

Polyphenylene Sulfide (PPS)

Table of Contents

A Report by **NexantThinking™**

Process Evaluation/Research Planning (PERP) Program

PERP Report 2015S12– Published December 2015

www.nexantthinking.com

Section	Page
1 Executive Summary	1
1.1 INTRODUCTION	1
1.2 COMMERCIAL TECHNOLOGIES	1
1.3 DEVELOPING TECHNOLOGIES AND TECHNOLOGY TRENDS	3
1.3.1 SK Chemicals' Process	3
1.3.2 Sichuan University's Process	3
1.3.3 Technology Trends and Research Activities of Major Producers	4
1.4 STRATEGIC AND BUSINESS CONSIDERATIONS	4
1.5.1 Raw Material Sensitivity	5
1.5.2 Sensitivity to Scale	6
1.6 REGIONAL DEMAND ANALYSIS	7
2 Introduction	9
2.1 POLYPHENYLENE SULFIDE	9
2.2 OVERVIEW OF PRODUCTION TECHNOLOGY	10
2.2.1 Conventional Technologies	10
2.2.2 Developing Technologies	10
2.3 MAJOR PRODUCERS	11
2.4 STRATEGIC AND BUSINESS CONSIDERATIONS	11
2.5 PHYSICAL AND THERMODYNAMICS PROPERTIES	12
2.6 HEALTH AND HAZARDS	18
2.7 STORAGE AND TRANSPORTATION	18
3 Technology	19
3.1 CHEMISTRY	19
3.2 CONVENTIONAL TECHNOLOGY	21

3.2.1	Process Description	22
3.2.2	Branched PPS via Flash Process with Curing	23
3.2.3	Linear PPS via Flash Process with Metal Carboxylate and/or Branching Agent	27
3.2.4	Linear PPS via Quench Process	30
3.2.5	Typical PPS Production Process in China	30
3.3	DEVELOPING TECHNOLOGIES AND TECHNOLOGY TRENDS	34
3.3.1	Introduction.....	34
3.3.2	SK Chemicals' Process	34
3.3.3	Sichuan University's Process	37
3.4	TECHNOLOGY TRENDS AND RESEARCH ACTIVITIES OF MAJOR PRODUCERS	40
3.4.1	U.S. Producers	40
3.4.2	Japanese producers.....	41
3.4.3	Chinese Producers.....	42
4	Process Economics.....	44
4.1	COSTING BASIS	44
4.1.1	Investment Basis	44
4.1.2	Pricing Basis.....	44
4.1.3	Cost of Production Basis	45
4.2	INVESTMENT	46
4.3	PRODUCTION COST ESTIMATES.....	46
4.4	SENSITIVITY ANALYSIS.....	58
4.4.1	Raw Material Sensitivity	58
4.4.2	Sensitivity to Scale	58
5	Commercial Applications.....	63
5.1	TYPE OF PPS.....	63
5.1.1	Conventional PPS Compound	63
5.1.2	PPS Fiber	64
5.1.3	PPS Film	64
5.1.4	PPS Coating	64
5.2	END-USES.....	65
5.2.1	Industrial Applications	65
5.2.2	Transportation	66
5.2.3	Electrical/Electronics	68
5.2.4	Others.....	70

6	Regional Market Analysis	72
6.1	REGIONAL DEMAND ANALYSIS	72
6.1.1	Global	72
6.1.2	North America	74
6.1.3	Asia Pacific	75
6.1.4	Western Europe and Rest of World	77
7	Glossary	78
8	References	80

Appendix		Page
A	Definitions of Capital Cost Terms Used in Process Economics	A-1
B	Definitions of Operating Cost Terms Used in Process Economics	B-1
C	PERP Program Title Index (2006 - 2015)	C-1

