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Plasma Engineering LLC: Consulting and Education in Plasmas and Plasma Applications

André Anders, Plasma Engineering LLC, El Cerrito, CA

Plasma Engineering LLC is a start-up consulting company registered in California. Founder/CEO is André Anders, who has worked in the field of plasmas, plasma diagnostics and plasma-based coatings for over 30 years. André's work has been recognized by SVC's Mentor Award (2011) and the Nathaniel Sugerman Memorial Award (2016), among other awards. Plasma Engineering LLC serves two related markets in plasma and ion beam processing of materials: (1) customized consulting and (2) customized educational workshops designed to empower companies' employees. Given the growing needs within the US and world-wide, especially in the field of plasma-based semiconductor manufacturing, Plasma Engineering LLC offers workshop / short courses for continuing education. The two fields, direct consulting and continuing education, are not exclusive but can be synergistic. Based on André's expertise in experimental physics and teaching experience as Professor of Applied Physics, consulting topics include, but are not limited to, (reactive) magnetron sputtering, HiPIMS, cathodic arc deposition, plasma and process diagnostics, plasma and ion source developments, plasma-based deposition, ion sources, ion beam deposition and etching. An overview can be found at https://plasmaengineering.com/. Due to the company's start-up phase, now is a good time to secure short- and long-term relationships.

DOI: https://doi.org/10.14332/svc25.proc.0033

Plasma Engineering LLC:
Consulting and Education in Plasmas and Plasma Applications

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SVC Society of Vacuum Coaters

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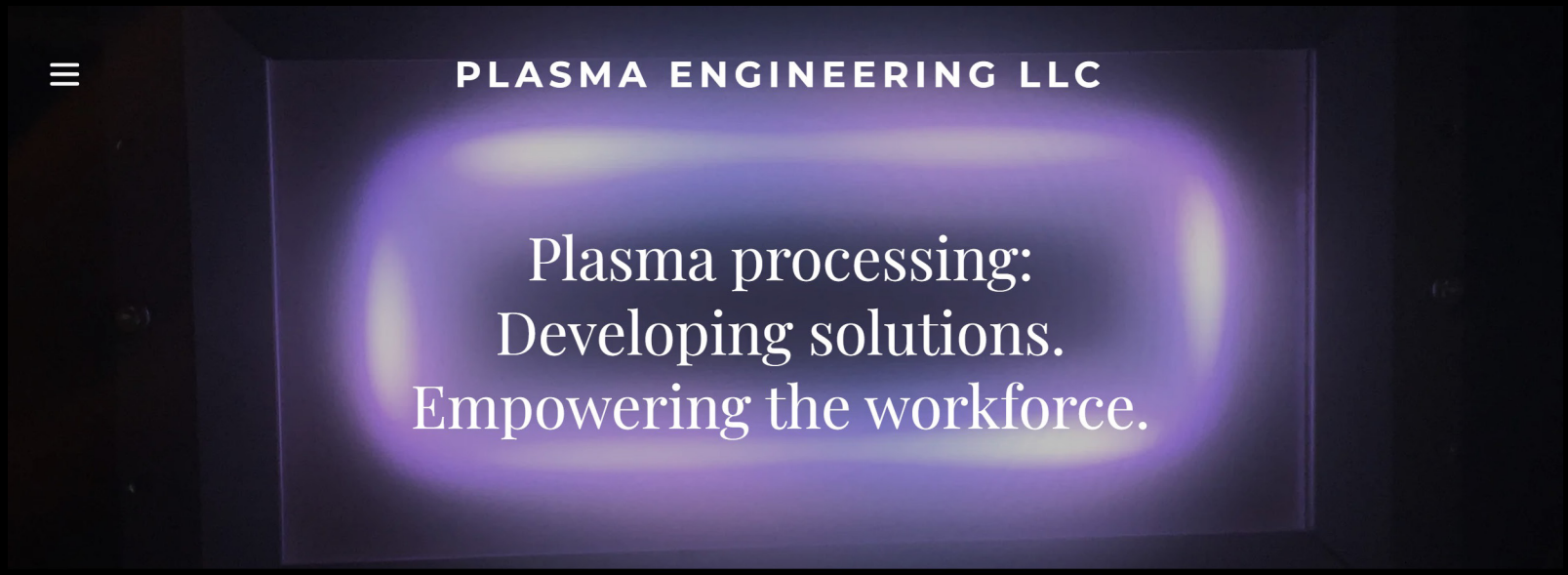

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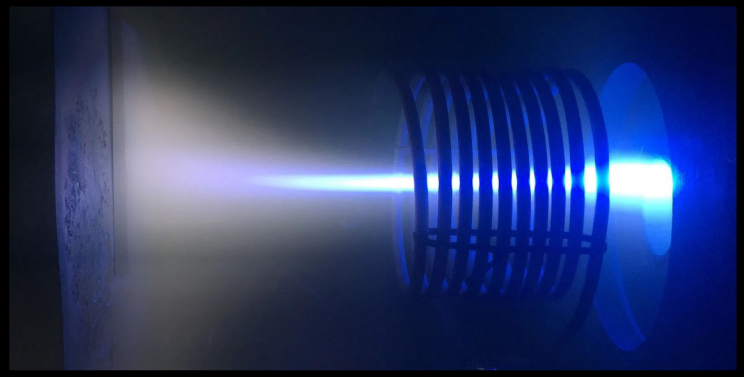


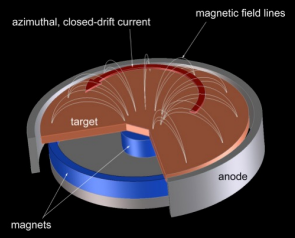
Based on customer needs, Plasma Engineering engages in the development of plasma and ion beam systems for surface engineering, materials synthesis, and electric propulsion. In addition, through customized workshops, Plasma Engineering helps companies enhance their employees' knowledge of plasmas and plasma/ion beam processing, guiding development strategies and reducing time to solutions.

