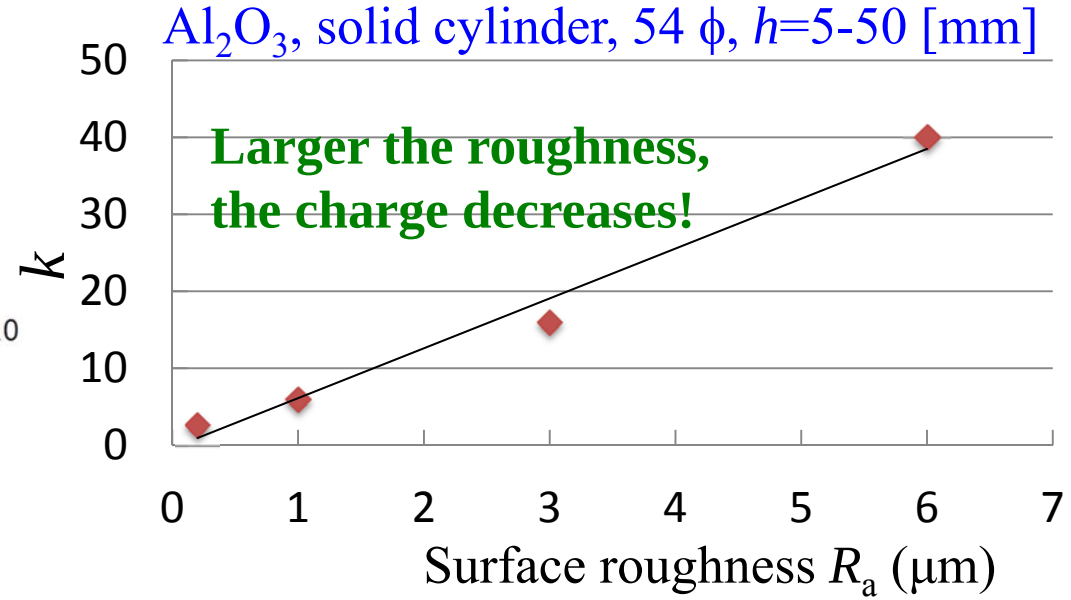
Panel Discussion II
"Is there anything fundamentally new in our field?"

(O. Yamamoto)
Sub-field of expertise: : **Charging and Flashover Mechanisms**

Was there any fundamental progress in the last 5 years?

- We have succeeded in estimating k, instead of A_1 and A_s.
  The estimation method includes probe measurement and calculation.





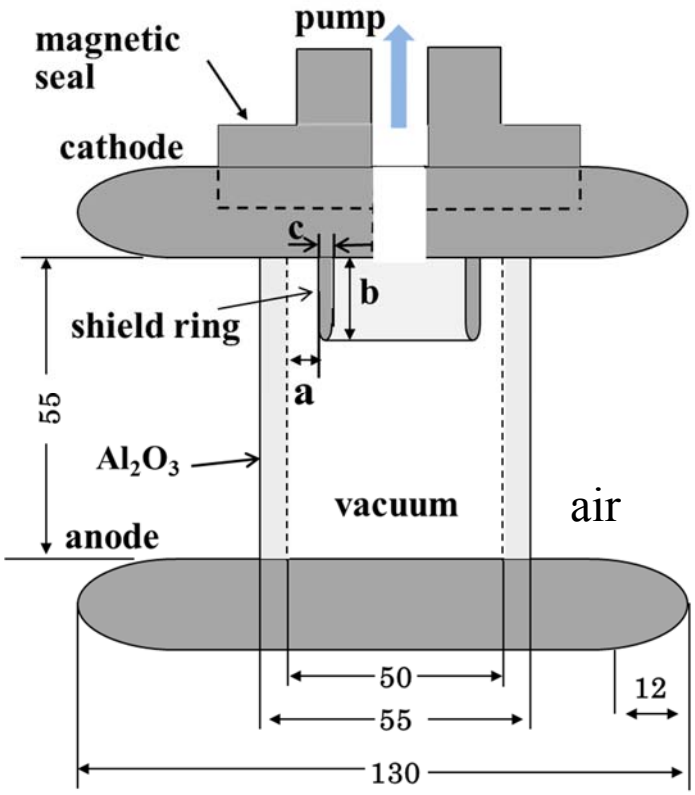
<O. Yamamoto et al (2012) >

Panel Discussion II
"Is there anything fundamentally new in our field?"

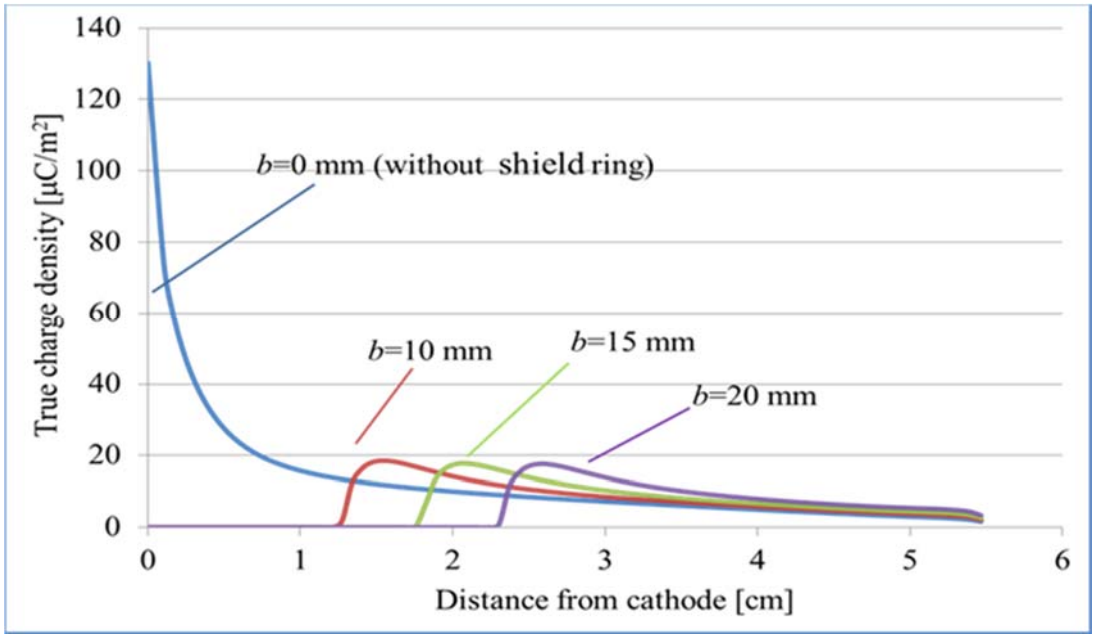
(O. Yamamoto)
Sub-field of expertise: **Charging and Flashover Mechanisms**

The impacts are:

1. We can calculate the SEEA charge distributions for various insulator/electrodes configurations.



Hollow cylinder, Al_2O_3 , R_a=0.2 μm (mirror finish)



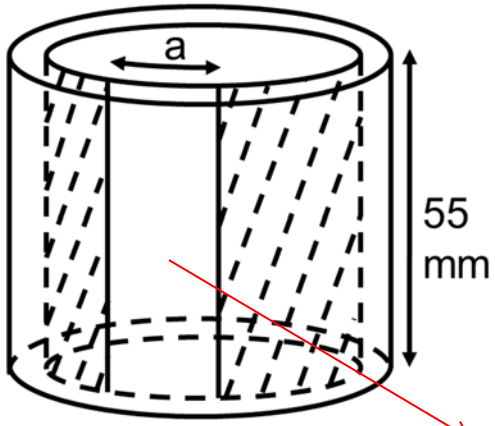
<See Vol.1 pp.141-144, in this Symposium>

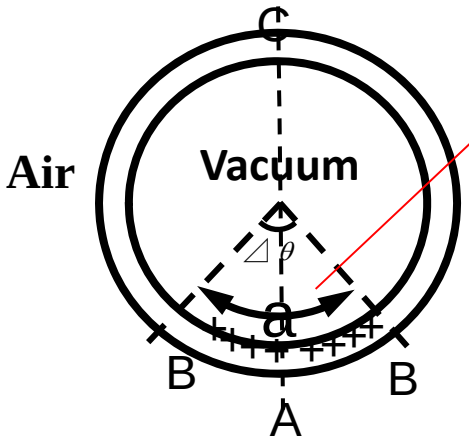
Panel Discussion II
"Is there anything fundamentally new in our field?"

(O. Yamamoto)
Sub-field of expertise: **Charging and Flashover Mechanisms**

The impacts are:

2. Three dimensional calculation is also available, if necessary.

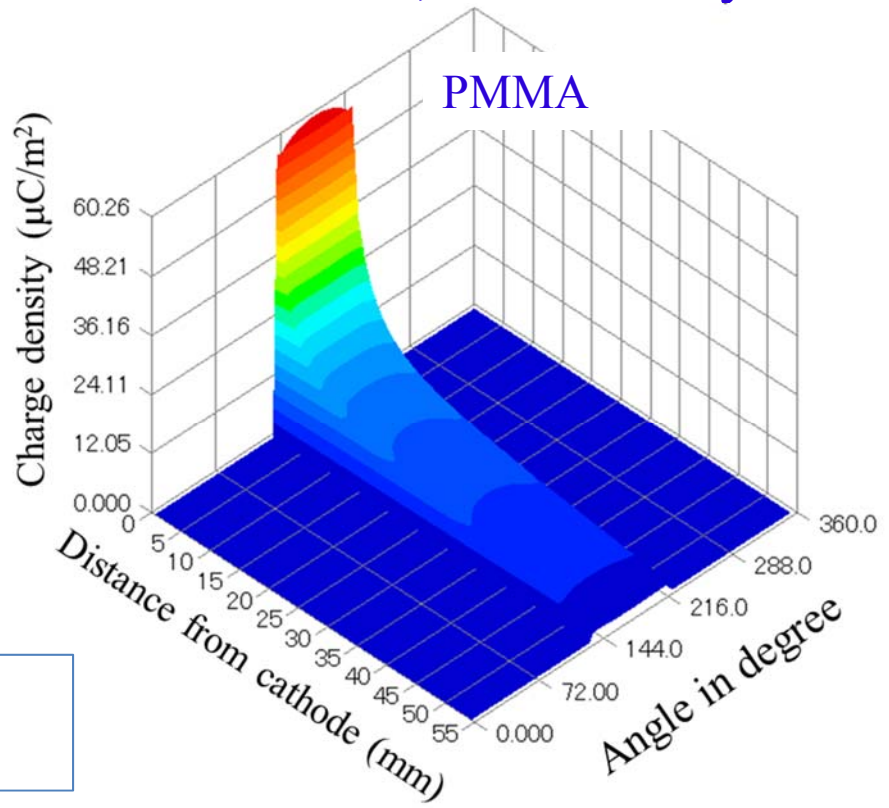




Charge acquiring area

Boundary conditions;
------ Eq. (1)

the other surfaces --- div *D*=0



<O. Yamamoto et al (2011)>

Panel Discussion II
"Is there anything fundamentally new in our field?"

