

Polystyrene

Table of Contents

A Report by **NexantThinking™**

Process Evaluation/Research Planning (PERP) Program

PERP Report 2016-6 – Published December 2016

www.nexantthinking.com

Section	Page
1 Executive Summary	1
1.1 INTRODUCTION.....	1
1.2 TECHNOLOGY	2
1.2.1 Technology Licensing Status	2
1.2.2 Technology Overview.....	2
1.3 PROCESS ECONOMICS.....	4
1.3.1 General Purpose Polystyrene Process Economics	4
1.3.2 High Impact Polystyrene Process Economics	5
1.3.3 Expandable Polystyrene Process Economics.....	6
1.4 GLOBAL MARKET ANALYSIS	7
1.4.1 General Purpose Polystyrene and High Impact Polystyrene Market Overview	7
1.4.2 Expandable Polystyrene Market Overview	8
2 Introduction.....	10
2.1 POLYSTYRENE TYPES AND GRADES	11
2.1.1 General Purpose Polystyrene	11
2.1.2 High Impact Polystyrene	11
2.1.3 Expandable Polystyrene	12
2.1.4 Syndiotactic Polystyrene	12
2.1.5 Speciality Grades	13
2.1.6 Styrene Copolymers.....	13
2.2 TECHNOLOGY OVERVIEW.....	14
2.3 MAJOR PRODUCERS.....	15
2.4 INDUSTRY STRUCTURE AND BUSINESS DEVELOPMENTS.....	17
2.5 TECHNOLOGY HOLDERS AND LICENSORS	20

2.6	ENVIRONMENTAL AND HEALTH HAZARDS	24
2.7	REGULATIONS.....	25
2.8	STORAGE AND TRANSPORT.....	26
3	Chemistry	27
3.1	OVERVIEW OF CHEMISTRY.....	28
3.2	POLYMERIZATION MECHANISMS.....	29
3.2.1	Free-Radical Polymerization.....	29
3.2.2	Ionic Polymerization	31
3.2.3	Ziegler-Natta and Metallocene Polymerization	31
3.2.4	Copolymerization – HIPS	33
4	Generic Process Descriptions	35
4.1	GENERAL PURPOSE POLYSTYRENE CONTINUOUS (BULK/MASS) PROCESS	35
4.1.1	Polymerization Reactor Design.....	36
4.1.2	Devolatilization	37
4.2	HIGH IMPACT POLYSTYRENE CONTINUOUS (MASS) PROCESS	38
4.3	EXPANDABLE POLYSTYRENE.....	39
4.3.1	Suspension Process.....	39
4.3.2	Continuous (Mass) Process	40
4.4	SYNDIOTACTIC POLYSTYRENE	41
5	Commercial Technology.....	42
5.1	INTRODUCTION.....	42
5.2	GENERAL PURPOSE AND HIGH IMPACT POLYSTYRENE TECHNOLOGY	44
5.2.1	Total Petrochemicals.....	44
5.2.2	INEOS Styrolution	51
5.2.3	Versalis.....	56
5.2.4	NOVA Chemicals	61
5.2.5	Toyo-Mitsui	66
5.2.6	POLYSTY	70
5.2.7	Sulzer Chemtech.....	76
5.3	EXPANDABLE POLYSTYRENE TECHNOLOGY	79
5.3.1	INEOS Styrenics	79
5.3.2	Versalis.....	81
5.3.3	NOVA Chemicals	83
5.3.4	POLYSTY	85

5.3.5	Sulzer Chemtech.....	87
6	Developing Technology.....	89
6.1	HIPS PATENT REVIEW.....	89
6.1.1	Versalis HIPS Integrated Continuous Process	89
6.1.2	HIPS Increasing Rubber-Phase Volume.....	91
6.1.3	HIPS Crosslinking Control.....	91
6.2	EPS PATENT REVIEW.....	92
6.2.1	Improvement to EPS Insulation and Fire Retardant Properties	92
6.2.2	Carbon Dioxide as an EPS Blowing Agent	92
7	Process Economics.....	93
7.1	COSTING BASIS	93
7.1.1	Investment Basis	93
7.1.2	Pricing Basis.....	93
7.1.3	Cost of Production Basis	95
7.2	COST OF PRODUCTION ESTIMATES.....	96
7.2.1	General Purpose Polystyrene (GPPS).....	96
7.2.2	High Impact Polystyrene (HIPS)	99
7.2.3	Expanded Polystyrene (EPS).....	102
8	General Purpose and High Impact Polystyrene Market Review	105
8.1	GLOBAL	105
8.1.1	Consumption	105
8.1.2	Supply	106
8.1.3	Supply/Demand and Trade	107
8.2	NORTH AMERICA	109
8.2.1	Consumption	109
8.2.2	Supply	111
8.2.3	Supply/Demand and Trade	112
8.3	WESTERN EUROPE	114
8.3.1	Consumption	114
8.3.2	Supply	114
8.3.3	Supply/Demand and Trade	116
8.4	ASIA PACIFIC	117
8.4.1	Consumption	117
8.4.2	Supply	121
8.4.3	Supply/Demand and Trade	125