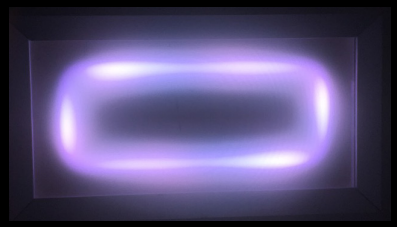
Markets served

- Scientific/Technical Consultations

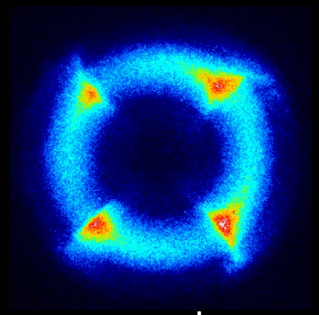
- Custom Educational Workshops

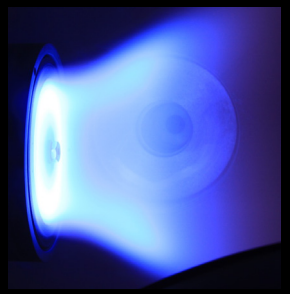
Expertise incl. Plasma- and Ion-Beam-Based Processing



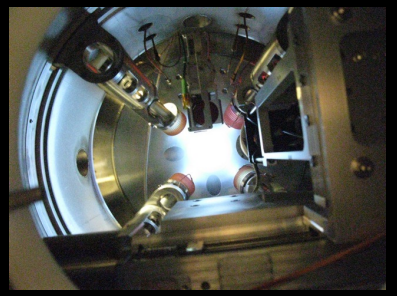


all kinds of magnetron sputtering



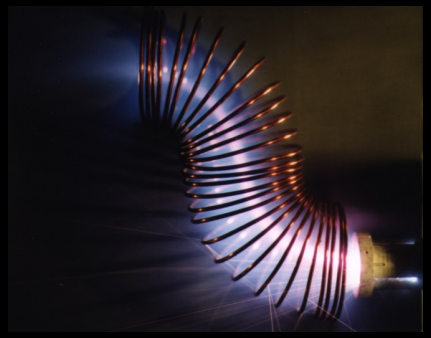


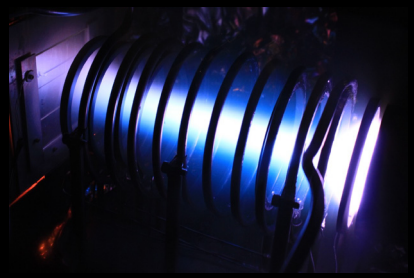
plasma diagnostics



electric propulsion

cathodic arc deposition





plasma transport and filtering

dielectric barrier discharges

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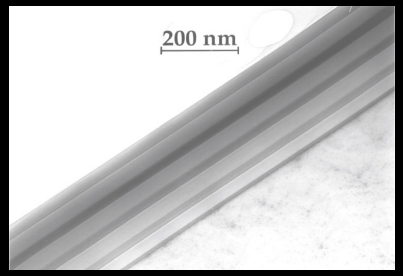
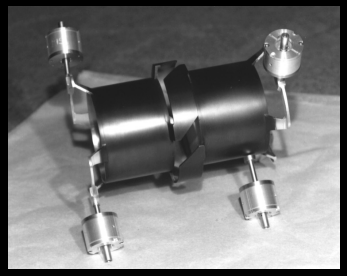
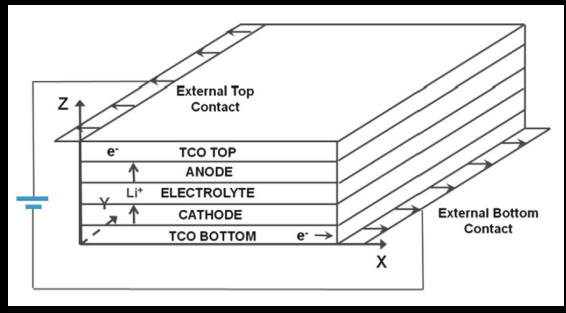
Expertise incl. Plasma- and Ion-Beam-Based Processing



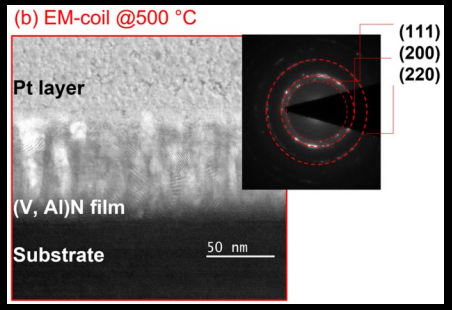
DLC and ta-C



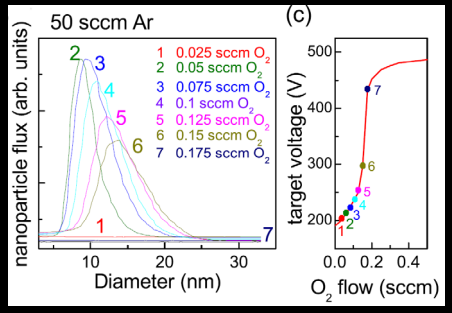
high and low emissivity coatings



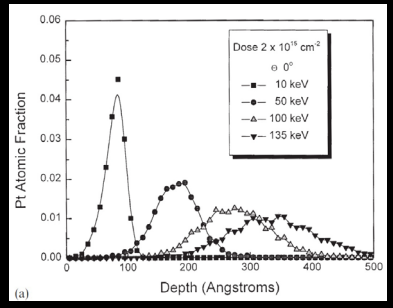
window glass coating, incl. EC, TC



hard, protective, decorative coatings



nanoparticles by gas phase condensation



doping and buried layers by ion implantation

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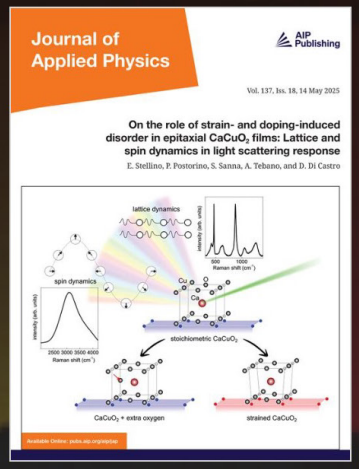

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Plasma Engineering LLC

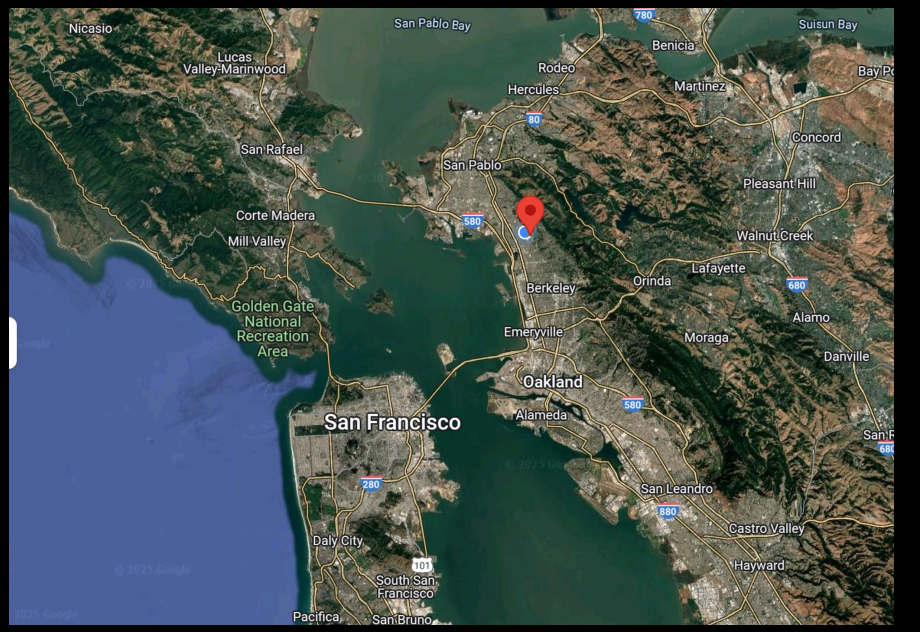
Timing is good!