(O. Yamamoto)
Sub-field of expertise: **Charging and Flashover Mechanisms**

What I think we have or should have posted on Wikipedia:

It seems to be a good question, but ? ? ?

Explanation of flashover phenomena, *as simple as possible*, could be appropriate.

Panel Discussion II
"Is there anything fundamentally new in our field?"

(O. Yamamoto)
Sub-field of expertise: **Charging and Flashover Mechanisms**

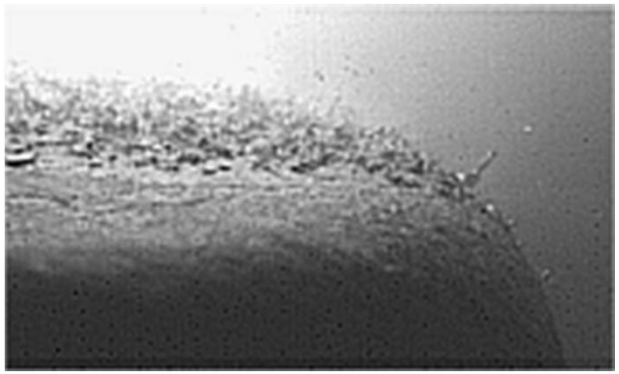
Thank you for your attention!

Panel Discussion II
"Is there anything fundamentally new in our field?"

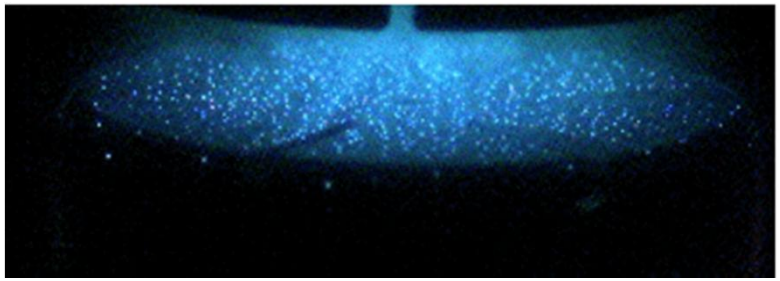
(Shenli Jia)
Sub-field of expertise: Vacuum arc & vacuum switch

The greatest progress I have seen in my professional live (Since 1990~)

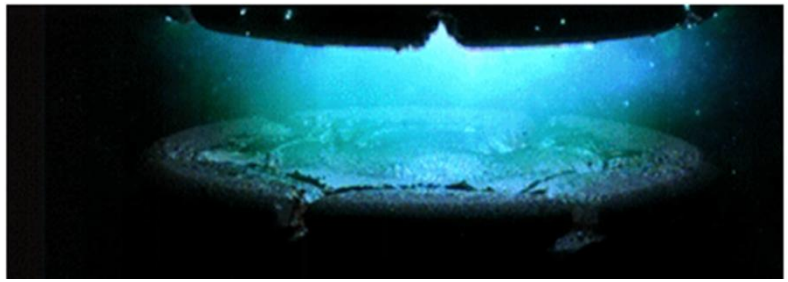
- Digital high-speed photographing technique of vacuum arc
  - Particularly, for electrode phenomena, i.e., cathode spots, anode activity.
  - Much convenient for experimental procedure, record, storage, and quantitatively analysis.



protrusion and droplets formation in the interaction region between the columnar arc and the cathode surface (Dr. W. Hartmann et. al., 2008)



Cathode spots in high-current vacuum arc

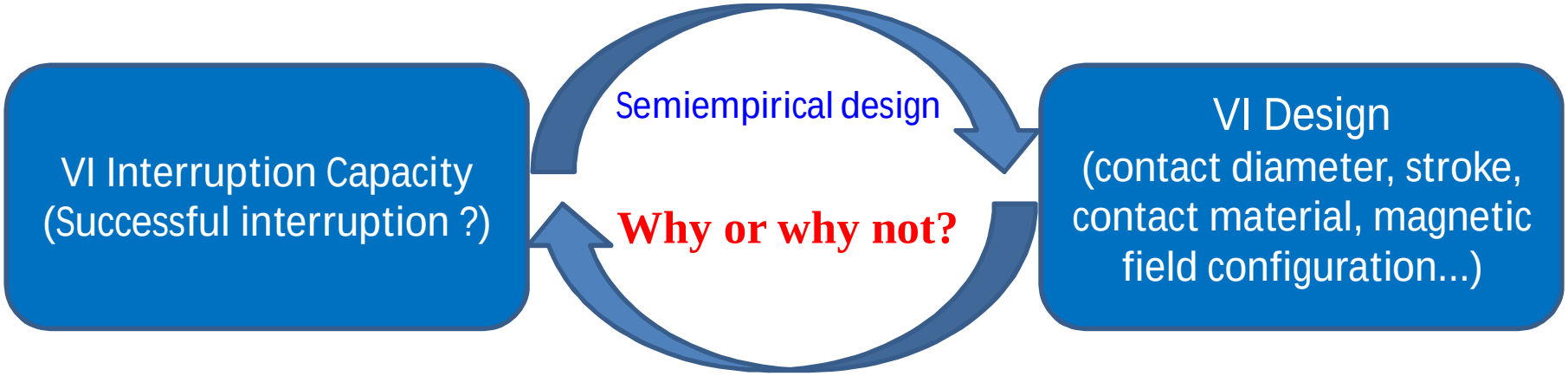


Anode activity in high-current vacuum arc

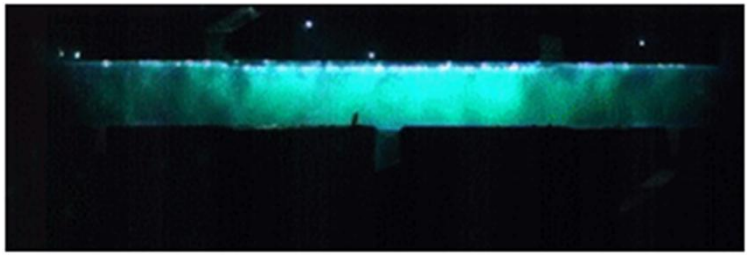
Panel Discussion II
"Is there anything fundamentally new in our field?"

(Shenli Jia)
Sub-field of expertise: Vacuum arc & vacuum switch

The greatest lack of progress / unmet need in my subfield



For a given VI, the exact arcing process can not be foreseen theoretically at present, such as: evolution of arc appearance, cathode spots distribution, electrode erosion, etc.



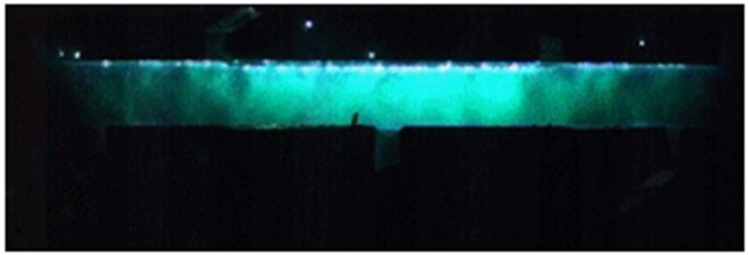
Panel Discussion II
"Is there anything fundamentally new in our field?"

(Shenli Jia)
Sub-field of expertise: Vacuum arc & vacuum switch

Was there any fundamental progress in the last 5 years?

We need a comprehensive model of high-current vacuum arc.

Transient 3D model



Arc column model with ideal/preset cathode spots distribution

Arc column

Arc column model coupled with anode activity

Cathode spots motion & distribution

?

Anode activity

Single/multi cathode spots model

Transient thermal model

Panel Discussion II
"Is there anything fundamentally new in our field?"

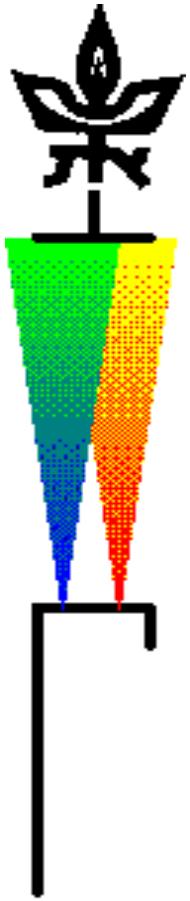
(Shenli Jia)
Sub-field of expertise: Vacuum arc & vacuum switch

What I think we have or should have posted on Wikipedia:

Absent items on Wikipedia in my sub-field of expertise:

- Cathode spot
- Anode spot
- Axial magnetic field (AMF)
- Radial/Tangential magnetic field (RMF/TMF)

Panel Discussion II
"Is there anything fundamentally new in our field?"



Ray Boxman

Tel Aviv University

Vacuum arc physics, deposition of thin films and coating

The greatest progress I have seen in my professional life:

Fundamental:

"quantitative" modeling and experimental characterization of the vacuum arc plasma.

Models of the cathode spot

Increasingly inclusive plasma models (e.g. 3D) recently

In situ observations into cathode spot (Jüttner, Anders)

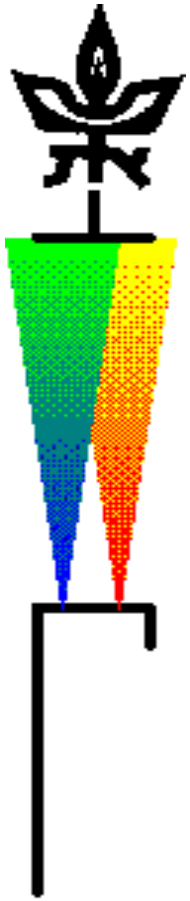
Technological

~ universal adoption of VI's for medium voltage

Vacuum (cathodic) arc deposition of hard coatings on cutting tools

Panel Discussion II
"Is there anything fundamentally new in our field?"

