

Contents

Foreword	<i>XIII</i>
Preface	<i>XV</i>
Acknowledgment	<i>XVII</i>

1	Introduction to Pyrolants	1
	References	3
2	History	6
2.1	Organometallic Beginning	6
2.2	Explosive & Obscurant Properties	8
2.3	Rise of Fluorocarbons	10
2.4	Rockets Fired Against Aircraft	13
2.5	Metal/Fluorocarbon Pyrolants	15
	References	17
	Further Reading	19
3	Properties of Fluorocarbons	20
3.1	Polytetrafluoroethylene (PTFE)	20
3.2	Polychlorotrifluoroethylene (PCTFE)	22
3.3	Polyvinylidene Fluoride (PVDF)	24
3.4	Polycarbon Monofluoride (PMF)	25
3.5	Vinylidene Fluoride–Hexafluoropropene Copolymer	27
3.5.1	LFC-1	28
3.6	Vinylidene Fluoride–Chlorotrifluoroethylene Copolymer	28
3.7	Copolymer of TFE and VDF	30
3.8	Terpolymers of TFE, HFP and VDF	31
3.9	Summary of chemical and physical properties of common fluoropolymers	33
	References	33
4	Thermochemical and Physical Properties of Metals and their Fluorides	36
	References	41

5	Reactivity and Thermochemistry of Selected Metal/Fluorocarbon Systems	42
5.1	Lithium	42
5.2	Magnesium	45
5.3	Titanium	47
5.4	Zirconium	52
5.5	Hafnium	53
5.6	Niob	53
5.7	Tantalum	54
5.8	Zinc	55
5.9	Cadmium	56
5.10	Boron	57
5.11	Aluminium	59
5.12	Silicon	63
5.13	Calcium Silicide	64
5.14	Tin	65
	References	66
6	Ignition and Combustion Mechanism of MTV	68
6.1	Ignition and Pre-Ignition of Metal/Fluorocarbon Pyrolants	68
6.2	Magnesium–Grignard Hypothesis	68
	References	77
7	Ignition of MTV	80
	References	85
8	Combustion	87
8.1	Magnesium/Teflon/Viton	87
8.1.1	Pressure Effects on the Burn Rate	87
8.1.2	Particle Size Distribution and Surface Area Effects on the Burn Rate	88
8.2	Porosity	95
8.3	Burn Rate Description	96
8.4	Combustion of Metal–Fluorocarbon Pyrolants with Fuels Other than Magnesium	97
8.4.1	Magnesium Hydride	97
8.4.2	Alkali and Alkaline Earth Metal	98
8.4.2.1	Lithium	98
8.4.2.2	Magnesium–Aluminium Alloy	99
8.4.3	Titan	99
8.4.4	Zirconium	102
8.4.5	Zinc	103
8.4.6	Boron	104
8.4.7	Magnesium Boride, MgB_2	105
8.4.8	Aluminium	105

8.4.9	Silicon	108
8.4.10	Silicides	110
8.4.10.1	Dimagnesium Silicide, Mg_2Si	110
8.4.10.2	Calcium Disilicide	111
8.4.10.3	Zirconium Disilicide	113
8.4.11	Tungsten–Zirconium Alloy	113
8.5	Underwater Combustion	114
	References	115
9	Spectroscopy	119
9.1	Introduction	119
9.2	UV–VIS Spectra	120
9.2.1	Polytetrafluoroethylene Combustion	121
9.2.2	Magnesium/Fluorocarbon Pyrolants	122
9.2.3	MgH_2 , MgB_2 , Mg_3N_2 , $\text{Mg}_2\text{Si}/\text{Mg}_3\text{Al}_2$ /Fluorocarbon Based pyrolants	128
9.2.4	Silicon/PTFE Based Pyrolants	133
9.2.5	Boron/PTFE/Viton Based Pyrolants	134
9.3	MWIR Spectra	135
9.3.1	Polytetrafluoroethylene Combustion	136
9.3.2	Magnesium/Fluorocarbon Combustion	136
9.3.3	MgH_2 , MgB_2 , Mg_3N_2 , $\text{Mg}_2\text{Si}/\text{Fluorocarbon}$ Based Pyrolants	139
9.3.4	Si/Fluorocarbon Based Pyrolants	140
9.3.5	Boron/PTFE/Viton Based Pyrolants	141
9.4	Temperature Determination	141
9.4.1	Condensed-Phase Temperature	142
9.4.2	Gas-Phase Temperature	144
	References	148
10	Infrared Emitters	151
10.1	Decoy Flares	151
10.2	Nonexpendable Flares	153
10.2.1	Target Augmentation	153
10.2.2	Missile Tracking Flares	156
10.3	Metal–Fluorocarbon Flare Combustion Flames as Sources of Radiation	158
10.3.1	Flame Structure and Morphology	160
10.3.2	Radiation of MTV	162
10.4	Infrared Compositions	165
10.4.1	Inherent Effects	166
10.4.1.1	Influence of Stoichiometry	166
10.4.2	Spectral Flare Compositions	180
10.4.3	Particle Size Issues	181
10.4.4	Geometrical Aspects	181
10.5	Operational Effects	184