Now is a good time to engage

- Plasma Engineering is not yet fully booked (as of the time of this writing)
- later: there may be limitations later due to NDAs / non-compete clauses

https://plasmaengineering.com/

info@plasmaengineering.com



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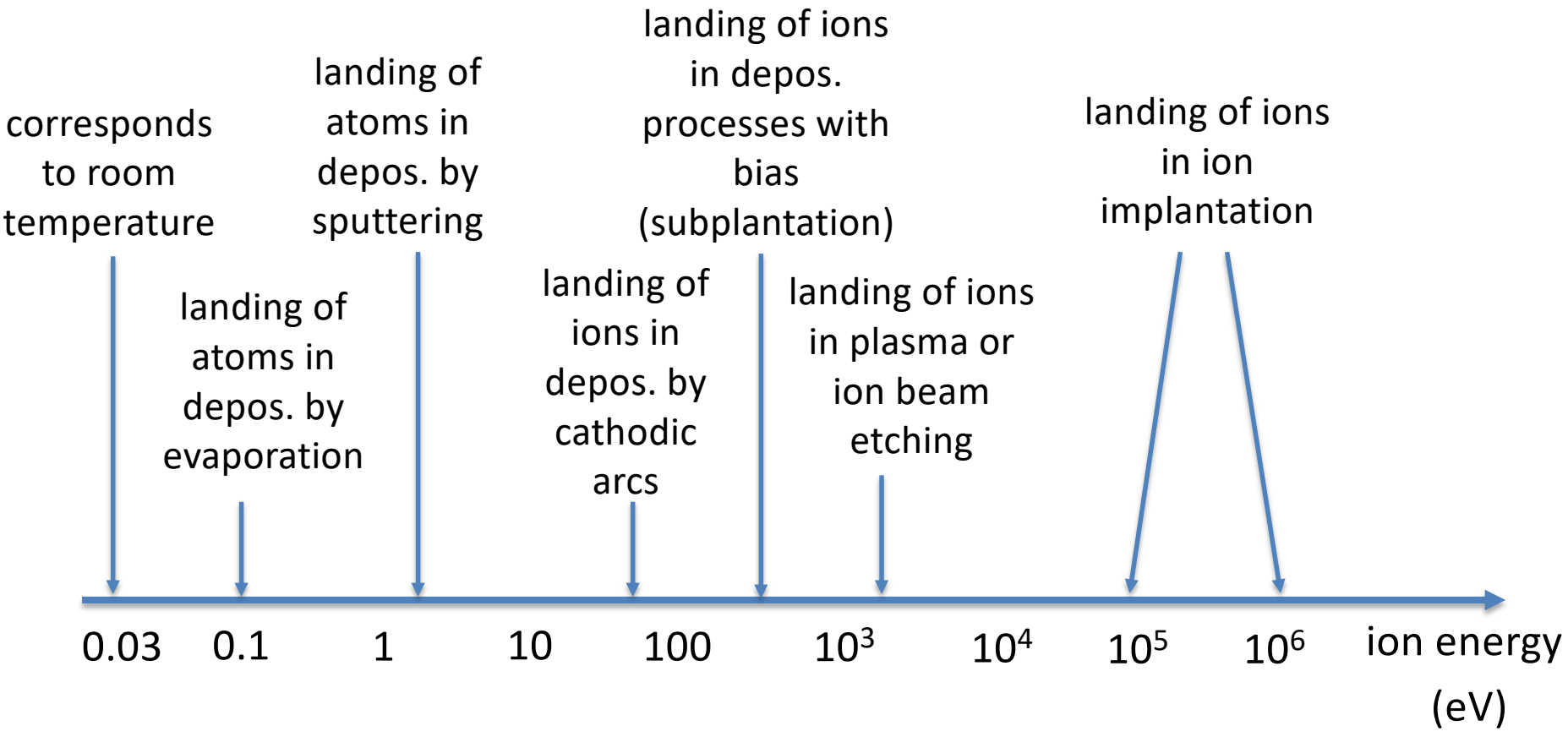
A very brief overview over

Surface Engineering with Plasmas and Ions

(incl. selected slides from the Keynote)

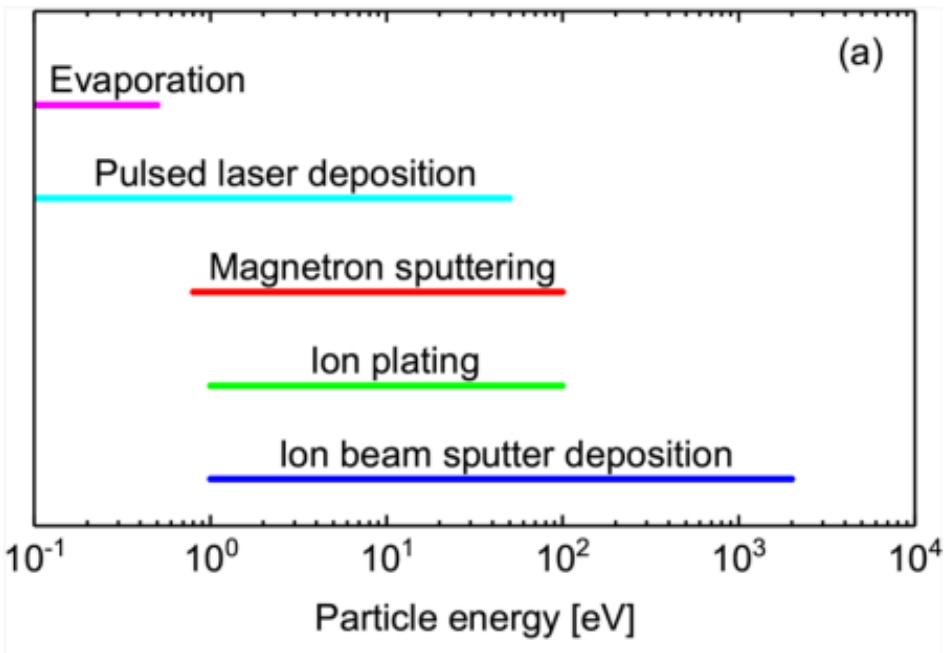
Processing of materials - sorted by typical ion energies



