Study of glow discharge plasma in a hydrogen and helium mixture on the Uragan-2M

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Introduction

In the preparation and research of high-temperature plasma for magnetic confinement fusion, wall conditioning is an important and necessary procedure. There are various methods for wall conditioning, one of which is glow discharge [1-3]. Hydrogen or helium are usually used as working gases in glow discharge. A glow discharge is also used in the boronization procedure [4, 5]. In this case, a mixture of helium and diborane can be used, which releases hydrogen upon dissociation. Therefore, it is necessary to conduct research on glow discharge in a mixture of hydrogen and helium.

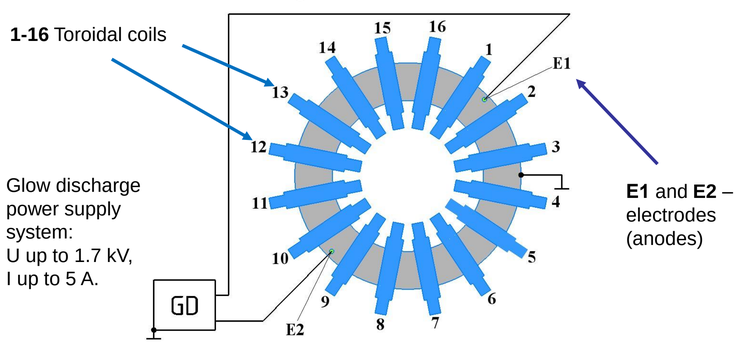
This paper presents the first results of a research study on glow discharge plasma in a mixture of helium and hydrogen, with hydrogen concentrations in the mixture from 25% to 75%. The current-voltage (I-V) characteristics of the discharges are obtained, the plasma parameters are measured, and its composition is determined.

Experimental setup and glow discharge (GD) system

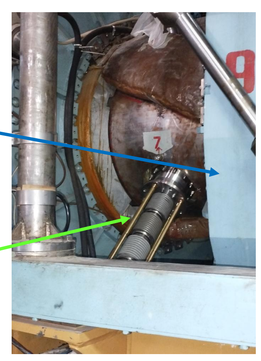
The Uragan-2M (U-2M) is a medium-size stellarator of the torsatron type, in Kharkiv (Ukraine).

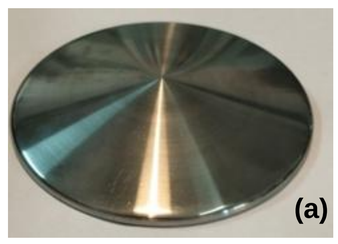
Stellarator Uragan-2M

Device characteristics	
Large radius	**1.7 m**
Minor radius	**0.34 m**
Volume of the torus	**3.879 m^3**
Surface area	**22.819 m^2**
Chamber pressure	**10^{-5} Pa**
Magnetic field	**≤ 2.4 T**
Helical coils	**2**
Toroidal coils	**16**



The scheme of glow discharge on Uragan-2M





Anode: top view (a), bottom view (b)

"new" anode	
Diameter	**130 mm**
Thickness	**5 mm**
Material	**Stainless steel**
Cooling	**Water**