Boxman: plasma physics and thin film deposition



The greatest lack of progress / unmet need in my subfield:

Fundamentals:

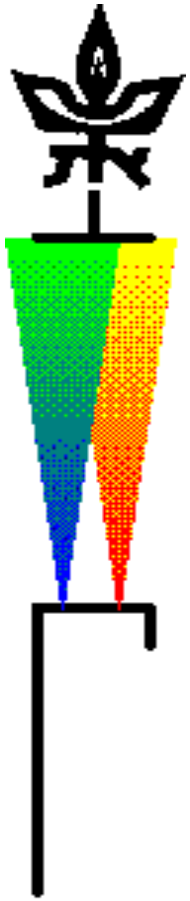
In situ diagnostics of cathode spots for long life (ms-s-minutes) arcs

Technology

Industrial adoption of filtered vacuum deposition in electronics and optics

Panel Discussion II
"Is there anything fundamentally new in our field?"

Boxman: plasma physics and thin film deposition



Was there any fundamental progress in the last 5 years?

Incremental progress – nothing world changing

intensive use of increased computing power in modeling

Here and there fresh approaches (e.g. Djurabekova at this symposium)

If no: why not? What is the barrier?

Biggest challenge: experimental characterization of the cathode spot

Fundamentally hard: ns, nm, etc.

But: big recent advances in electronics, optics

near-field optics

digital photography

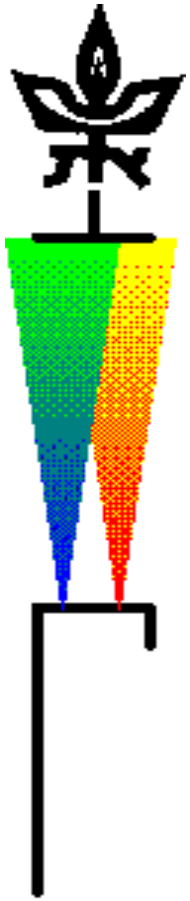
GHz processing

Need someone to put above together for time & space resolved diagnostics of cathode spots

especially in long duration arcs

Panel Discussion II
"Is there anything fundamentally new in our field?"

Boxman: plasma physics and thin film deposition



What I think we have or should have posted on Wikipedia:

Existing articles on vacuum arcs and cathodic arc deposition need revision and expansion

Need articles on almost all aspects, e.g. cathode spots, anode spots, vacuum breakdown, VI's, etc.

PISC should form an action committee!

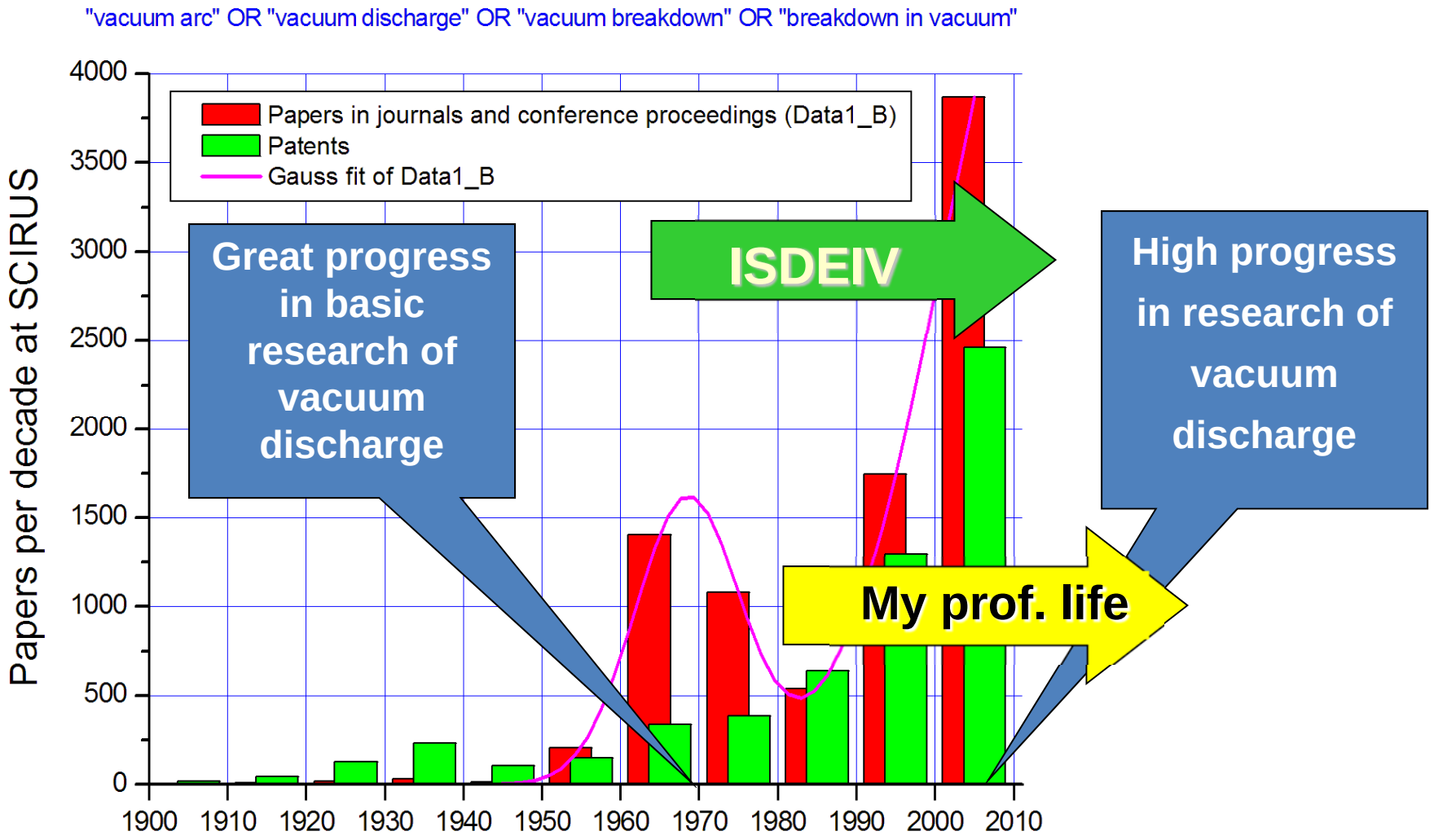
Panel Discussion II

“Is there anything fundamentally new in our field?”

Alexander Batrakov, Institute of High Current Electronics SB RAS, Tomsk, Russia

Sub-field of expertise: electrical insulation in vacuum, vacuum arc diagnostics

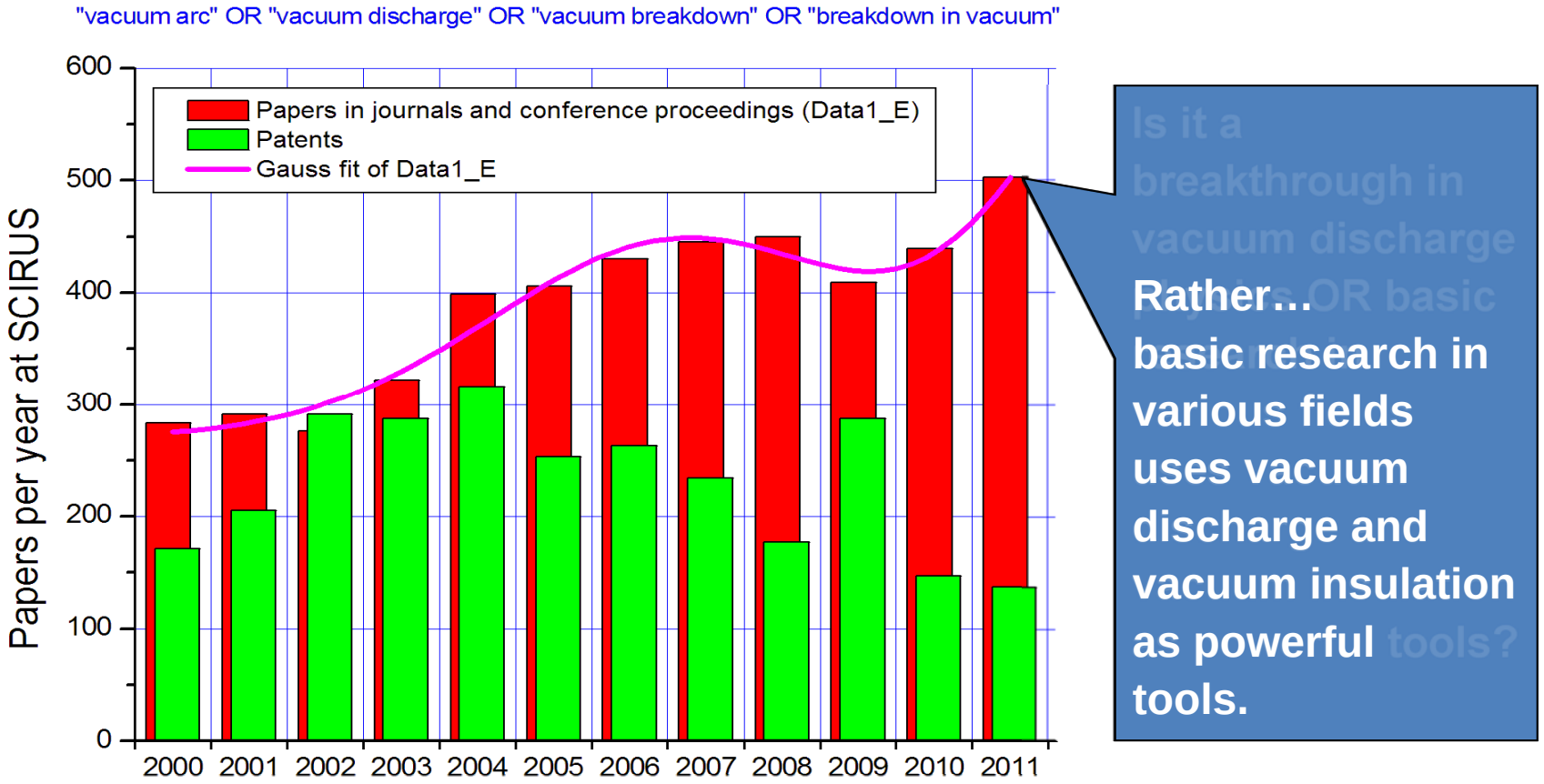
The greatest progress I have seen in my professional life:



Panel Discussion II
"Is there anything fundamentally new in our field?"

Alexander Batrakov, Institute of High Current Electronics SB RAS, Tomsk, Russia

Sub-field of expertise: electrical insulation in vacuum, vacuum arc diagnostics



There is no lack of progress in vacuum discharge physics. However, the progress is not so great. There is strong saturation in basic research activity, caused by lack of funds for most advanced experimental technique.

Panel Discussion II
"Is there anything fundamentally new in our field?"