Plasmas in Deposition Techniques

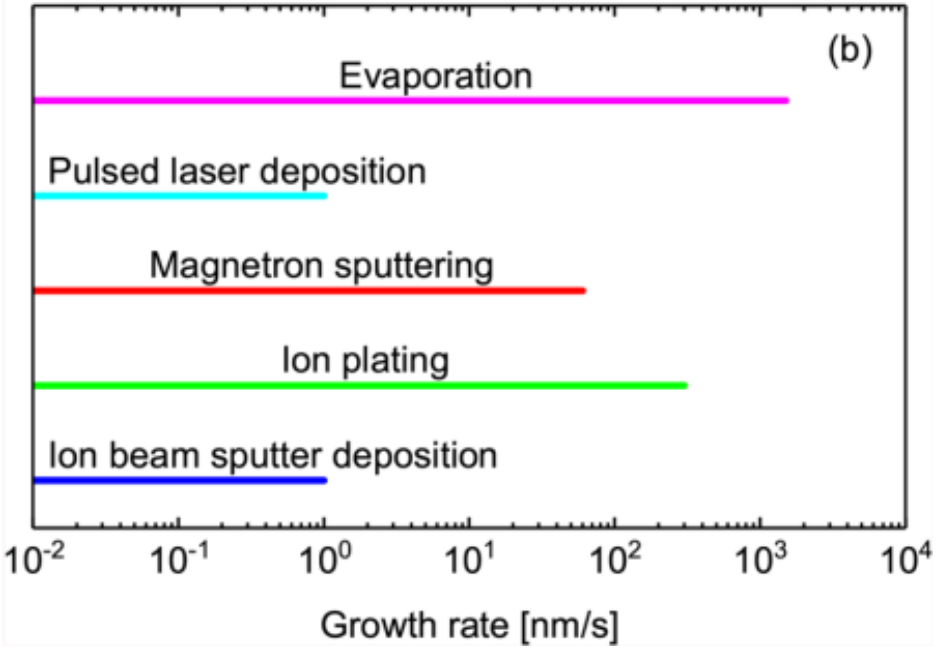
filtered cathodic arc

unfiltered cathodic arc



filtered cathodic arc

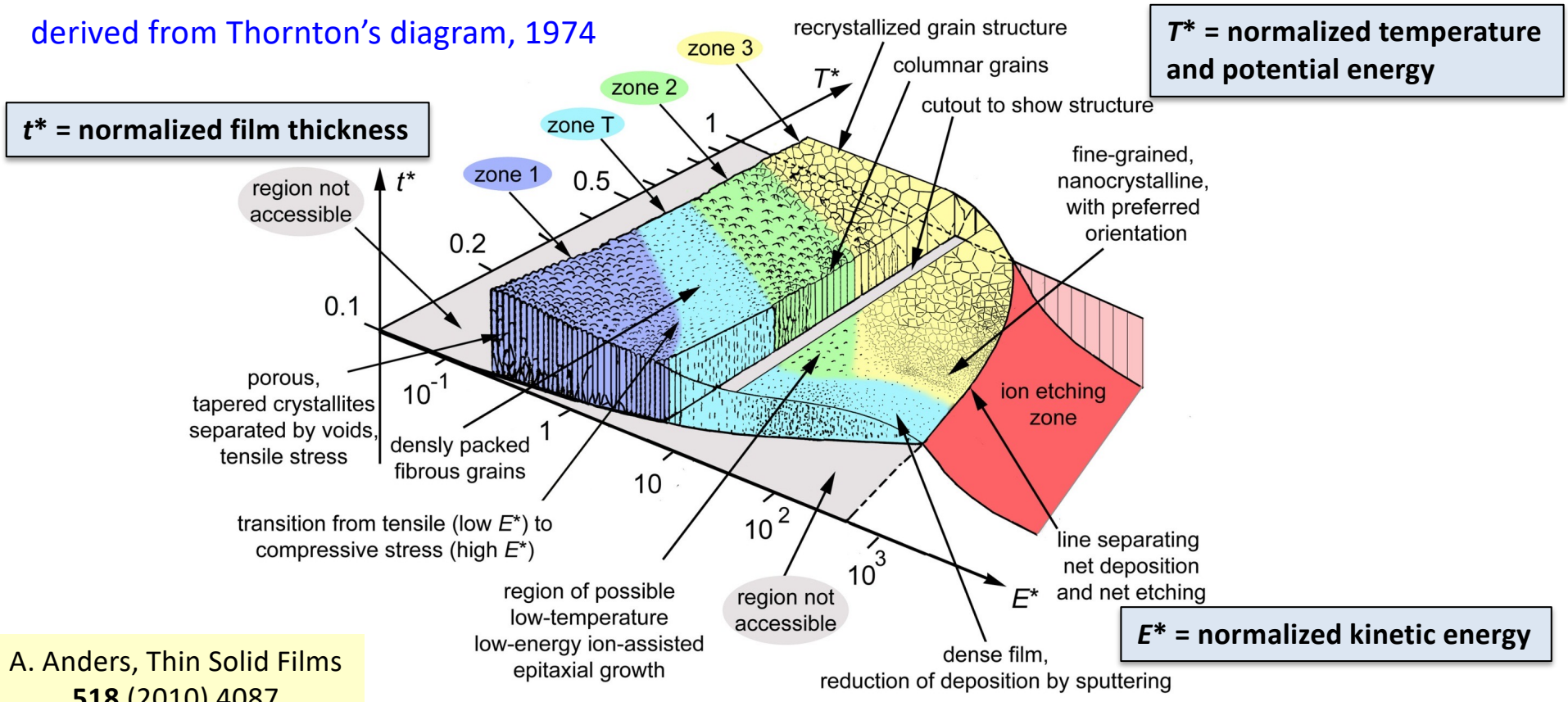
unfiltered cathodic arc



adapted from: C. Bundesmann and H. Neumann, J. Appl. Phys. 124 (2018) 231102

A generalized structure zone diagram including the effects of plasma assistance on microstructure of films