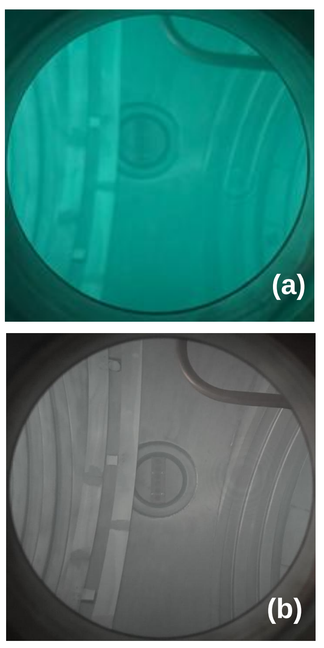
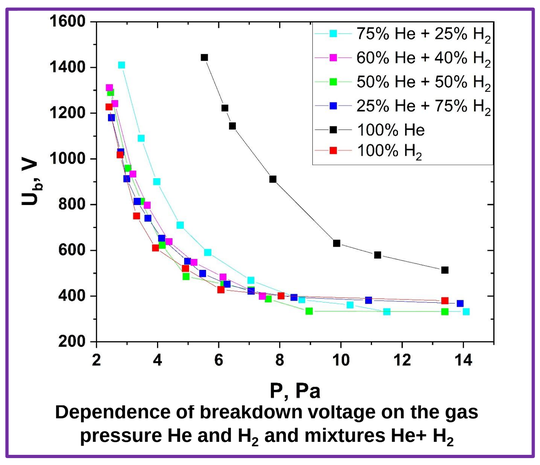
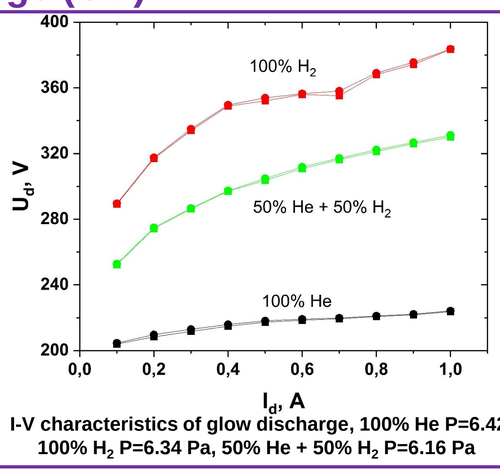


Photo emission of plasma in a glow discharge: 100% He (a), 50% He + 50% H_2 (b)

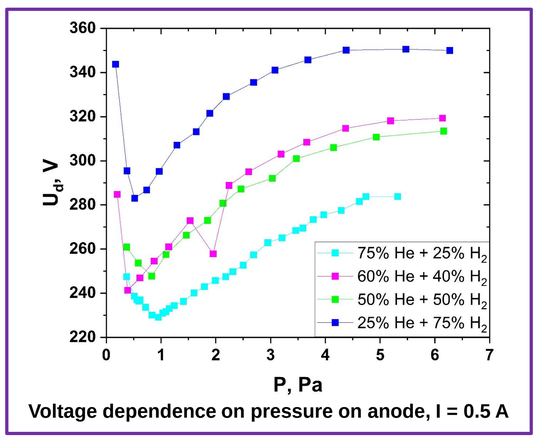
Glow discharge (GD)



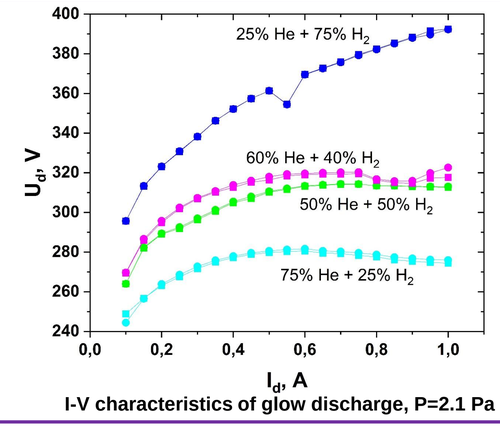
Dependence of breakdown voltage on the gas pressure He and H_2 and mixtures He+ H_2



I-V characteristics of glow discharge, 100% He P=6.42 Pa, 100% H_2 P=6.34 Pa, 50% He + 50% H_2 P=6.16 Pa