9	Expandable Polystyrene Market Review.....	129
9.1	GLOBAL	129
9.1.1	Consumption	129
9.1.2	Supply	130
9.1.3	Supply/Demand and Trade	131
9.2	NORTH AMERICA	133
9.2.1	Consumption	133
9.2.2	Supply	134
9.2.3	Supply/Demand and Trade	135
9.3	WESTERN EUROPE	137
9.3.1	Consumption	137
9.3.2	Supply	138
9.3.3	Supply/Demand and Trade	139
9.4	ASIA PACIFIC	141
9.4.1	Consumption	141
9.4.2	Supply	144
9.4.3	Supply/Demand and Trade	149
10	Glossary	152
11	References	154

	Appendix	Page
A	Definition of Capital Cost Terms Used in Process Economics	A-1
B	Definitions of Operating Cost Terms Used in Process Economics	B-1
C	Cost of Production Estimates	C-1
D	PERP Program Title Index (2007 - 2016)	D-1

Figure	Page
1.1 Styrene Polymerization	1
1.2 Regional Cost of Production Summary for GPPS.....	4
1.3 Regional Cost of Production Summary for HIPS	5
1.4 Regional Cost of Production Summary for EPS.....	6
1.5 Global Polystyrene Supply and Demand	8
1.6 Global EPS Supply and Demand	9
2.1 Global Polystyrene (GPPS/HIPS/EPS) Capacity Share by Region	15
2.2 Global Polystyrene (GPPS/HIPS/EPS) Capacity Share by Marketer	17
3.1 Polystyrene Structures	27
3.2 Styrene Polymerization	28
3.3 Formation of the Styrene Dimer Radical	29
3.4 Free Radical Polymerization Mechanism.....	30
3.5 Metallocene Catalyst Used for Syndiotactic Polystyrene (SPS) Production.....	31
3.6 Catalysts used for Syndiotactic Polystyrene Production	32
3.7 Metallocene Catalyst Used for Styrene-Ethylene Copolymerization.....	32
3.8 Phenyl-Phenyl Interaction and Chain Propagation Mechanism.....	33
3.9 HIPS Copolymerization Mechanism.....	34
5.1 Total Petrochemicals/ Atochem GPPS Continuous Process (Process Flow)	46
5.2 Total Petrochemicals GPPS Continuous Process (Process Flow)	47
5.3 Total Petrochemicals HIPS Continuous Process (Process Flow).....	49
5.4 Total Petrochemicals HIPS Integrated Continuous Process (Process Flow)	50
5.5 INEOS Styrolution GPPS Continuous Process (Process Flow).....	52
5.6 INEOS Styrolution HIPS Continuous Process (Process Flow)	55
5.7 Versalis GPPS Continuous Process (Process Flow)	57
5.8 Versalis HIPS Continuous Process (Process Flow)	59
5.9 NOVA/Huntsman/Shell GPPS Continuous Process (Process Flow)	63
5.10 NOVA/Huntsman/Shell HIPS Continuous Process (Process Flow).....	65
5.11 Toyo-Mitsui GPPS Continuous Process (Process Flow)	67
5.12 Toyo-Mitsui HIPS Continuous Process (Process Flow)	69
5.13 POYLSTY DV Plus Devolatizer.....	71
5.14 POYLSTY GPPS Process.....	73
5.15 POYLSTY HIPS Process	75
5.16 Sulzer Chemtech Polymerization Process	78