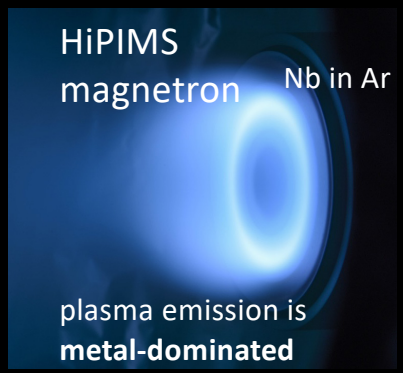
derived from Thornton's diagram, 1974



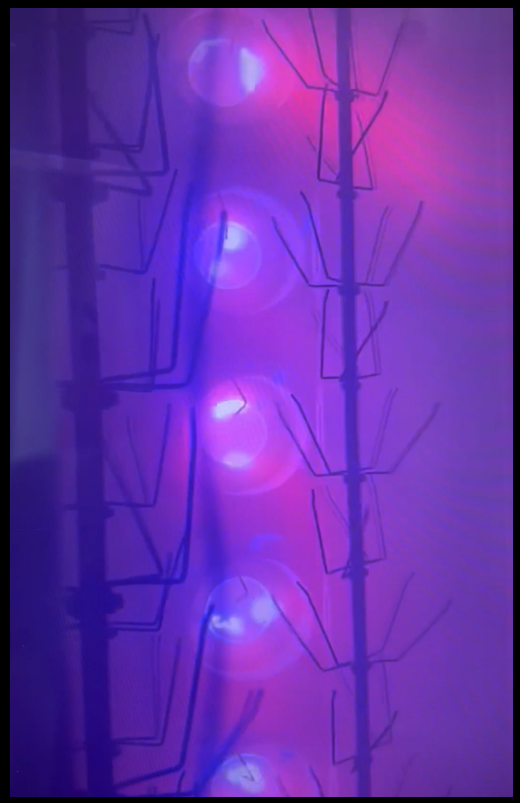
A. Anders, Thin Solid Films **518** (2010) 4087

Wide range of plasmas in surface engineering (examples)

