



# Contents

---

Elementary Plasma Reactions of Environmental Interest	
D. Smith and N. G. Adams	1
Plasma-Materials Interactions and Impurity Control in Magnetically Confined Thermonuclear Fusion Machines	
D. M. Gruen, S. Vepřek, and R. B. Wright	45
Preparation of Optical Waveguides with the Aid of Plasma-Activated Chemical Vapour Deposition at Low Pressures	
D. Küppers and H. Lydtin	107
Subject Index	133
Author Index Volumes 26–89	135

---



# Elementary Plasma Reactions of Environmental Interest

David Smith and Nigel G. Adams

Department of Space Research, University of Birmingham, Birmingham, B15 2TT, England

## Table of Contents

<b>1</b>	<b>Introduction</b>	2
<b>2</b>	<b>Description of the Environmental Plasma</b>	3
2.1	The Neutral Atmosphere: Composition and Temperature	3
2.2	The Ionized Atmosphere: Ion Composition and Number Density	6
<b>3</b>	<b>Elementary Charged-Particle Reactions of Significance in the Environmental Plasma</b>	13
3.1	General Considerations	13
3.2	Individual Reaction Processes	15
3.2.1	Experimental Techniques	15
3.2.2	Binary Ion-Molecule Reactions	17
3.2.3	Ternary Ion-Molecule Reactions	23
3.2.4	Electron-Ion Dissociative Recombination	29
3.2.5	Ion-Ion (Ionic) Recombination	31
<b>4</b>	<b>Current Status of Atmospheric Ion Chemistry</b>	34
	<b>References</b>	39



# Plasma-Materials Interactions and Impurity Control in Magnetically Confined Thermonuclear Fusion Machines\*

Dieter M. Gruen<sup>1</sup>, Stanislav Vepřek<sup>2</sup>, and Randy B. Wright<sup>1</sup>

1 Chemistry Division, Argonne National Laboratory, Argonne, Illinois 60439, USA

2 Institute of Inorganic Chemistry, University of Zurich, 8057 Zurich, Switzerland

*Progress achieved in plasma heating and magnetic confinement during the past decade has brought to the fore a number of problems which have to be solved if controlled thermonuclear fusion is to become an economically and environmentally acceptable energy source. Among them, the interactions of plasmas with solid surfaces represent a very serious obstacle to the achievement of a positive energy balance in the next generation of magnetic fusion devices. In present devices, plasma energy losses are dominated by radiation due to impurities released from the limiter and the vacuum vessel wall. The processes leading to impurity release are complex and still poorly understood, as are the mechanisms of impurity transport. The present chapter summarizes the status of this field at the beginning of 1979. The various elementary processes are discussed and an attempt is made to point out problems towards which future research has to be directed. Various approaches suggested up to now for impurity control as well as potential solutions to the materials erosion problem are discussed. Clearly, the elucidation of plasma-materials interactions presents a challenge to a broad spectrum of chemists, physicists and materials scientists.*

## Table of Contents

<b>1 Introduction</b>	47
<b>2 The Physics and Technology of Controlled Thermonuclear Fusion</b>	47
2.1 Thermonuclear Fusion Reactions	48
2.2 Confinement System	49
<b>3 The Role of Impurities in Tokamaks</b>	59
3.1 Effect of Impurities on Plasma Characteristics	59
3.2 Fluxes to the Wall	61
3.3 Survey of Impurity Release Mechanisms	63
<b>4 Hydrogen Isotope Recycling</b>	64
4.1 Reflection	65
4.2 Gas Re-emission and Trapping	67

---

\* Work performed in part under the auspices of the US Department of Energy and the Swiss National Science Foundation

<b>5</b>	<b>Impurity Release Mechanisms</b>	72
5.1	Sputtering	72
5.1.1	Physical Sputtering	72
5.1.2	Physicochemical Sputtering	75
5.2	Chemical Erosion	75
5.3	Desorption	77
5.3.1	Photon and Electron Induced Desorption	77
5.3.2	Ion and Neutral Impact Desorption	78
5.4	Vaporization	79
5.5	Blistering and Flaking	80
5.6	Other Mechanisms	81
5.6.1	Unipolar Arcing	81
5.6.2	Metal Snow	82
5.7	Interactive Effects	83
<b>6</b>	<b>Impurity Control</b>	84
6.1	Divertors	85
6.2	Discharge Cleaning	86
6.3	Protective Coatings	87
6.3.1	Coated Limiters and Beam Dumps	89
6.3.2	In-Situ Deposition	89
6.4	Trapping Surfaces	91
6.4.1	Mechanism of Chemical Trapping of Deuterium and Tritium in Metals	92
6.4.2	Characteristics of a Trapping Surface in a Thermonuclear Reactor	93
6.5	Near Surface Modifications and Secondary Ion Emission	94
6.5.1	Ion Nitriding	96
6.5.2	Plasma Nitriding	96
<b>7</b>	<b>Conclusions</b>	99
<b>8</b>	<b>References</b>	100







# Preparation of Optical Waveguides with the Aid of Plasma-Activated Chemical Vapour Deposition at Low Pressures

D. Küppers and H. Lydtin

Philips GmbH Forschungslaboratorium Aachen, D-5100 Aachen, F.R.G.

## Table of Contents

<b>1</b>	<b>Introduction</b>	108
<b>2</b>	<b>Optical Fibers for Telecommunication</b>	108
2.1	Attenuation and Pulse Broadening in Optical Fibers	109
2.2	Preparation Methods	111
<b>3</b>	<b>Plasma-Activated Deposition for Optical Preform Preparation</b>	113
3.1	General Aspects	113
3.2	Experimental Set-Up	114
3.3	Local Deposition of Silica	115
3.3.1	Depositions Profile of Silica; Experimental Results	115
3.3.2	Deposition Profile; Discussion	117
3.3.3	Properties of the Layers	120
	I Influence of the Tube Temperature	120
	II Impurity Content of the Layers	120
3.4	Co-Deposition of Silica and Germanium	121
3.4.1	Local Deposition of Doped Silica	121
3.4.2	Deposition of Doped Silica Layers	122
	I Reactor Movement in the Direction of the Gas Flow	122
	II Movement of the Reactor Against the Gas Flow	123
3.4.3	Deposition of Multilayer Structure	124
3.5	Deposition of Silica Doped with Materials Other than Germanium	125
3.5.1	Deposition of Silica from $\text{SiCl}_4/\text{SiF}_4/\text{O}_2$ Gas Mixtures	125
3.5.2	Incorporation of Boron Oxide	127
3.6	Optical Properties of the Resulting Fibers	128
<b>4</b>	<b>Summary</b>	130
<b>5</b>	<b>References</b>	130