10.5.1	Altitude Effects	184
10.5.2	Windspeed Effects	186
10.6	Outlook	191
	References	193
11	Obscurants	197
11.1	Introduction	197
11.2	Metal–Fluorocarbon Reactions in Aerosol Generation	199
11.2.1	Metal–Fluorocarbon Reactions as an Exclusive Aerosol Source	200
11.2.2	Metal–Fluorocarbon Reactions to Trigger Aerosol Release	201
11.2.2.1	Metal–Fluorocarbon Reactions to Trigger Soot Formation	201
11.2.2.2	Metal–Fluorocarbon Reactions to Trigger Phosphorus Vaporisation	204
	References	208
12	Igniters	210
	References	214
13	Incendiaries, Agent Defeat, Reactive Fragments and Detonation Phenomena	216
13.1	Incendiaries	216
13.2	Curable Fluorocarbon Resin–Based Compositions	217
13.3	Document Destruction	218
13.4	Agent Defeat	221
13.5	Reactive Fragments	223
13.6	Shockwave Loading of Metal–Fluorocarbons and Detonation-Like Phenomena	229
	References	232
	Further Reading	234
14	Miscellaneous Applications	235
14.1	Submerged Applications	235
14.1.1	Underwater Explosives	235
14.1.2	Underwater Flares	235
14.1.3	Underwater Cutting Torch	236
14.2	Mine-Disposal Torch	238
14.3	Stored Chemical Energy	240
14.3.1	Heating Device	240
14.3.2	Stored Chemical Energy Propulsion	240
14.4	Tracers	240
14.5	Propellants	241
	References	244
15	Self-Propagating High-Temperature Synthesis	247
15.1	Introduction	247

15.2	Magnesium	249
15.3	Silicon and Silicides	252
	References	256
16	Vapour-Deposited Materials	258
	References	262
17	Ageing	264
	References	270
18	Manufacture	271
18.1	Introduction	271
18.2	Treatment of Metal Powder	271
18.3	Mixing	273
18.3.1	Shock Gel Process	273
18.3.1.1	Procedure A	273
18.3.1.2	Procedure B	275
18.3.2	Conventional Mixing	276
18.3.3	Experimental Super Shock Gel Process	276
18.3.4	Experimental Dry Mixing Technique	280
18.3.5	Experimental Cryo-N ₂ Process	282
18.3.6	Extrusion	282
18.3.6.1	Twin Screw Extrusion	282
18.4	Pressing	286
18.5	Cutting	289
18.6	Priming	289
18.7	Miscellaneous	289
18.8	Accidents and Process Safety	290
18.8.1	Mixing	290
18.8.2	Pressing	293
18.8.3	Process Analysis	294
18.8.4	Personal Protection Equipment (PPE)	294
	References	296
19	Sensitivity	299
19.1	Introduction	299
19.2	Impact Sensitivity	300
19.2.1	MTV	300
19.2.2	Titanium/PTFE/Viton and Zirconium/PTFE/Viton	300
19.2.3	Metal-Fluorocarbon Solvents	301
19.2.4	Viton as Binder in Mg/NaNO ₃	301
19.3	Friction and Shear Sensitivity	301
19.3.1	Metal/Fluorocarbon	303
19.4	Thermal Sensitivity	304
19.4.1	MTV	304

19.5	ESD Sensitivity	305
19.6	Insensitive Munitions Testing	310
19.6.1	Introduction	310
19.6.2	Cookoff	314
19.6.3	Bullet Impact	316
19.6.4	Sympathetic Reaction	319
19.6.5	IM Signature Summary	320
19.7	Hazards Posed by Loose In-Process MTV Crumb and TNT Equivalent	321
	References	323
20	Toxic Combustion Products	326
20.1	MTV Flare Composition	326
20.2	Obscurant Formulations	330
20.3	Fluorine Compounds	331
20.3.1	Hydrogen Fluoride	331
20.3.2	Aluminium Fluoride	331
20.3.3	Magnesium Fluoride	332
	References	332
21	Outlook	334
	References	335
	Index	337