Coatings by sputtering



Coatings by cathodic arc

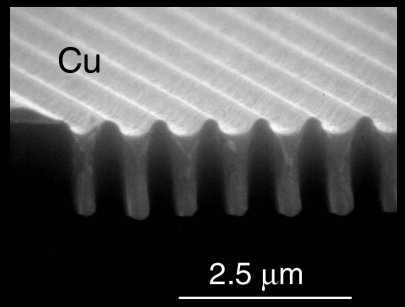


Pernagidis 2023

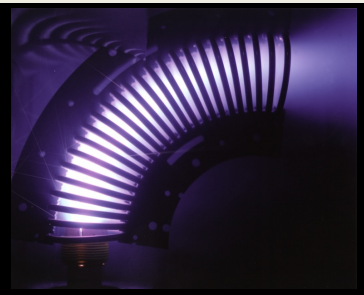
Coatings by ion plating

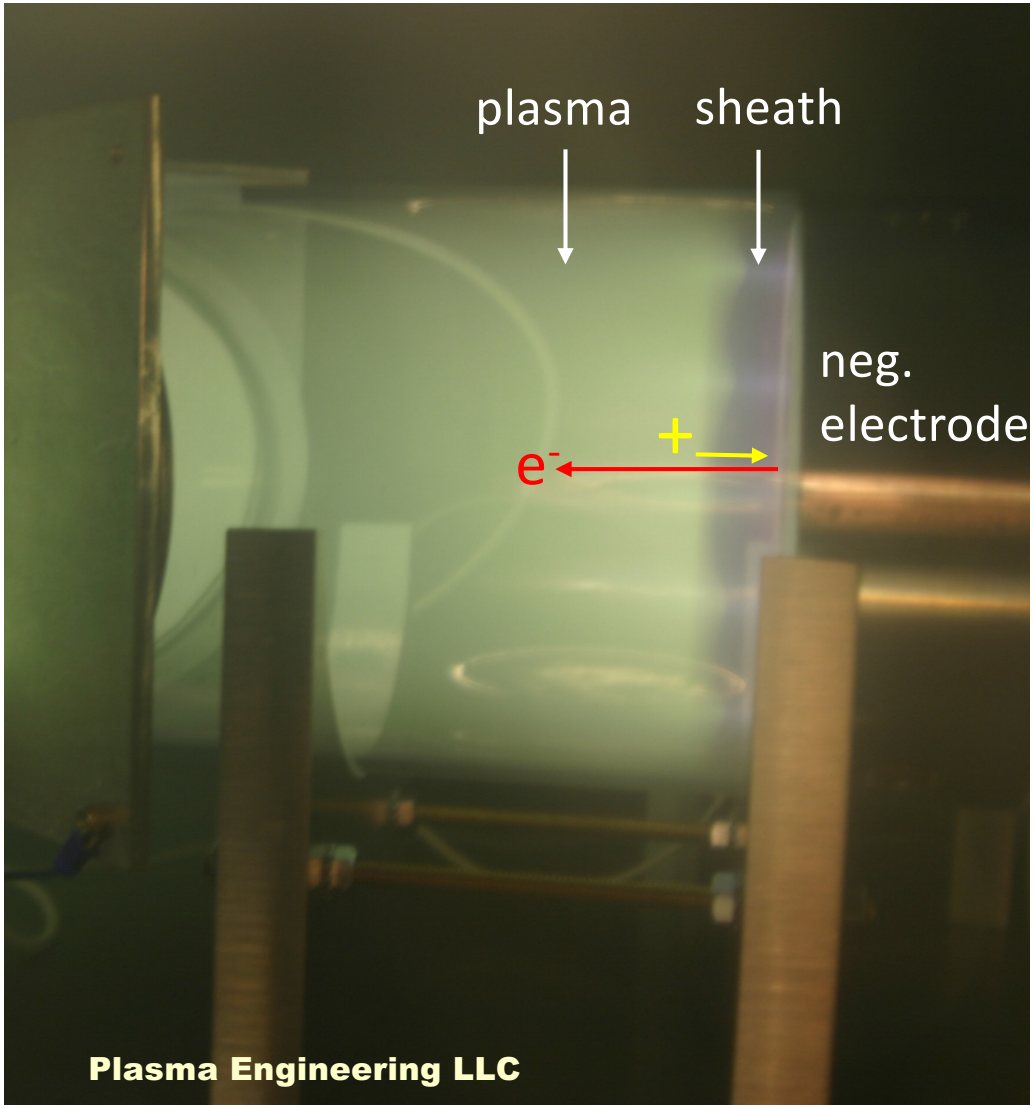
Mattox, 1963

Etching with ions



Plasma Immersion Ion Implantation and Deposition





Sheath determines ion and secondary electron energies

kinetic ion energy upon impact on surface

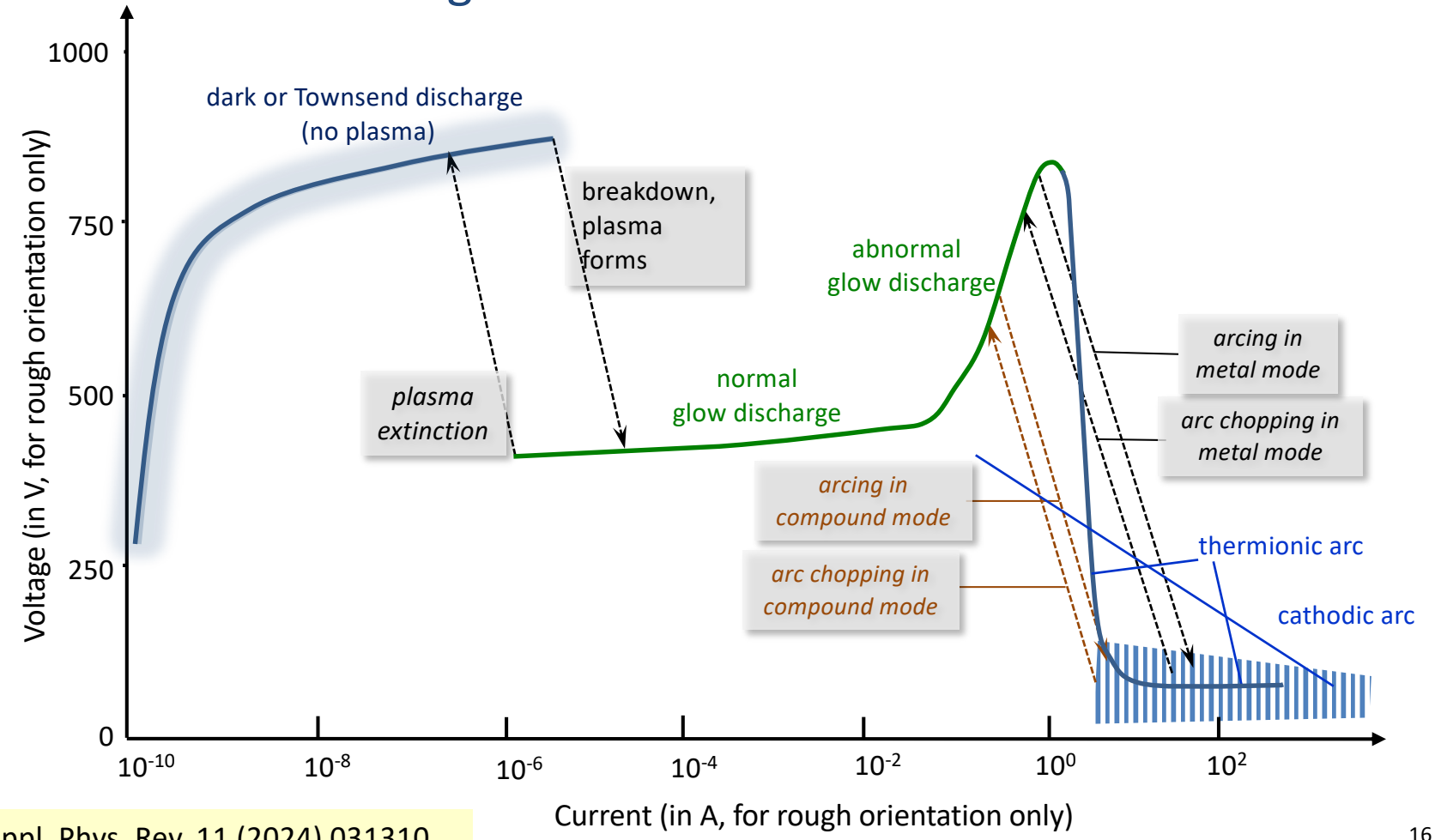
$$E_i = E_0 + Qe\underbrace{\left(V_{plasma} - V_{surface}\right)}_{V_{sheath}}$$

Secondary electrons are energized by crossing the sheath

$$E_{SE} \approx e\underbrace{\left(V_{plasma} - V_{surface}\right)}_{V_{sheath}}$$

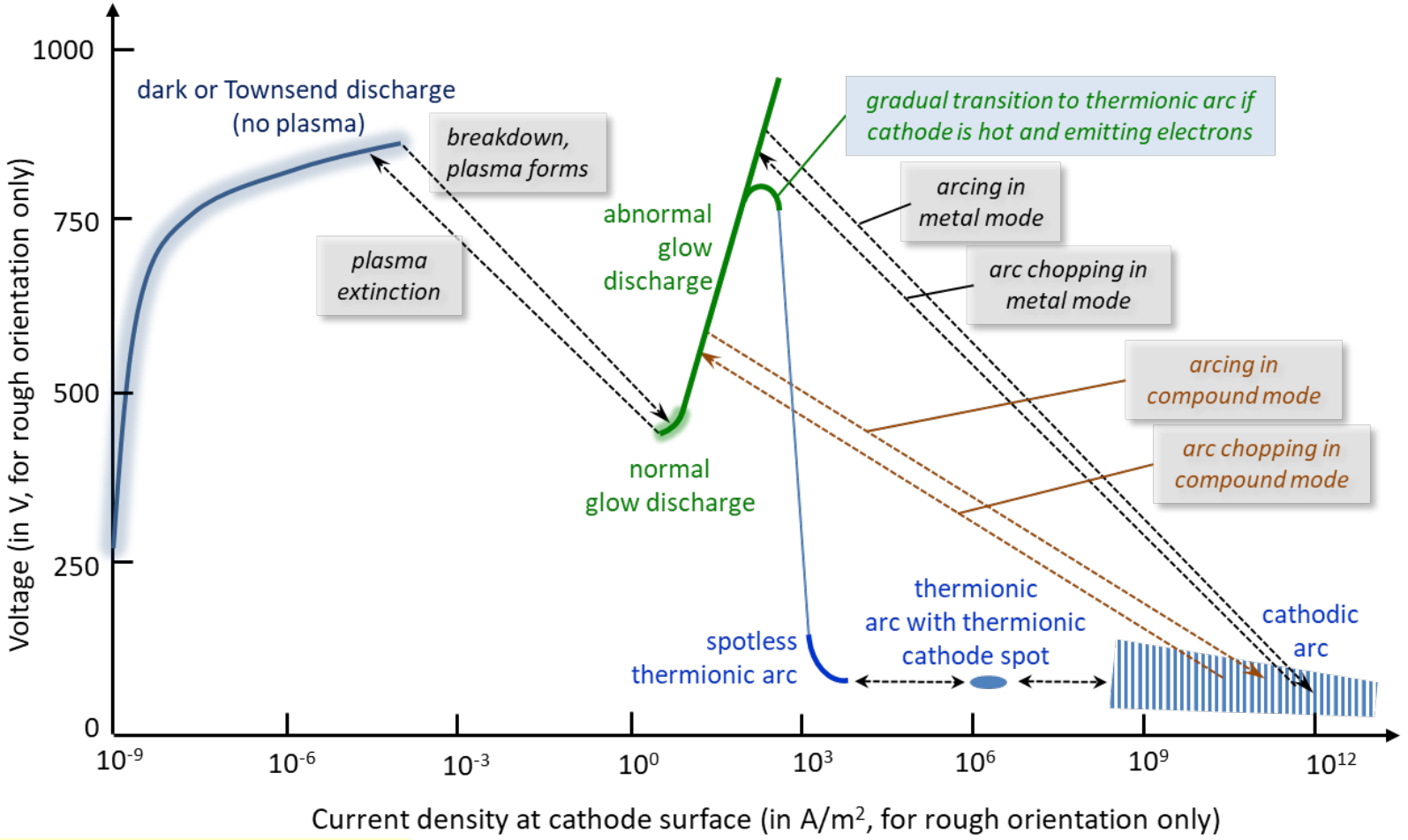
leading to ionizing collisions, sustaining the plasma (Penning, Thornton)