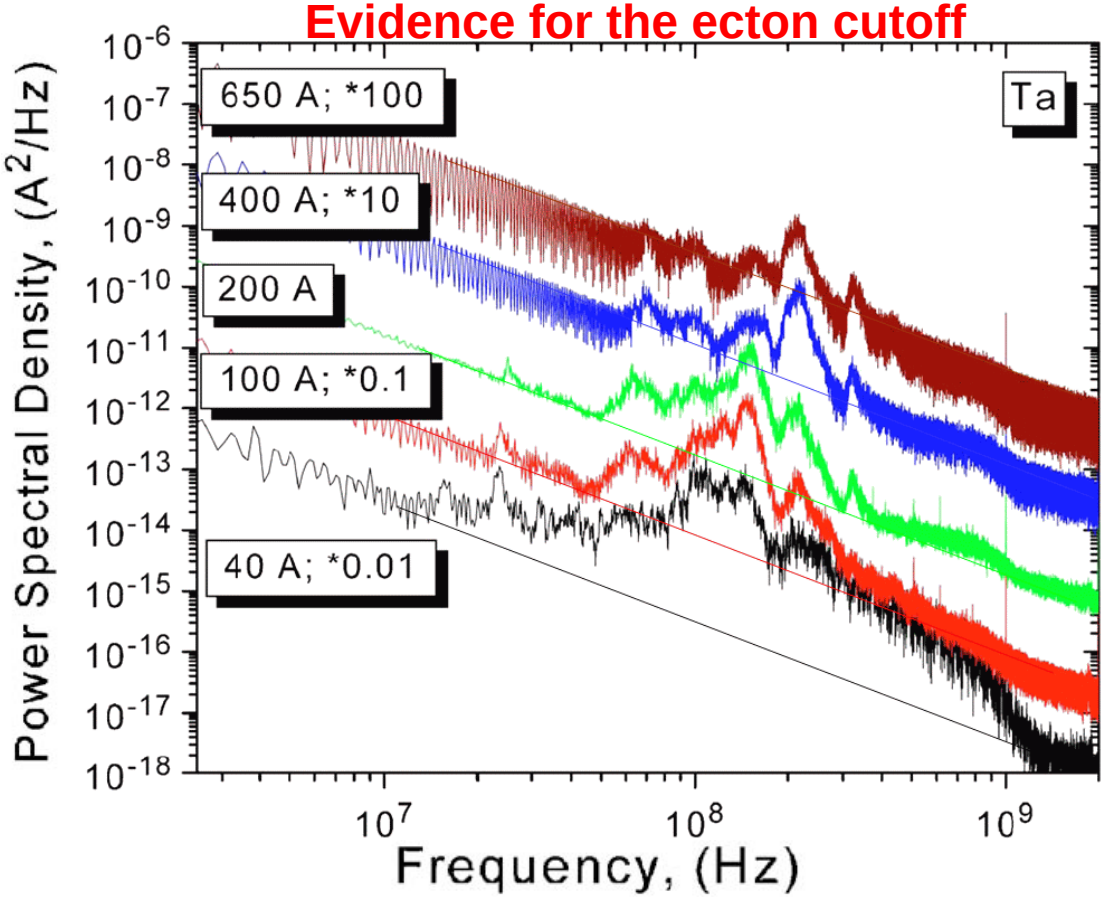
Alexander Batrakov, Institute of High Current Electronics SB RAS, Tomsk, Russia

Sub-field of expertise: electrical insulation in vacuum, vacuum arc diagnostics

Was there any fundamental progress in the last years? **YES.**

Some IHCE-related examples:

Evidence for the ecton cutoff



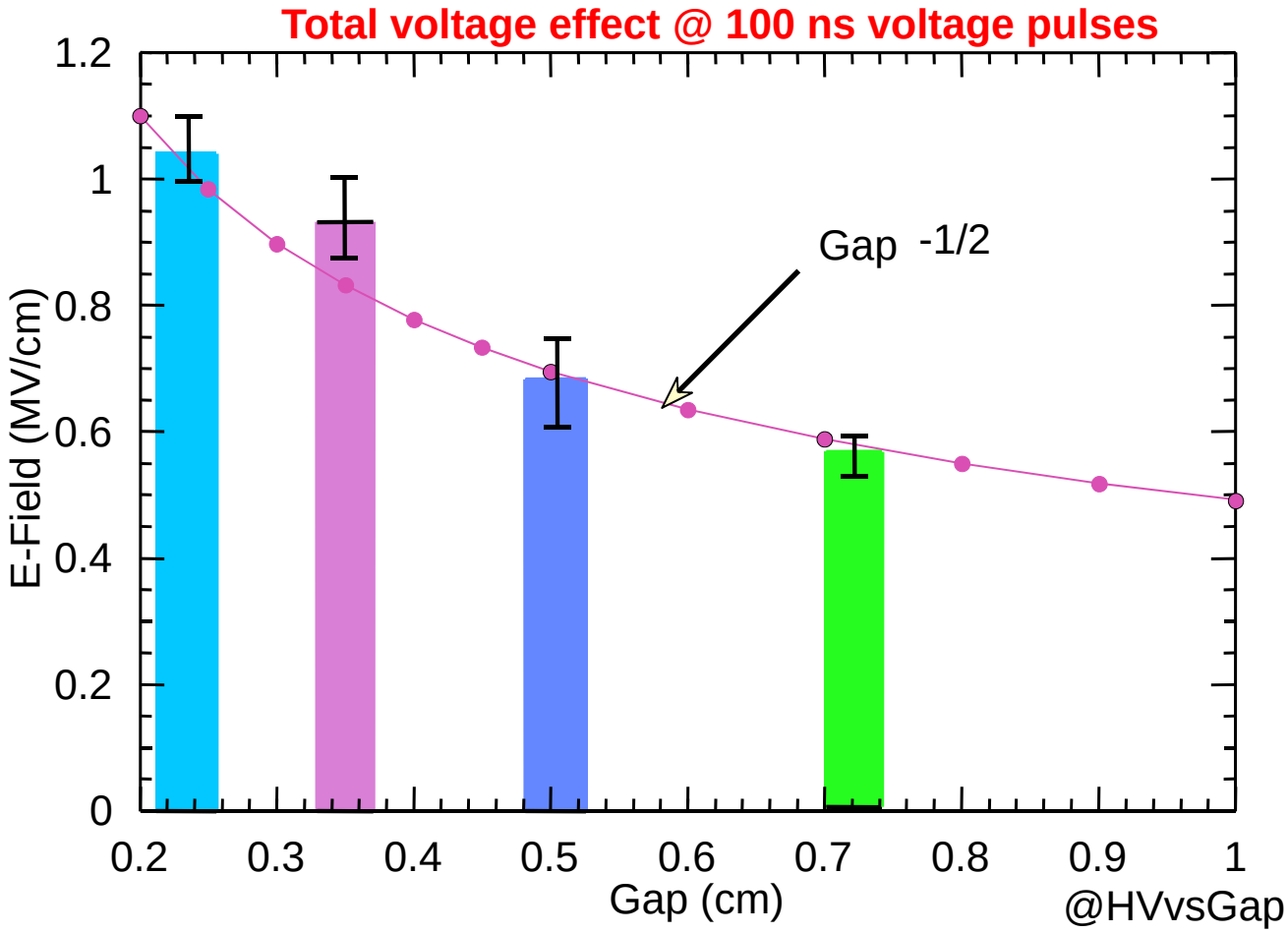
LBL – IHCE

A. Anders, E. Oks, and G. Yushkov, 2006

Panel Discussion II
"Is there anything fundamentally new in our field?"

Alexander Batrakov, Institute of High Current Electronics SB RAS, Tomsk, Russia

Sub-field of expertise: electrical insulation in vacuum, vacuum arc diagnostics



SNL – IHCE

D.J. Johnson, M.E. Savage, R.A. Sharpe, A.V. Batrakov, and D.I. Proskurovsky, 2006

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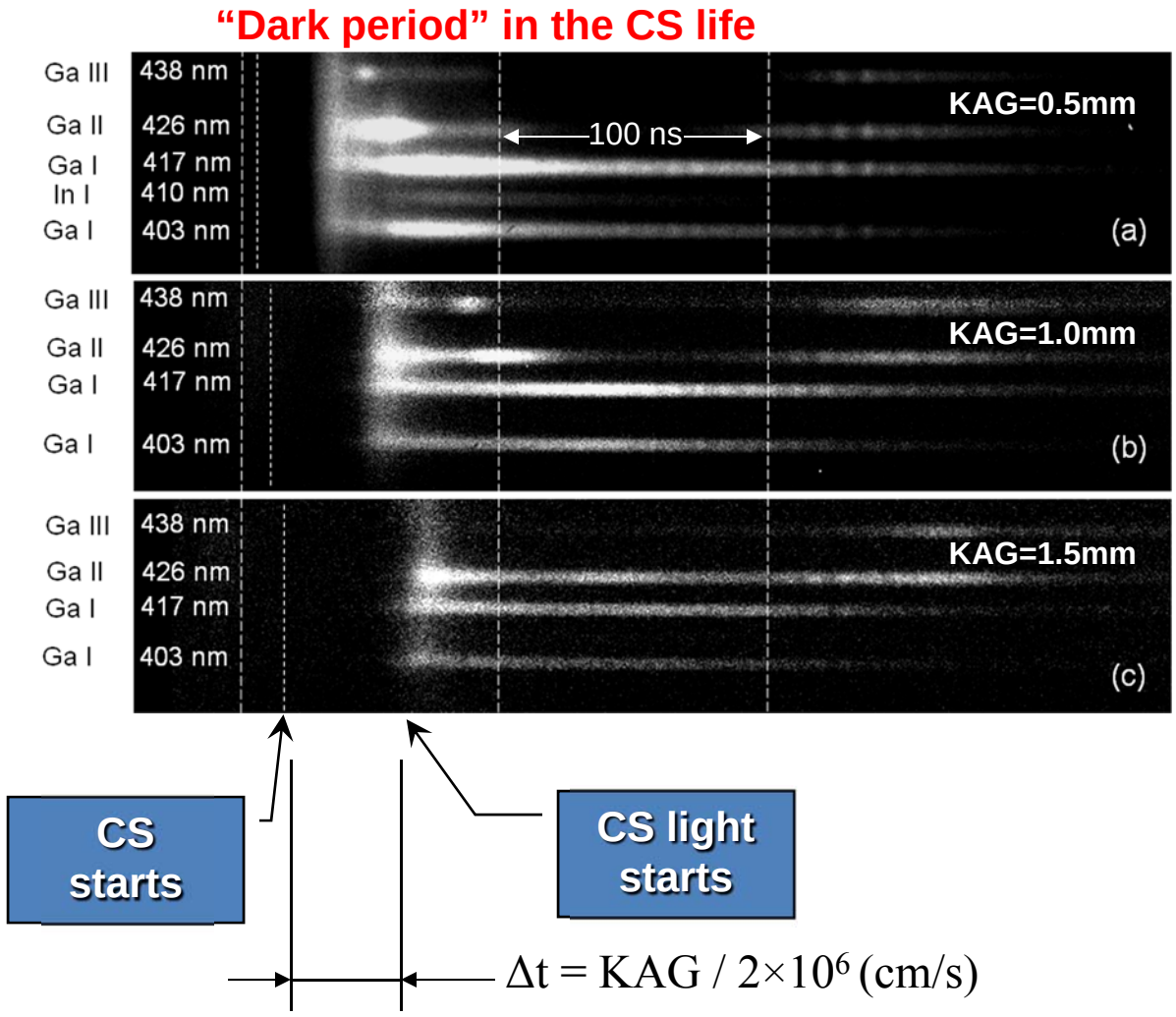
"Is there anything fundamentally new in our field?"

