The Effect of Anode Material and Secondary Gas Injection on Self-organized Patterns in Atmospheric Pressure Glows

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Abstract

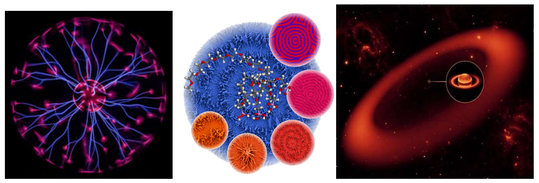
Plasma self –organization on anode surfaces in DC glow discharges remains poorly understand. This effort aims to elucidate the nature of self-organization through the study of resulting patterns on both metal and liquid electrode surfaces. Self-organization pattern formation and behavior were studied as a function of inter-electrode spacing, electrode material type, gas composition and gas flow rate using fast camera imaging. The response of the patterns to variation in these parameters is reported. These results are used as a basis for speculating upon the underlying physical processes that give rise to self-organization.

Keywords: *Self-organization, electrode material type, metal and liquid electrodes surfaces, gas injection.*

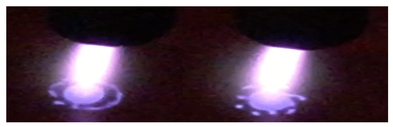
Introduction with Motivation

- **Self-organization pattern is ubiquitous in nature**

- **Pattern formation in plasma physics**



- **Questions in our research studying:**

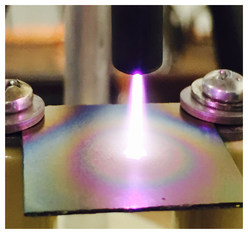


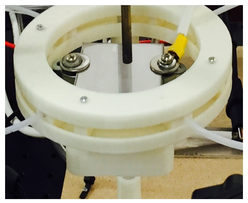
- Why do self-organized dots pattern form ?
- Why do dots pattern move?
- What is the composition of those pattern dots?
- Why do they seem to self-organized?
- Why do dots on metal surface return to the main attachment?
- What is the sign of the anode fall voltage?

Project Overview

Experiment Principle

- Flows 200 SCCM Helium gas to generate plasma between cathode (brass rod) and anode electrode (metal plates or liquid surface).
- Local gas injected to the metal surface in its diagonal direction by controlling the local gas flow rate at 5 SCFH.
- By adjusting the controlling parameters (gap length, discharge voltage and discharge current), self-organized patterns observed on anode surface.

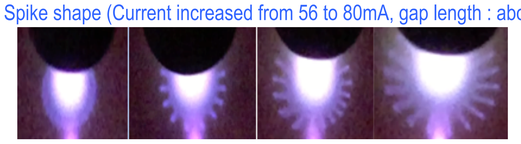




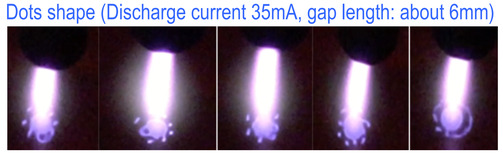
Patterns on Liquid Surface

Two types of pattern shape observed on sodium chloride solution

1. Spike shape (Current increased from 56 to 80mA, gap length : about 3mm)

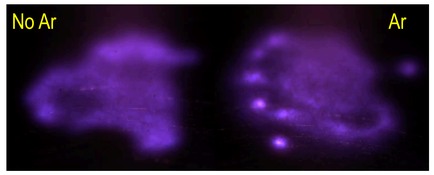


2. Dots shape (Discharge current 35mA, gap length: about 6mm)

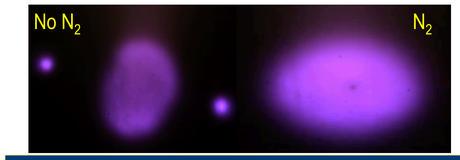


Secondary Gas Injection

Argon injection : More dots formed, plasma surface area and discharge current increased.

