

[handwritten:] 61 95-1/593-2

MOSCOW ENGINEERING PHYSICS INSTITUTE  
(TECHNICAL UNIVERSITY)

---

This material may be protected by Copyright law (Title 17 U.S. Code)

Manuscript

Dmitriy V. MOZGRIN

**HIGH-CURRENT LOW-PRESSURE  
QUASI-STATIONARY DISCHARGE IN A MAGNETIC FIELD:  
EXPERIMENTAL RESEARCH**

04/01/08 - Plasma Physics and Chemistry

Ph.D. Thesis in Physics and  
Mathematics

Author [signature]

Research advisor [signature]

of the Ph.D. candidate in Physics and Mathematics

Associate Professor Igor Konstantinovich Fetisov

Moscow - 1994

## TABLE OF CONTENTS

|  |     |
|--|-----|
| TABLE OF CONTENTS.....   | 2   |
| INTRODUCTION.....  | 4   |
| Chapter 1. High-current low-pressure discharges in a magnetic field and their use for generation of dense plasma and intense flows of charged particles..... | 7   |
| 1.1 Experimental research of low-pressure gas discharge in a magnetic field and its application in modern technology.....                                    | 7   |
| 1.2 Methods for generating high-power low-pressure discharges with homogeneous plasma structure.....   | 25  |
| Conclusions.....   | 32  |
| Chapter 2. Experiment methods and techniques.....  | 34  |
| 2.1 The experimental setup.....  | 34  |
| 2.2 The probe method for determining plasma and ion flow parameters.....   | 45  |
| 2.3 Double-mode laser method for determining the density of the plasma.....  | 54  |
| 2.4 Pulsed biasing.....  | 57  |
| Chapter 3. Parameter ranges and conditions of high-current low-pressure quasi-stationary discharge in a magnetic field of various configurations.....        | 59  |
| 3.1 Quasi-stationary discharge regimes.....  | 59  |
| 3.2 Application of pulse probe method to determine plasma and ion flow parameters.....   | 73  |
| 3.3 Determination of the discharge plasma parameters by double-mode laser interferometry.....  | 82  |
| 3.4 Discussion of results.....   | 87  |
| Chapter 4. Emission and sputtering characteristics of the high-current low-pressure quasi-stationary discharge.....  | 100 |
| 4.1 Features of cathode sputtering in a high-current quasi-stationary magnetron discharge and implementation thereof in pulsed sputtering technology.....    | 100 |

4.2 Emission properties of the high-current diffuse discharge plasma and  
implementation thereof in the technology of ion-stimulated etching of  
materials..... 103

CONCLUSION..... 110

REFERENCES ..... 111

## **INTRODUCTION.**

Low-pressure discharges in a transverse magnetic field are the subject of intensive research due to their wide use in technological magnetron devices, closed-electron-drift plasma accelerators, and as plasma emitters in electron and ion injectors.

An analysis of the literature shows that the properties of the discharge in a transverse magnetic field with closed electron drift in the area of transition from a magnetron discharge with a growing current-voltage characteristic to an arc discharge are practically unknown. There are no sound theoretical and experimental data to determine the limit regimes of the magnetron discharge in which most technological devices operate. The study of high-power pulsed discharges used for the generation of dense homogeneous plasma indicates the possibility of existence of stable forms of discharge in a magnetic field, not transiting to a contracted phase at high currents, and generally corresponding to the arc regime of the current-voltage characteristic of such discharges.

Purpose of the research:

To study the current-voltage characteristics and the regimes of existence of the high-current quasi-stationary low-pressure discharge in magnetic fields of different configurations.

To determine the local plasma characteristics of the above-mentioned forms of discharge.

To study the possibility of using a high-current discharge plasma to generate dense plasma formations and intense flows of charged particles.

Scientific novelty and practical value of the work:

In carrying out this work, we have investigated a range of parameters and regimes of high-current forms of quasi-stationary low-pressure discharge in magnetic fields of different configurations.

A new stable form of quasi-stationary discharge in a transverse magnetic field was discovered, which is an intermediate stage of transition from the magnetron discharge to the arc discharge (high-current diffuse mode) and has the following main characteristics: voltage  $\approx 100$  V, duration of several milliseconds, and current intensity range between 10 A and  $2 \times 10^3$  A. A qualitative model is proposed, explaining the possible mechanism of emergence and existence of this type of discharge.

We have established the existence of a high-voltage high-current form of quasi-stationary magnetron discharge (high-current magnetron regime), characterized by high voltage (up to 1200 V) and high cathode current density (up to  $25 \text{ A/cm}^2$ ). The duration of this type of discharge can exceed 20 ms.

We have indicated the possibility of obtaining plasma formations with a density of up to  $1.5 \times 10^{15} \text{ cm}^{-3}$  in a volume of up to  $1000 \text{ cm}^3$ , which ensures the emission of an ion beam with a density of more than  $10 \text{ A/cm}^2$  and an energy of 100 eV.

We have also demonstrated the possibility of intensive cathode sputtering and creation of high density flows of sputtered material particles.

The results obtained are used:

- In new plasma technology for ion-stimulated etching and in building a plasma reactor for rapid layer etching (NPO [*Nauchnoe-*

# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

## Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

## Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

## Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

## API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

## LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

## FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

## E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.