Alexander Batrakov, Institute of High Current Electronics SB RAS, Tomsk, Russia

Sub-field of expertise: electrical insulation in vacuum, vacuum arc diagnostics



INP – IHCE

A. Batrakov,
S. Popov,
R. Methling,
D. Uhrlandt, and
K.-D. Weltmann,
2010

Panel Discussion II
"Is there anything fundamentally new in our field?"

Alexander Batrakov, Institute of High Current Electronics SB RAS, Tomsk, Russia
Sub-field of expertise: electrical insulation in vacuum, vacuum arc diagnostics

Best results in physics of vacuum discharge appeared at IHCE under collaboration.

Let's collaborate
to unite experience and advanced techniques.

What I think, the community could be interested in study **next** in basics of vacuum discharge physics:

1. Sub-nanosecond vacuum discharge.

2. Total voltage effect at nanosecond voltage breakdown.

Panel Discussion II
"Is there anything fundamentally new in our field?"

Alexander Batrakov, Institute of High Current Electronics SB RAS, Tomsk, Russia
Sub-field of expertise: electrical insulation in vacuum, vacuum arc diagnostics

What I think we **have posted** on Wikipedia on basics of vacuum discharge physics? **ALMOST NOTHING.**

What I think we should **have to post** on Wikipedia **as a first step**:

(i) The paper Electrical breakdown could be extended with a new section devoted to **vacuum breakdown** being a result of excess of the field emission limit … **vacuum breakdown** … followed by vacuum arc*,

(ii) **vacuum arc** … being originated and fed by cathode spot,

(iii) **cathode spot** … operating in the explosive electron emission (ecton*) mode on a cold cathode and in the thermionic emission mode on a hot cathode, and

(iv) **explosive electron emission** … involving filed emission and thermionic emission from condensed matter and emission of electrons and ions from cathode spot plasma.

---

* An article must be extended significantly.

Panel Discussion II
"Is there anything fundamentally new in our field?"

Hans Schellekens

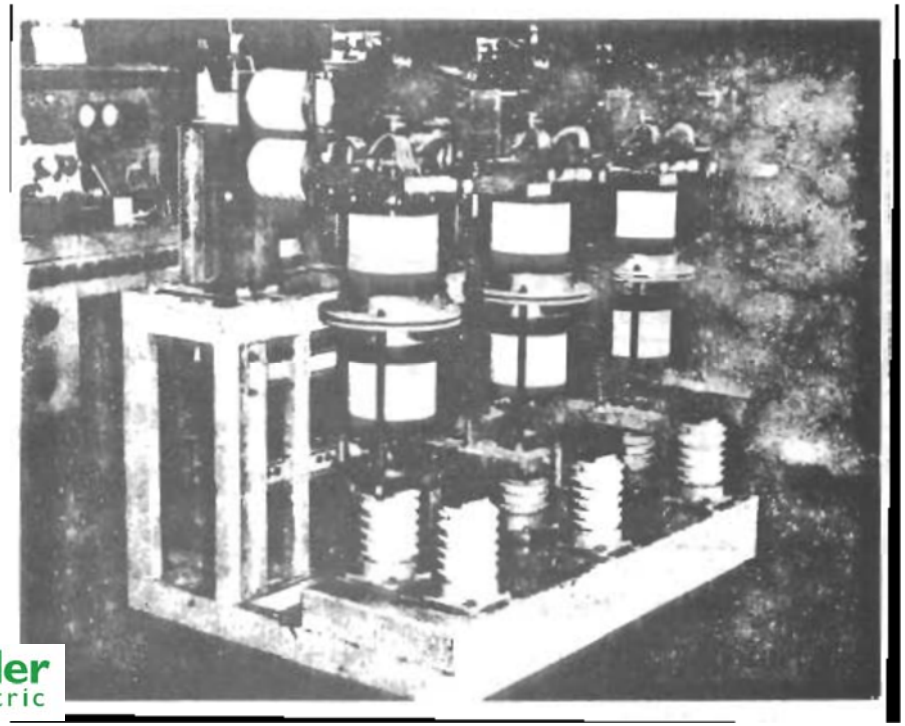
Sub-field of expertise: Vacuum Interrupter Technology

The greatest progress I have seen in my professional live:

- ***High Current Interruption 13.8kV 200 kA***
  - ***Toshiba 1982***

- High Voltage Vacuum Interrupters
  - Pioneer Meidensha
    - 84 kV in 1976
    - 145 kV interrupter 2001
  - Xihari + Siemens 2011;

- First Vacuum Disconnector
  - Toshiba 2005



Panel Discussion II
"Is there anything fundamentally new in our field?"

Hans Schellekens

Sub-field of expertise: Vacuum Interrupter Technology

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- ***High Voltage Vacuum Interrupters***
  - ***Pioneer Meidensha***
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    - ***145 kV interrupter 2002***
  - Xihari + Siemens 2011;

- First Vacuum Disconnector
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Schneider Electric

Panel Discussion II
"Is there anything fundamentally new in our field?"

Hans Schellekens
Sub-field of expertise: Vacuum Interrupter Technology

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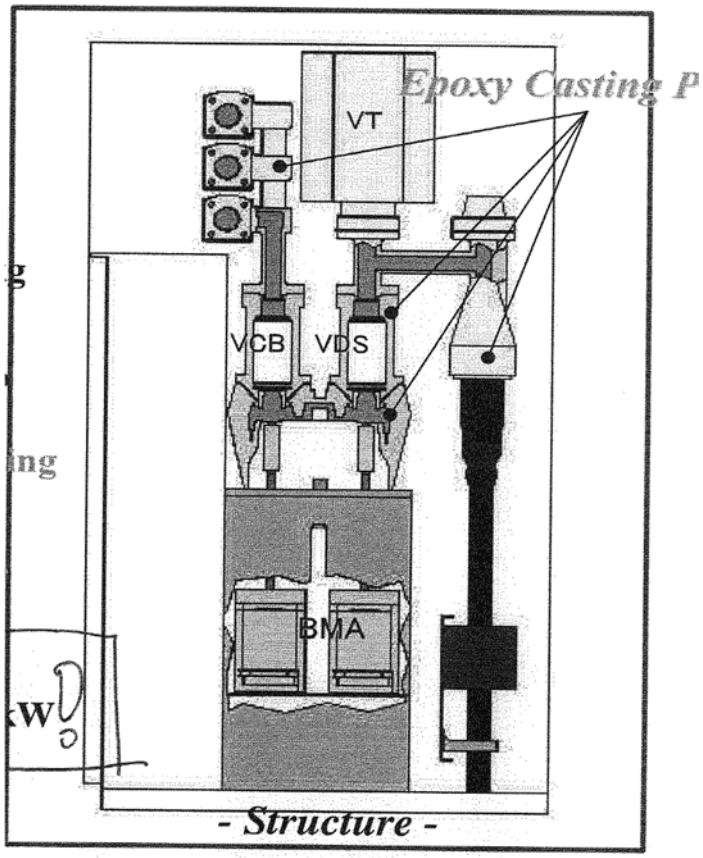
  - Xihari + Siemens 2011;

- ***First Vacuum Disconnector***
  - ***Toshiba 2005***



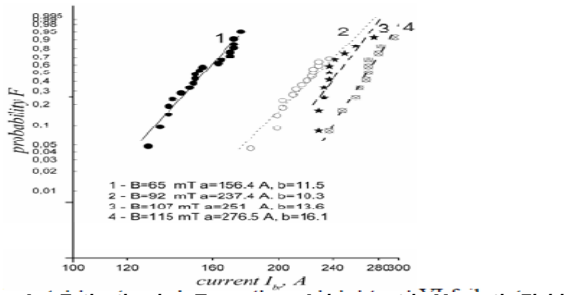
Panel Discussion II
"Is there anything fundamentally new in our field?"

Hans Schellekens

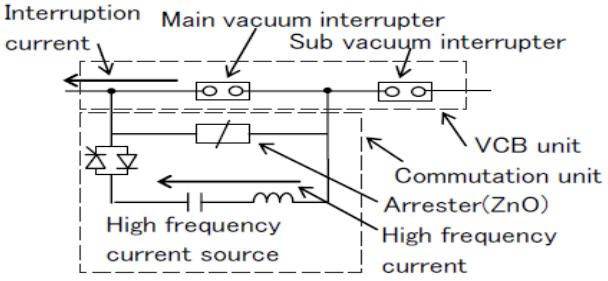
Sub-field of expertise: Vacuum Interrupter Technology

The greatest lack of progress / unmet need in my subfield:

- ***Direct Current Interruption***



DC Vacuum Arc Extinction in a Transverse Axisymmetric Magnetic Field
D. Alferov, G. Belkin, D. Yevsin



Fundamental Investigation and Application of High-speed VCB for DC Power System of Railway
Y. Niwa1 , K. Yokokura1 and J. Matsuzaki1

- ***Restrike free Vacuum Interrupter***

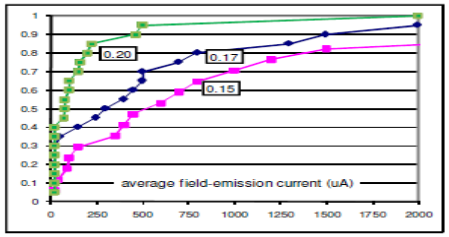


Fig. 2. Cumulative "smaller than" plot of FEE current for three vacuum interrupters type V1 corresponding to CB No.1. Boxes figures are fractions of tests that resulted in late breakdowns

An investigation into late breakdown phenomena during capacitor switching performances in relation with vacuum interrupter design and field emission current
G. Sandolache, S. Chakraborty, L. Gaches
R. Smeets, S. Kuivenhoven, and P. Novak, P. Beer

Schneider Electric

Panel Discussion II
"Is there anything fundamentally new in our field?"