Extended Current-Voltage Characteristics



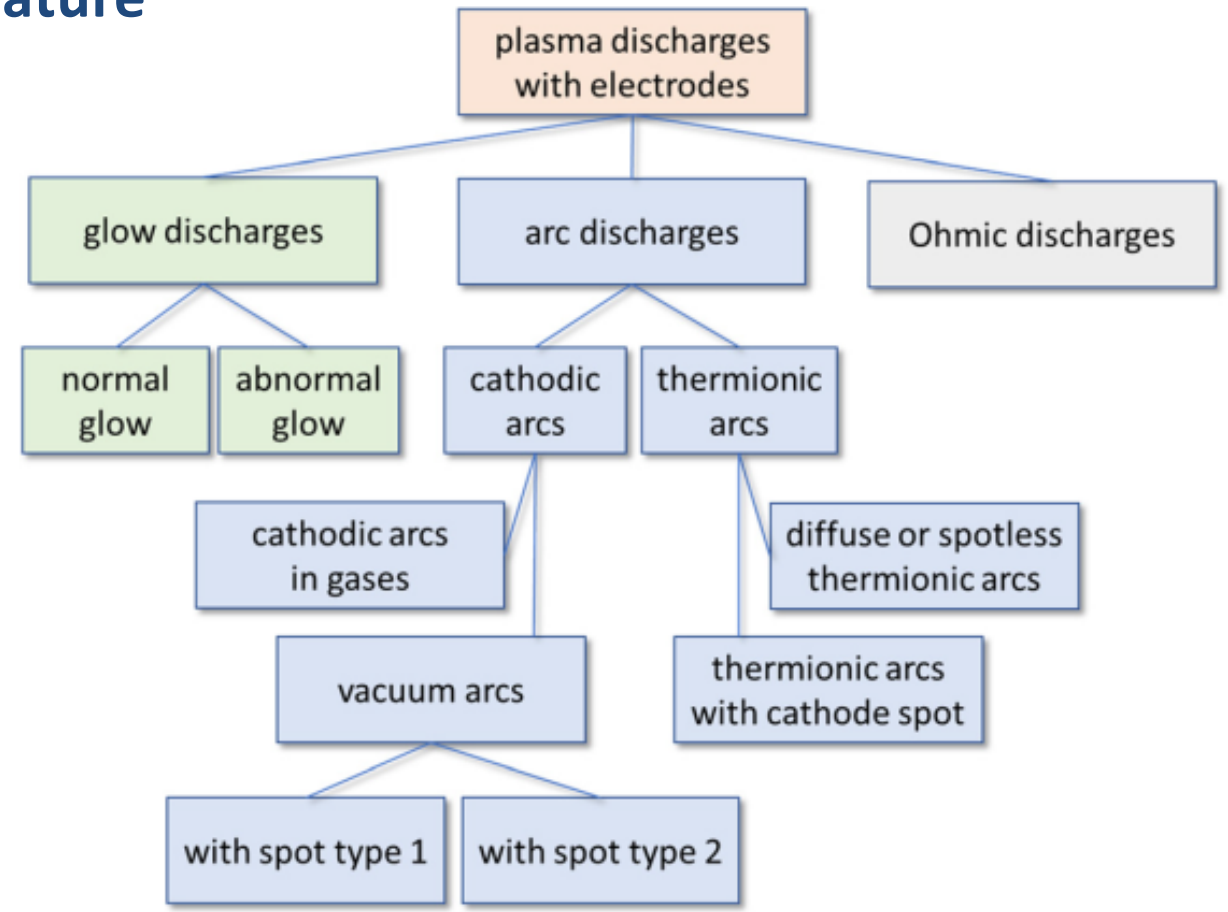
A. Anders, Appl. Phys. Rev. 11 (2024) 031310.

Extended Current Density-Voltage Characteristics



A. Anders, Appl. Phys. Rev. 11 (2024) 031310.

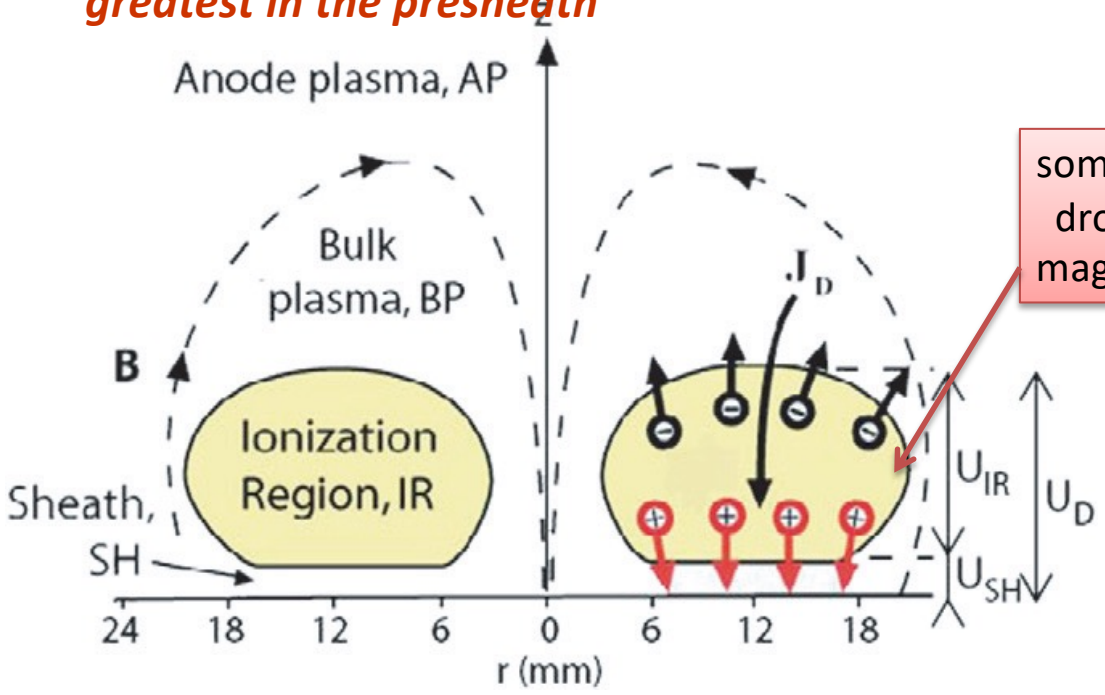
Mode Nomenclature



A. Anders, Appl. Phys. Rev. 11 (2024) 031310.

Beyond electron sheath energization: Ohmic heating

- **Penning-Thornton paradigm**: secondary electrons are energized in the sheath $E_{SE} = eV_{sheath}$
- However, electron current in the **presheath** is much greater and than in the sheath while voltage drop is still substantial → ***electron heating and energy dissipation and can be greatest in the presheath***