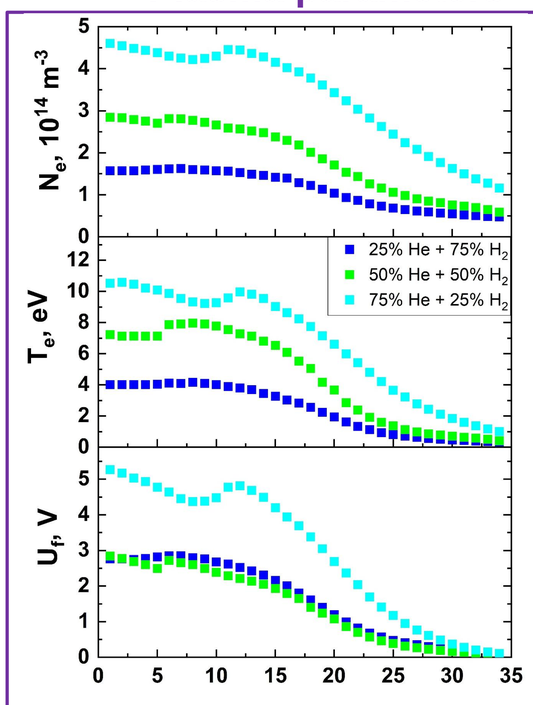


Voltage dependence on pressure on anode, I = 0.5 A



I-V characteristics of glow discharge, P=2.1 Pa

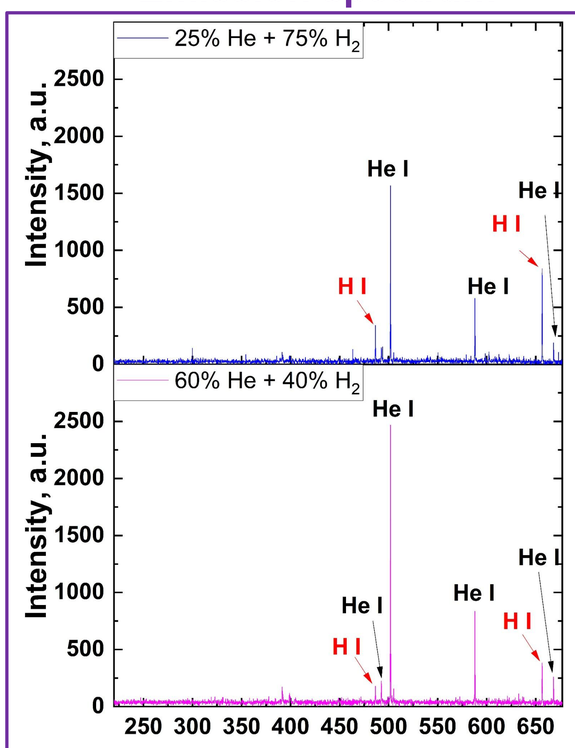
Plasma parameters



The radial profile of density (N_e), temperature (T_e) and floating potential (U_f)

Gas	P, Pa	U, V	I, A
25% He + 75% H_2	6.27	275	0.1
50% He + 50% H_2	6.15	275	0.1
75% He + 25% H_2	6.15	240	0.1

Emission spectrum



Optical emission spectrum of glow discharge, I=1 A.

Gas	P, Pa	U, V	I, A
25% He + 75% H_2	6.27	325	1
60% He + 40% H_2	6.14	299	1

Concluding remarks:

- **The glow discharge characteristic curve showed that an increase in voltage leads to an increase in discharge current. The experimentally observed I-V characteristics are similar to those of a hollow cathode discharge.**
- **The measured breakdown voltage is observed to be higher in the case when the He+H_2 mixture contains a higher percentage of He than H_2 (75 % He + 25% H_2).**
- **The maximum values of plasma parameters are observed in the centre of the plasma column, but at 75% He + 25% H_2 the parameters are higher than for other mixtures. For example, the plasma density was up to ≈ $4.6 \cdot 10^{14}$ m^{-3}, the temperature was up to ≈ 10.5 eV, the floating potential was up to ≈ 5.3 V. Plasma parameters can be said to be characteristic of glow discharge.**
- **In the optical spectrum of plasma emission, the lines of excited He I (He*), hydrogen atoms H I (H*) are observed.**

References

1. Wauters T. et al. "Wall conditioning in fusion devices with superconducting coils," Plasma Physics and Controlled Fusion 62 (2020): 034002.
2. Kovtun Y. V. et al., "Design and Application of Glow Discharge Cleaning at Uragan-2M Stellarator," Probl. At. Sci. Technol., Problems of Atomic Science And Technology 27 (2021): 19-24.
3. Yu. Martsenuik et al. "Upgrade glow discharge cleaning system on the Uragan-2M stellarator," 51st EPS Conference on Plasma Physics, Vilnius, Lithuania, July, 2025. 2 P 110.
4. Winter, J. et al. "Boronization in TEXTOR." Journal of Nuclear Materials 162 (1989): 713-723.
5. M. Mayer et al. "Properties of boron layers deposited during boronisations in W7-X," Nuclear Materials and Energy 41 (2024): 101778.

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