Hans Schellekens

Sub-field of expertise: Vacuum Interrupter Technology

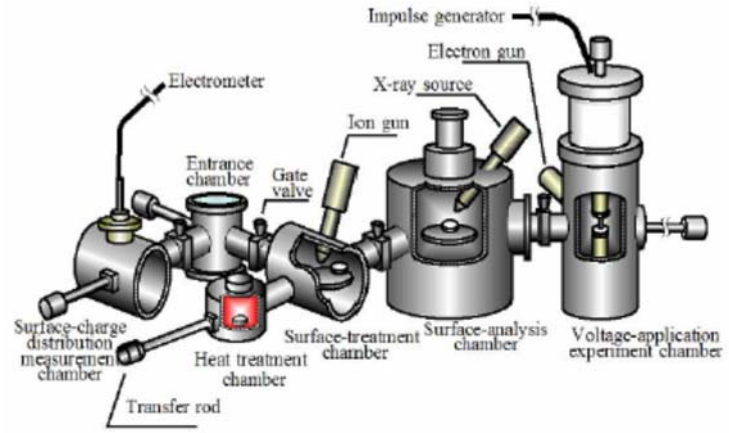
Was there any fundamental progress in the last 5 years?

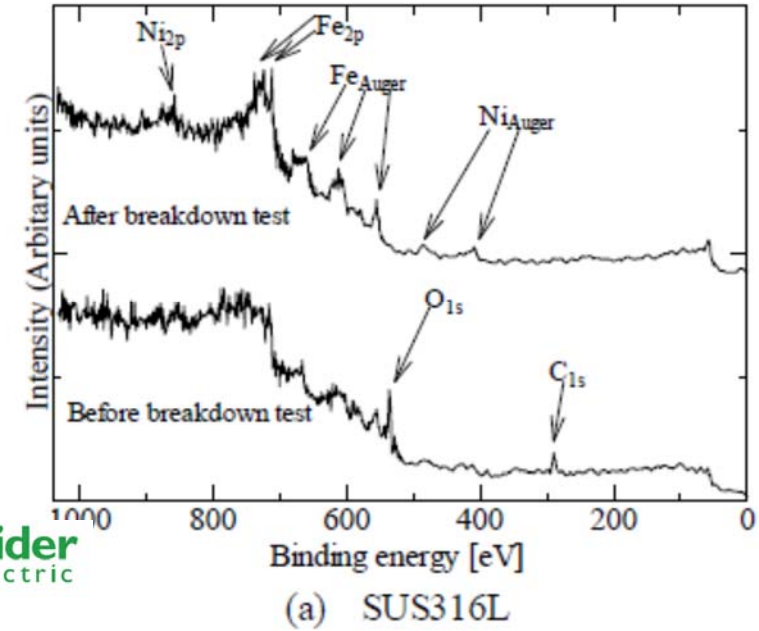
For VI Technology : Small Steps Result in a Giant Leap

- Understanding of breakdown mechanisms
  - "Saitama university"

Vacuum Breakdown Characteristics for Stainless Steel Electrode and Influence of Contamination Degree of the Electrode Surface on the Breakdown Characteristics

Yasushi Yamano, Keisuke Akashi, Shinichi Kobayashi and Yoshio Saito





(a) SUS316L

Schneider Electric

Panel Discussion II
"Is there anything fundamentally new in our field?"

Hans Schellekens

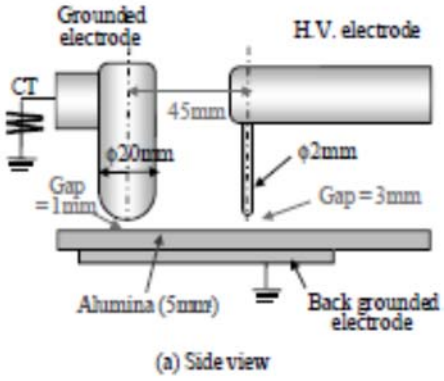
Sub-field of expertise: Vacuum Interrupter Technology

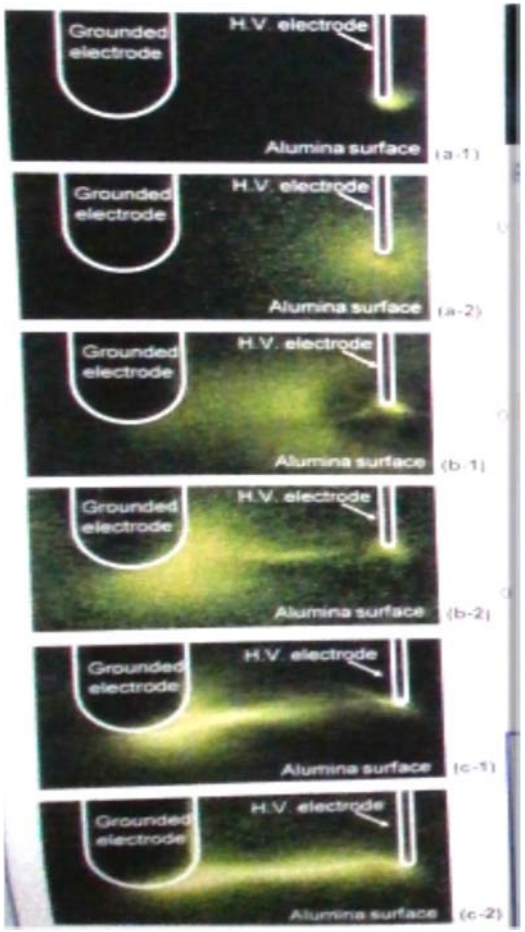
Was there any fundamental progress in the last 5 years?

For VI Technology : Small Steps will result in a Giant Leap

- Understanding of breakdown mechanisms
  - "Nagoya university" 2010

Development Mechanism of Impulse Surface Flashover on Alumina Dielectrics in Vacuum
Tsugunari Ishida, Hiroki Kojima, Kenji Tsuchiya, Hitoshi Okubo





Panel Discussion II
"Is there anything fundamentally new in our field?"

Hans Schellekens

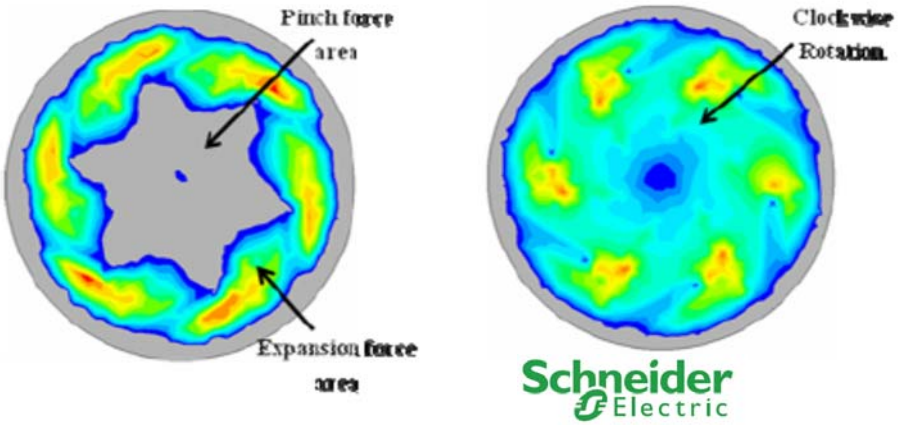
Sub-field of expertise: Vacuum Interrupter Technology

Was there any fundamental progress in the last 5 years?

For VI Technology : Small Steps Result in a Giant Leap

- Arc Modelling Full 3D : (2008) Papers from Korea, Germany and Switzerland

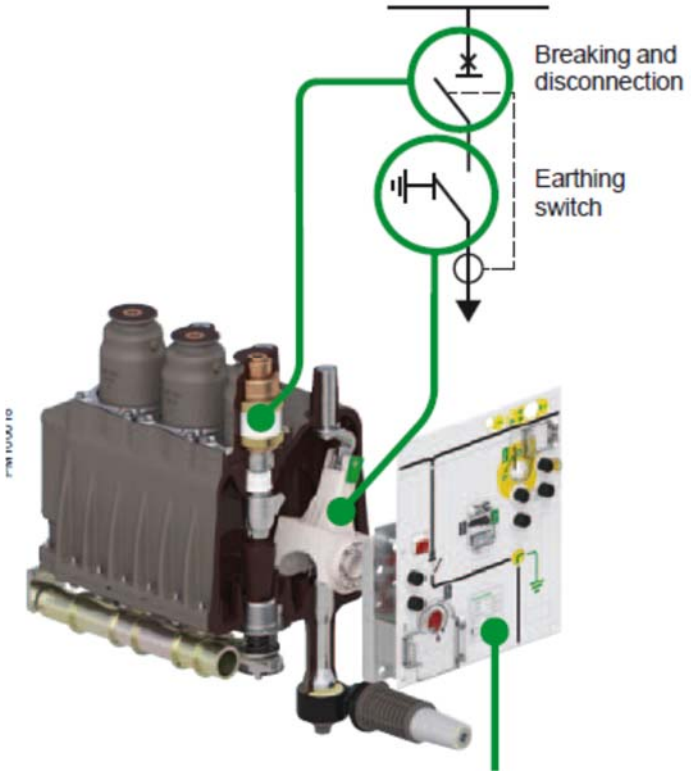
3-D Numerical Analysis of Diffuse Vacuum Arcs with an Axial Magnetic Field
J.-C. Lee, S.-H. Cho, H.-G. Lee, M.–J. Choi, J.–R. Kwon, Y.-J. Kim



Panel Discussion II
"Is there anything fundamentally new in our field?"