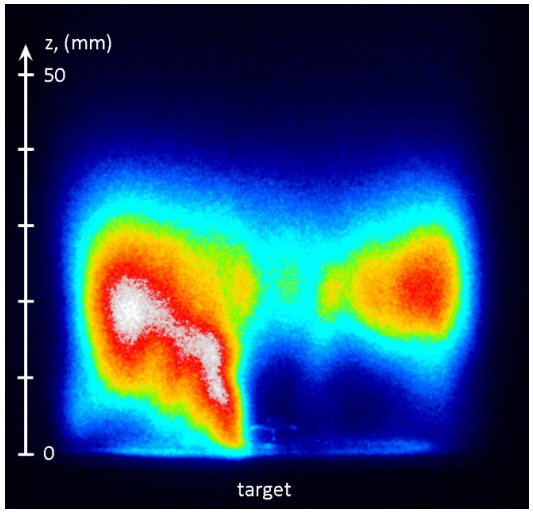
some of the voltage drops here, in the magnetic presheath

global model of the ionization region:
M.A. Raadu, *et al.*, Plasma Sources Sci. Technol. **20** (2011) 065007.

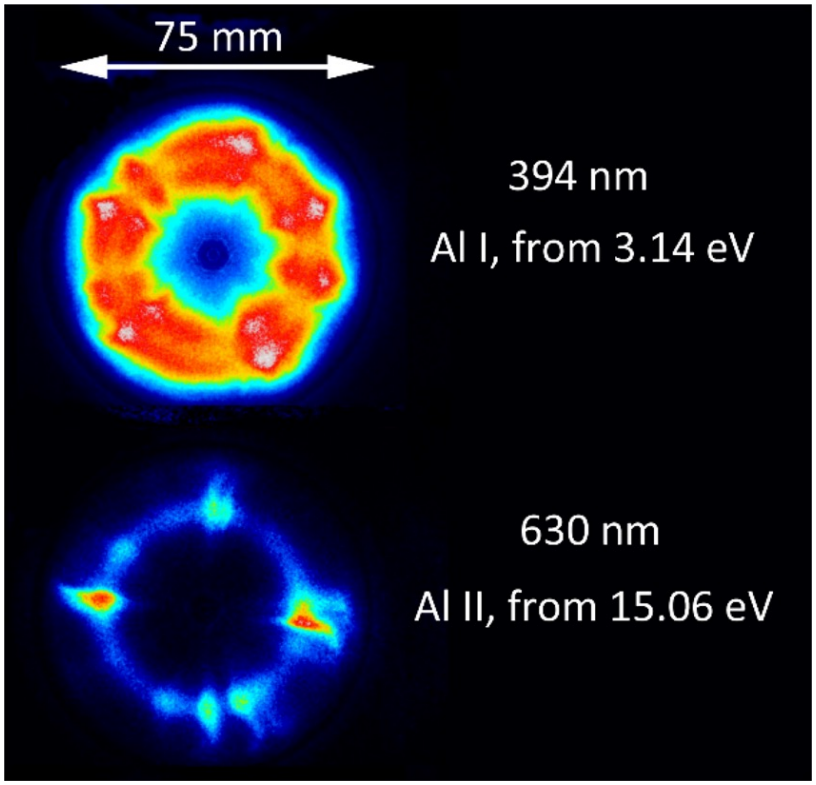
electron heating in presheath:
C. Huo, *et al.*, Plasma Sources Sci. Technol. **22** (2013) 045005.

Magnetron discharges are partial Ohmic discharges

Much power dissipation occurs in a structured presheath



Spectroscopic imaging, side view in the light of Ar II 436 nm; 7.5 cm Al target, Ar, current at the time of this image was 100 A



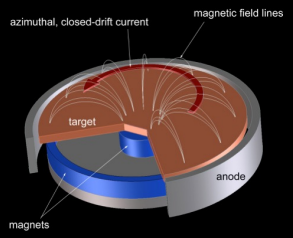
Spectroscopic imaging in light of Al atom and ions

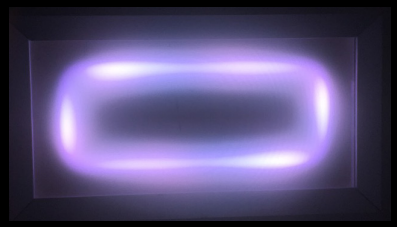
- global model averages over azimuthal coordinate, but ohmic heating of electron occurs in spokes, locations of space charge double layers

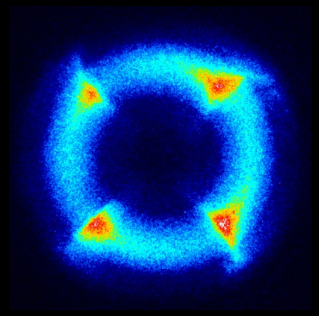
→ spectroscopic images can be interpreted as images of electric potential, electron heating, and power dissipation

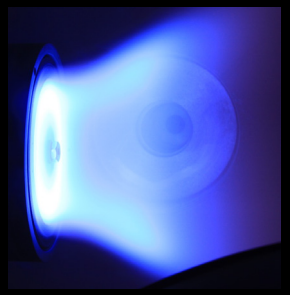
J. Andersson, *et al*., Appl. Phys. Lett. 103 (2013) 054104.

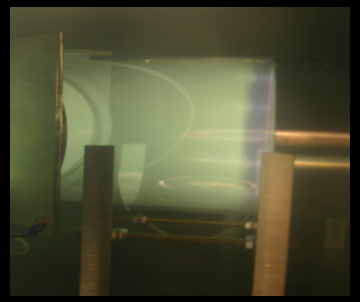
Summary, Take-aways







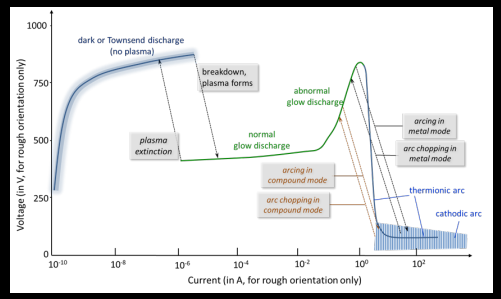




1. Main Activities of Plasma Engineering LLC:
    - Consulting in the fields of plasma-assisted processing
    - Educational services (like custom workshops for staff)

2. Range of plasma processes is very wide (think: materials, process power, pressure, mode of operation etc.)

3. Plasma Engineering can serve as a bridge to academia and also engage in proprietary works under a mutual NDA.



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