5.17 INEOS Styrenics EPS Process (Process Flow)	80
5.18 Versalis EPS Batch Suspension Process (Process Flow)	82
5.19 NOVA Chemicals/ Huntsman EPS Continuous Process (Process Flow)	84
5.20 POLYSTY EPS Batch Process (Process Flow)	86
5.21 Sulzer Chemtech EPS Continuous Process (Process Flow)	88
6.1 Versalis HIPS Integrated Continuous Process.....	90
7.1 Regional Cost of Production Summary for GPPS.....	98
7.2 Regional Cost of Production Summary for HIPS	101
7.3 Regional Cost of Production Summary for EPS.....	104
8.1 Global Polystyrene Consumption, 2016.....	106
8.2 Global Polystyrene Capacity Share by Marketer in 2015	107
8.3 Global Polystyrene Supply and Demand	107
8.4 North America Polystyrene Consumption, 2016	109
8.5 North American Polystyrene Supply/Demand and Trade	113
8.6 Western European Polystyrene Supply/Demand and Trade	117
8.7 Asia Pacific Polystyrene Supply/Demand and Trade.....	125
9.1 Global EPS Capacity Share by Marketer in 2015	131
9.2 Global EPS Supply and Demand	131
9.3 North American EPS Supply/Demand and Trade	136
9.4 Western European Polystyrene Supply/Demand and Trade	140
9.5 Asia Pacific EPS Supply/Demand and Trade	149

Table	Page
1.1 Polystyrene Licensors and Licensees	2
2.1 Typical GPPS Resin Properties	11
2.2 Typical HIPS Resin Properties	12
2.3 Global Polystyrene (GPPS/HIPS/EPS) Top 25 Producers	16
2.4 Polystyrene Joint Ventures.....	20
2.5 Polystyrene Licensors and Licensees	21
4.1 Reactor Types and Degree of Mixing.....	36
7.1 Prices of Raw Materials, Products, Utilities and Wages	94
7.2 Summary of Economics for U.S. Production of GPPS.....	97
7.3 Summary of Economics for Western Europe Production of GPPS.....	97
7.4 Summary of Economics for China Production of GPPS	98
7.5 Summary of Economics for U.S. Production of HIPS	100
7.6 Summary of Economics for Western Europe Production of HIPS	100
7.7 Summary of Economics for China Production of HIPS	101
7.8 Summary of Economics for U.S. Production of EPS.....	103
7.9 Summary of Economics for Western Europe Production of EPS	103
7.10 Summary of Economics for China Production of EPS	104
8.1 Global Polystyrene Supply and Demand	108
8.2 Capacities for Polystyrene in North America.....	112
8.3 North American Polystyrene Supply/Demand and Trade	113
8.4 Capacities for Polystyrene in Western Europe.....	116
8.5 Western European Polystyrene Supply/Demand and Trade	117
8.6 Capacities for Polystyrene in Asia Pacific	123
8.7 Asia Pacific Polystyrene Supply/Demand and Trade.....	125
9.1 Global EPS Supply and Demand	132
9.2 Capacities for EPS in North America	135
9.3 North American EPS Supply/Demand and Trade	136
9.4 Capacities for EPS in Western Europe	139
9.5 Western European Polystyrene Supply/Demand and Trade	140
9.6 Capacities for Polystyrene in Asia Pacific	147
9.7 Asia Pacific EPS Supply/Demand and Trade	149

Nexant Thinking™

Process Evaluation/Research Planning



The NexantThinking™ Process Evaluation/Research Planning (PERP) program is recognized globally as the industry standard source for information relevant to the chemical process and refining industries. PERP reports are available as a subscription program or on a single report basis.

Contact Details:

New York: Marcos Nogueira Cesar, Vice President, Global Products, E&CA: Nexant Thinking™
Phone: + 1-914-609-0324, e-mail: mcesar@nexant.com

London: Sonia Ouertani, Client Services Coordinator
Phone: + 1-44 (0) 20 7950 1587, e-mail: souertani@nexant.com

Nexant, Inc. (www.nexant.com) is a leading management consultancy to the global energy, chemical, and related industries. For over 38 years, Nexant has helped clients increase business value through assistance in all aspects of business strategy, including business intelligence, project feasibility and implementation, operational improvement, portfolio planning, and growth through M&A activities. Nexant has its main offices in San Francisco (California), White Plains (New York), and London (UK), and satellite offices worldwide.

Copyright © by Nexant Inc. 2016. All Rights Reserved.