Hans Schellekens
Sub-field of expertise: Vacuum Interrupter Technology

What I think we have or should have posted on Wikipedia: ***YOUTUBE***



Development of a new Vacuum Interrupter for disconnecting and breaking in a Shielded and Solid Insulated Switchgear

By Cyril Nicolle

+

PREMSET

Product Presentation in Exhibition Boot

Schneider Electric

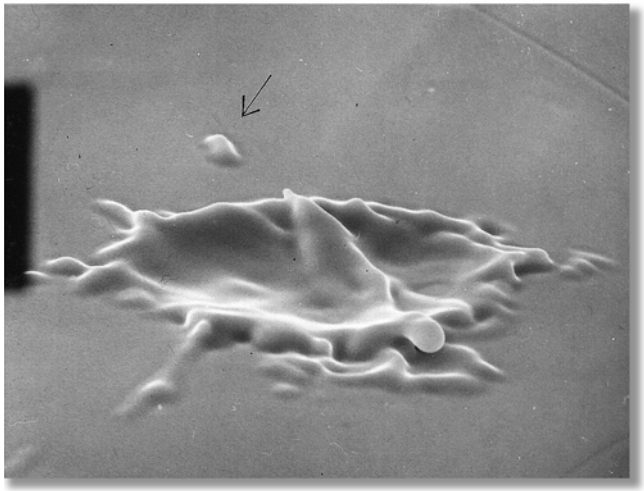
Panel Discussion II
"Is there anything fundamentally new in our field?"

Andre Anders

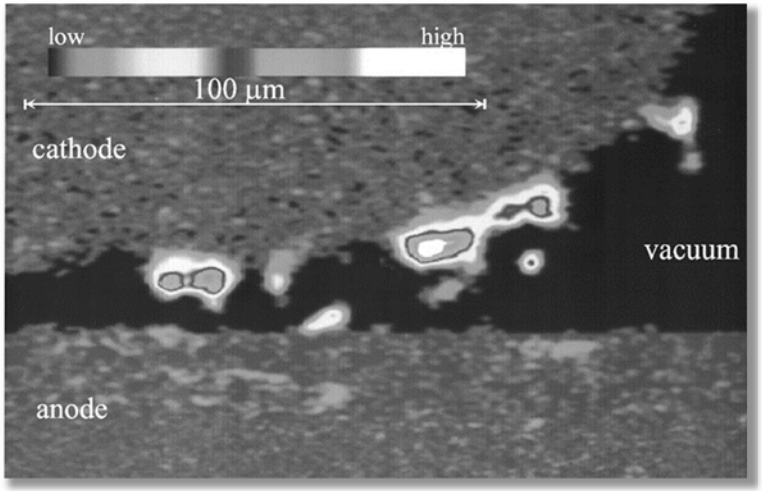
Sub-field of expertise: vacuum arc discharges, cathodic arc deposition

The greatest progress I have seen in my professional live:

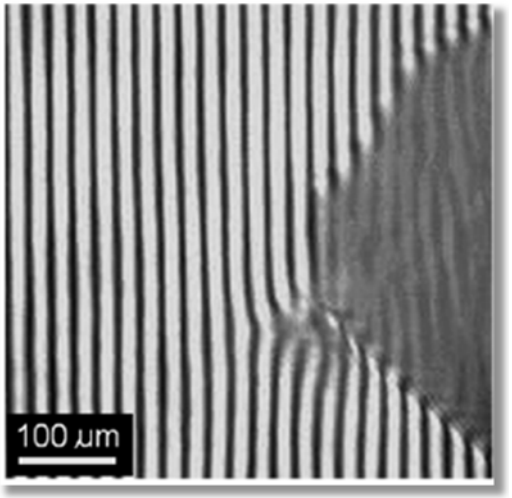
- Significant improvement in research tools, delivering ever high resolution
- ecton & fractal model understood as compatible, complementary views



SEM to arc traces
(Jüttner, 1979)



Laser absorption photography
(Anders et al., 1992)



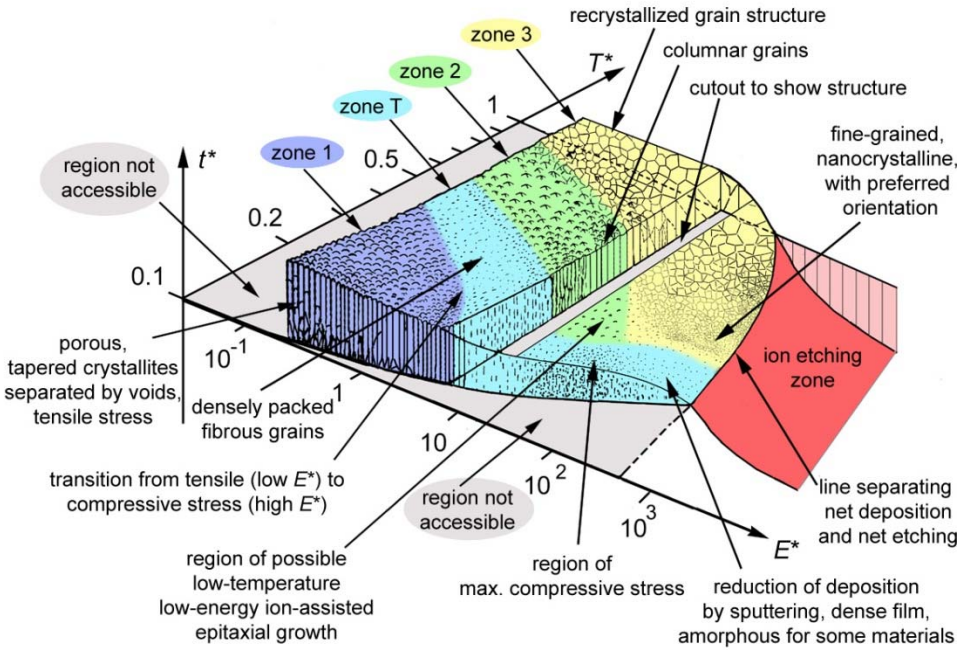
Resonance line
interferometry
(Batrakov et al., 2005)

Panel Discussion II
"Is there anything fundamentally new in our field?"

Andre Anders
Sub-field of expertise: vacuum arc discharges, cathodic arc deposition

The greatest lack of progress / unmet need in my subfield:

- demonstration of large area, uniform films consistently free of macroparticles, made with vacuum or "cathodic" arc



Structure Zone Diagram
A. Anders, Thin Solid Films 518 (2010) 4087.

Panel Discussion II
"Is there anything fundamentally new in our field?"

Andre Anders
Sub-field of expertise: vacuum arc discharges, cathodic arc deposition

Was there any fundamental progress in the last 5 years?

- Some. Incremental.

If no: why not? What is the barrier?

- we have established only weak connections to growth areas: electronics, MEMS, NEMS, plasmonics, spintronics, materials for solar power, batteries, fuel cells, ….
- Vacuum arc is not considered a "growth area" → lack of funding, especially in the U.S.
- For coatings: Competition by alternative technologies
  - ALD, HiPIMS, PECVD, ….
- challenging difficulties to do develop verifiable models free of "fudge factors";
- still serve limitation in computational power e.g. for MC- PIC codes dealing with strong gradients and non-uniform magnetic fields

many of the barriers for practical applications are related to the unresolved issues of control over macroparticles and spot location

Wikipedia: An untapped resource

- The following slides will illustrate the untapped and free resource to better disseminate knowledge in our field
- A call to action by the community.

  - What I think we have or should have posted on Wikipedia:
    - Much more than we have now!
    - Wikipedia has evolved as the main quick stop for information to the general public and to the experts
    - it is free!
    - it is readily to be affect by us, the scientific community!
    - the essence of our “ISDEIV” field is physics and technology of surface in presence of high electric field and plasma

Example: Vacuum Arc

"A stub is an article containing only one or a few sentences of text that, although providing some useful information, is too short to provide encyclopedic coverage of a subject, and that is capable of expansion"

Vacuum arc

From Wikipedia, the free encyclopedia

A **vacuum arc** can arise when the surfaces of metal electrodes in contact with a good vacuum begin to emit electrons either through heating (thermionic emission) or via an electric field that is sufficient to cause field electron emission. Once initiated, a vacuum arc can persist since the freed particles gain kinetic energy from the electric field, heating the metal surfaces through high speed particle collisions. This process can create an incandescent **cathode spot** which frees more particles, thereby sustaining the arc. At sufficiently high currents an incandescent **anode spot** may also be formed.

Electrical discharge in vacuum is important for certain types of vacuum tubes and for high voltage vacuum switches.

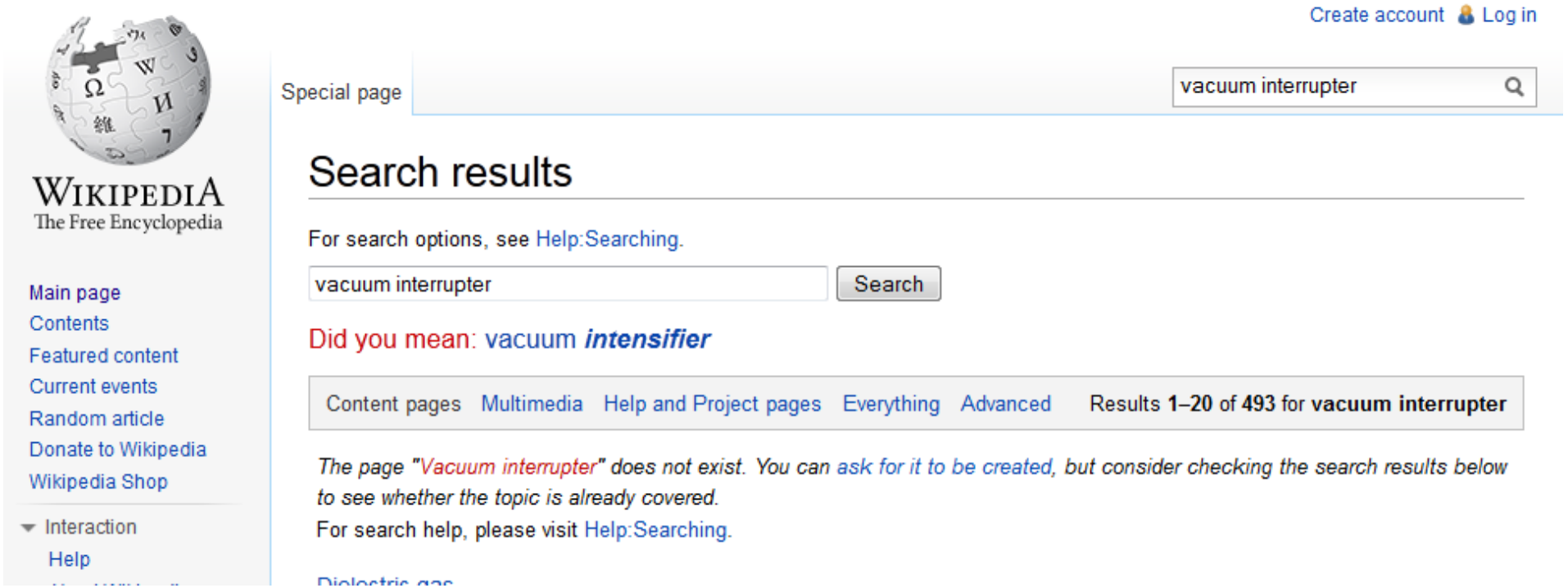
The thermionic vacuum arc (TVA) is a new type of plasma source, which generates a pure metal and ceramic vapour plasma containing ions with a directed energy. TVA discharges can be ignited in high vacuum conditions between a heated cathode (electron gun) and an anode (tungsten crucible) containing the material. The accelerated electron beam, incident on the anode, heats the crucible, together with its contents, to a high temperature. After establishing a steadystate density of the evaporating anode material atoms, and when the voltage applied is high enough, a bright discharge is ignited between the electrodes.