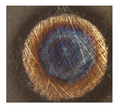


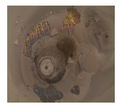
Nitrogen injection : Reduced dots formation, plasma surface area and discharge current slightly increased.

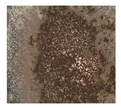


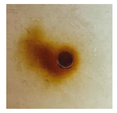
Anode Appearance after each Experiment

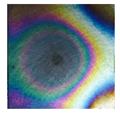
Heat pattern recorded after each experiment
surface melting, burning, and vaporizing
Local gas injection cool down the electrode surface

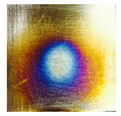

Stainless steel + Graphite


Tungsten + Ba


silicon

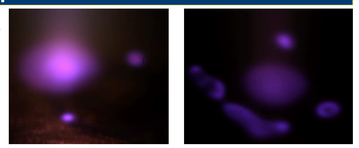

Stainless steel


Tungsten

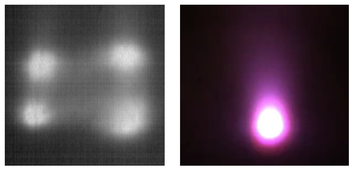

Tungsten after gas injection

Pattern Comparison on Anode material

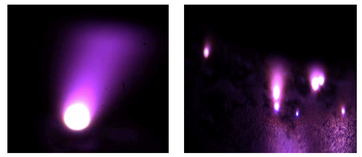
- Stainless steel (L) vs Stainless steel with graphite coating (R)
  Large patterns found with graphite coating



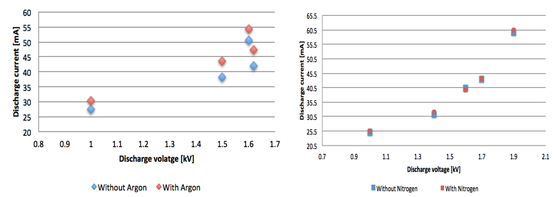
- Tungsten plate (L) vs Tungsten with Barium coating (R)
  Ba coating reduces pattern and stabilized main plasma

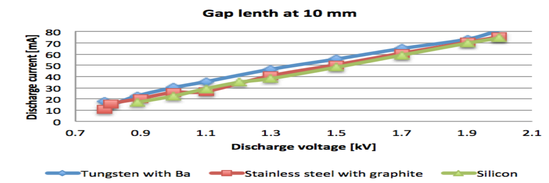


- Silicon
  Multiple attachment appeared when the surface was melting



Data Analysis in IV Curve





Conclusion

- **The influence of gas injection on tungsten plate resulted that self-organized patterns are sensitive with the ionization efficiency of the local gas . Particularly, Argon injection process had low energy loss and Nitrogen injection process gives high energy loss.**
- **The coating on anode metal surface effects self-organization pattern which varied the thermal condition of surface. Graphite lowered the conductivity of anode surface which required higher voltage for plasma to breakdown. Barium coating decreases the work function of tungsten plate surface.**
- **At 200 SCCM Helium flow, the gap length became a major controlling factor on anode of metal surface. Current controlling is more sensitive with liquid anode surface.**

Future Work

1. Continuously focus on objective the origin of self-organization formation by setting an advanced current diagnostics and exam it in below directions.
2. Study the self-organized pattern behavior by apply magnetic field.
3. Take parameter "time " into a consideration since it is not an ideal steady state situation.
4. Investigate the characteristic of self-organized anode patterns by testing space charge limit methodology.
5. Testing thermal feature of the anode surface.

Reference

Naoki Shirai, Uchida Satoshi, Fumiyoshi Tochikubo, and Shozo Ishii. "Self- Organized Anode Pattern on Surface of Liquid or Metal Anode in Atmospheric DC Glow Discharges." *IEEE TRANSACTION ON PLASMA SCIENCE* 39 (2011).