Figure	Page
1.1	Cost Comparison of PPS Costs of Production
1.2	Effect of <i>para</i> -Dichlorobenzene Price on Cross-linked PPS Resin Economics
1.3	Sensitivity Analysis of Plant Scale of Flash Process with Curing
1.4	Global PPS Demand by Region (Compounded Basis)
1.5	PPS Demand by End-Use
2.1	Engineering Thermoplastics Price/Performance
2.2	Comparison of Coefficient of Thermal Expansion for Selected High Temperature Polymers.....
2.3	Comparison of Mold Shrinkage of High Temperature Polymers.....
2.4	High Temperature Polymer Flow Characteristics.....
2.5	Property Comparison of Selected Semi-Crystalline Polymers.....
2.6	Impact Resistance of 30% Glass Fiber Reinforced Engineering Plastics.....
3.1	PPS Synthesis Routes
3.2	Properties Comparison of Linear and Branched PPS Resin
3.3	Poly(Phenylene Sulfide) Powder Production Flash Process with Curing
3.4	Poly(Phenylene Sulfide) NMP and DCB Recovery
3.5	Plant for Finishing Polyphenylene Sulfide
3.6	Poly(Phenylene Sulfide) Powder Production - Flash
3.7	Poly(Phenylene Sulfide) Powder Production - Quench Process
3.8	Typical Commercialized Polyphenylene Sulfide Powder Production in China
3.9	SK Chemicals' PPS Process Block Flow Diagram.....
3.10	Sichuan University's PPS Production Process

4.1	Cost Comparison of PPS Costs of Production	47
4.2	Effect of para-Dichlorobenzene Price on Cross-linked PPS Resin Economics	58
4.3	Sensitivity Analysis of Plant Scale of Flash Process with Curing	59
4.4	Sensitivity Analysis of Plant Scale of Flash Process with Curing	59
5.1	Samples of Industrial Applications	66
5.2	Samples of Application in Transportation.....	67
5.3	Samples of Application in E&E	69
6.1	Global PPS Demand by Region (Compounded Basis)	72
6.2	PPS Demand by End-Use	73

Table	Page
1.1 Key PPS Producers and Their Brands	2
1.2 Strategic/Business Considerations.....	4
1.3 PPS Base Resin Capacity by Region.....	8
2.1 Key PPS Producers and Their Brands	11
2.2 Strategic/Business Considerations.....	12
2.3 Nominal Properties of PPS Compounds	13
2.4 High Temperature Polymer Resistance against IR Reflow Soldering	14
2.5 Typical Melt Flow Rates for PPS Resins	17
4.1 Raw Material, Products, Utilities, and Labor Prices	45
4.2 PPS Production Capital Cost Estimates.....	46
4.3 Summary of Economics for PPS Production.....	47
4.4 Cost of Production Estimate for: Cross-linked PPS in the United States Process: Flash Process with Curing.....	49
4.5 Cost of Production Estimate for: Linear PPS in the United States Process: Flash Process with Metal Carboxylate	50
4.6 Cost of Production Estimate for: Linear PPS in the United States Process: Quench Process	51
4.7 Cost of Production Estimate for: Cross-linked PPS in Japan Process: Flash Process with Curing.....	52
4.8 Cost of Production Estimate for: Linear PPS in Japan Process: Flash Process with Metal Carboxylate	53
4.9 Cost of Production Estimate for: Linear PPS in Japan Process: Quench Process	54
4.10 Cost of Production Estimate for: Cross-linked PPS in China Process: Flash Process with Curing.....	55
4.11 Cost of Production Estimate for: Linear PPS in China Process: Flash Process with Metal Carboxylate	56

4.12	Cost of Production Estimate for: Linear PPS in China Process: Quench Process	57
4.13	Cost of Production Estimate for: Cross-Linked PPS Process in the United States Flash Process with Curing.....	60
4.14	Cost of Production Estimate for: Linear PPS Process in the United States Flash Process with Metal Carboxylate	61
4.15	Cost of Production Estimate for: Linear PPS in the United States Process: Quench	62
5.1	Properties of Ryton PPS 40% GF Grade	63
5.2	Typical Values of PROCON® Fiber	64
5.3	Industrial Applications for PPS	65
5.4	Transportation Applications for PPS	67
5.5	Electrical/Electronic Applications for PPS	68
5.6	Other Applications for PPS.....	71
6.1	PPS Base Resin Capacity by Region.....	74
6.2	Major Capacity in North America, 2015.....	74
6.3	Major Capacity in Asia Pacific, 2015	76

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

New York: Heidi Junker Coleman, Global Programs Support Manager
Phone: + 1-914-609-0381, e-mail: hcoleman@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. 2015. All Rights Reserved.