References [edit]

- Messyats, Gennady A.; Proskurovsky, D. I. (1989). *Pulsed Electrical Discharge in Vacuum (Springer Series on Atoms and Plasmas, 5)* (1st ed.). Springer-Verlag. ISBN 0-387-50725-6.
- Greenwood, Allan (1994). *Vacuum Switchgear (I E E Power Engineering Series)* (1st ed.). Pergamon Press. ISBN 0-85296-855-8.
- Akan, Tamer; Demirkol, Serdar; Ekem, Naci; Pat, Suat; Musa, Geavit (2007). "Study of Metal and Ceramic Thermionic Vacuum arc Discharges". *Plasma Sci. Technol.* **9** (3): 280–283. Bibcode 2007PIST....9..280A. doi:10.1088/1009-0630/9/3/06.

Example: Vacuum Interrupter

- The page “Vacuum Interrupter” does not exist.



Example: Electrical Breakdown in Vacuum

- Redirected to (no information on the vacuum case):

Electrical breakdown

From Wikipedia, the free encyclopedia

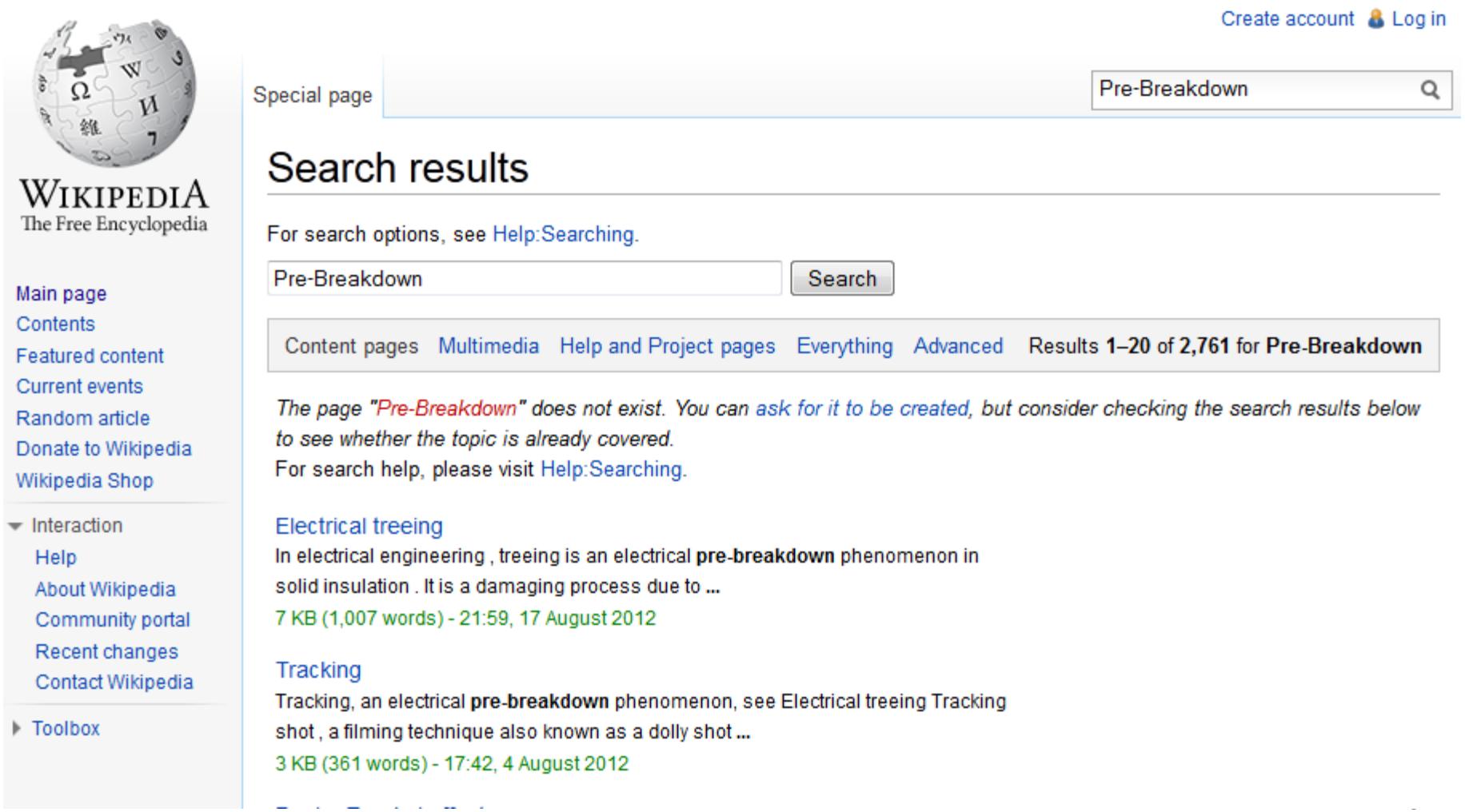
(Redirected from Electrical Breakdown in Vacuum)

The term **electrical breakdown** or **electric breakdown** has several similar but distinctly different meanings. For example, the term can apply to the failure of an electric circuit. Alternatively, it may refer to a rapid reduction in the resistance of an electrical insulator that can lead to a spark jumping around or through the insulator. This may be a momentary event (as in an electrostatic discharge), or may lead to a continuous arc discharge if protective devices fail to interrupt the current in a high power circuit.

Contents [hide]

Example: Pre-Breakdown

- The page “Pre-Breakdown” does not exist.



Create account Log in

Special page

Pre-Breakdown

WIKIPEDIA
The Free Encyclopedia

Main page
Contents
Featured content
Current events
Random article
Donate to Wikipedia
Wikipedia Shop

Interaction
Help
About Wikipedia
Community portal
Recent changes
Contact Wikipedia

Toolbox

Search results

For search options, see Help:Searching.

Pre-Breakdown Search

Content pages Multimedia Help and Project pages Everything Advanced Results **1–20** of **2,761** for **Pre-Breakdown**

The page "Pre-Breakdown" does not exist. You can ask for it to be created, but consider checking the search results below to see whether the topic is already covered.
For search help, please visit Help:Searching.

Electrical treeing
In electrical engineering , treeing is an electrical **pre-breakdown** phenomenon in solid insulation . It is a damaging process due to ...
7 KB (1,007 words) - 21:59, 17 August 2012

Tracking
Tracking, an electrical **pre-breakdown** phenomenon, see Electrical treeing Tracking shot , a filming technique also known as a dolly shot ...
3 KB (361 words) - 17:42, 4 August 2012

Example: Surface Flashover in Vacuum

- The page “Surface Flashover in Vacuum” does not exist

Search results

For search options, see Help:Searching.

Surface Flashover in Vacuum [Search]

Content pages | Multimedia | Help and Project pages | Everything | Advanced

Results **1–7** of **7** for **Surface Flashover in Vacuum**

The page "Surface Flashover in Vacuum" does not exist. You can ask for it to be created, but consider checking the search results below to see whether the topic is already covered.

For search help, please visit Help:Searching.

Insulator (electricity)

Even a **vacuum** can suffer a sort **...** charges ejected from the **surface** of metal **...** (18-27 k lbf), have a dry **flashover** voltage of about 72 kV, and **...**

27 KB (3,749 words) - 04:48, 23 August 2012

Electric arc

immersion in transformer oil , dielectric gas or **vacuum ...** Electric arc over the **surface** of plastic s causes their degradation. **...**

12 KB (1,547 words) - 20:16, 30 May 2012

ISDEIV Publications: Status Quo

1. Proceedings.
   - Not peer reviewed.
   - Available at beginning of each symposium in print and in PDF.
   - Most previous proceedings available on IEEE Xplore (for a fee, unless institution has subscription)
2. Special Issues
   - IEEE Trans. Plasma Science; IEEE Trans. Dielectrics and Electrical Insulation

- to be provocative:
  - the world of information in general, and publications in particular, has changed, and so may our approach to publications
  - information is today on our fingertips such as
    - Wikipedia,
    - instant download of research papers.

Questions to be considered in the long term

1. Proceedings:
   1. While printed proceedings are nice to have, is it worth effort and cost?
   2. Shall we consider possible alternatives such as
      - electronic-only via IEEE Xplore?
      - electronic-only as PDF on memory and ISDEIV self-publishing?

2. Do we want SPECIAL ISSUES, or shall we recommend publication of regular papers in IEEE Transactions?
   - pros: nice collection when in print, helps to determine the Best Paper winner, advertises our symposium
   - cons: slows down the publication process compared to Regular Paper, causes lot's of work for a Guest Editor.

Some Comments, Highlights, and a Summary

- Huge progress seen in the period of last 50 years:
  - modeling can now be done in 3D,
  - diagnostics equipment has tremendously improved;
  - huge amounts of data can be collected and processed;
  - switching in vacuum is today firmly established for medium voltage and makes even in-roads to the high voltage range

Some Comments, Highlights, and a Summary

- When looking at more recent progress, it is more incremental:
  - "The flashover is fast but the speed of our understanding is slow" (Yamamoto)
  - difficulties to improve and verify modeling due to the unpredictable nature of arc spots (Shenli Jia)
  - improved diagnostics and data handling allows us now to address the issues at ns and nm-scales (Boxman)
  - limited resources can be overcome by increased collaboration (Batrakov)
  - many small steps…may result in a giant leap (Schellekens)
  - lack of control of spot location and lack of complete elimination of macroparticles are the greatest barriers to wider use of cathodic arc plasma, e.g. for microelectronics and optical coatings (Anders)

Some Comments, Highlights, and a Summary

- Actions (as further discussed in PISC):
  - PISC to explore shared copyright for Proceedings, post proceedings paper on web, if possible
  - PISC to lead efforts in introducing / improving material related to ISDEIV to Wikipedia for the broader dissemination of knowledge in our field: current status is not satisfactory
  - Call to all experts in contributing to this effort.