Go/NoGo® Assessment Report

Novel Polymerization of Monomers

SAMPLE

Developer's NAIC: 325211

Science/Technology Fields: Polymer Chemistry; Living/Controlled Polymerizations (Block Copolymers)

Arena NAIC: 325211

Technology Type: Process

Supply Chain: Processing tools and techniques

International Patent Classification: C08F 2/00 Processes of polymerization

Geographic Region: Global

Prepared by

Foresight Science & Technology

401-273-4844

sales@foresightst.com

Foresight Science & Technology, Inc. 34 Hayden Rowe St., Suite 300, Hopkinton, MA 01748

Voice: 401-273-4844; Fax: 401-354-1301; Web: http://www.foresightst.com/

Recommendation and Findings

The function of the Go/NoGo® is to identify potential showstoppers for a technology. We will look at four areas — products, patents, research projects, and commercialization strategy considerations. We also provide an overall recommendation based on the factors outlined in the individual sections of the report.

Our recommendation is based on a cursory examination of:

- The material provided by the client;
- Patents listed on the Thomson Innovation server;
- R&D found via Web searches;
- Products found via Web and literature searches; and
- Targets found via the Thomas Register and Web searches.

Recommendation: Foresight recommends a GO.

After being negatively impacted by the global economic downturn, the market for polymers is currently growing, bolstered by the improved automotive industry, expanded applications for these materials in adhesives and as substitutes for metal and glass, and growing demand for engineered plastics from emerging economies.

In the competition space, there seems to be a keen focus on improving the polymer production process with respect to production costs, polymer characteristics, and molecular weight distribution. Thus in our review, we found a number of technologies with similar functionality; however, we were unable to identify any that employ atom transfer polymerization for industrial polymerization. Although the publicly accessible literature does not provide details related to polymerizations processes and actual costs, it is possible that polymer producers are developing polymer processes that eliminate the need for water sensitive techniques and that such information is not publicly available.

Nonetheless, given its potential cost savings and ease-of-use, there appears to be a market opening for the proposed sensor, especially within organizations offering innovative polymer products. As such, we recommend that the client file a provisional patent application. We note that, obviously, prior to active commercialization it will be important for the client to demonstrate the proposed technology's performance characteristics, cost benefit, and scalability.

The key findings are:

1. **Technology's Maturity Level**: The technology has been reduced to practice and the developers have completed proof of concept.

2. **Intellectual Property**: The technology is currently protected by trade secret.

3. **Possible Competing Products**: There are a number of engineered polymers currently available on the market. According the various polymer producer web sites, these polymers

are typically developed via anionic polymerization. In our review, we did not find any that employed atom transfer or offered alternatives to the commonly used anionic polymerization. We note, however, that many of the engineered polymer producers that we reviewed do not explicitly describe their polymerization process. Thus it is possible that some of these producers may use less costly alternatives to the water sensitive techniques usually used in the industrial polymerization of dienes.

4. **Possible Competing Patents**: In the patent and published application literature we found technologies that offered improved bulk and solution polymerization processes. Many of these technologies appeared to be aimed at offering an alternative to the polymerization process, by providing reduced cost and environmental impact. Nevertheless, we did not identify any technologies that offered the same combination of features, functionality, and technical approach as the proposed technology.

5. **Possible Competing R&D**: In the research and development space, there appears to be a focus on enhanced diene polymerization processes. However, the majority of these process related to primary research and do not appear to be tailored to industrial scale polymerization. Moreover, none of them appear to employ atom transfer polymerization.

6. **Market Barriers**: Substitutes and competing technology used in industry and under development pose a key barrier for new entrants. Given the expected industrial use of the proposed technology, scalability is likely to be a major concern for potential adopters of this technology. If the technology does not prove to be scalable, market acceptance is highly unlikely. Cost-effectiveness will be another important consideration in the commercialization of the proposed technology. Industrial producers concerned with switching costs may be hesitant to new technology unless a significant cost savings is projected.

7. **Commercialization Strategy Considerations**: Given the increased use of engineered plastics, diene-based polymers in particular, as alternatives to metals and glasses and in adhesives applications, this market is experiencing growth. Rising economies across the globe are also increasing demand for diene-based polymers, especially those commonly used in the automotive industry. The industry appears to be open to technological innovation as a means of gaining competitive advantage and reducing production costs. As such it is quite possible that industry players may show favorable acceptance to the client's technology. However, given the large quantities of diene-based polymers supplied to the automotive industry, large industry players may be reluctant to adopt unproven technology. Even if the technology proves to be cost-effective, there is bound to be questions regarding its scalability. Entering this market may require that the client demonstrate some level of scalability based on a pilot study. It is also possible that a company focused on offering more innovative products, such as Kraton Performance Polymers may be interested in the proposed technology.

   Before contacting potential partners, the client should file a provisional patent. We suggest that the client reach out to potential commercialization partners.

8. **Examples of Potential Targets**: Potential targets may include: Kraton Performance Polymers Inc., Firestone Polymers, Dynasol Elastomers, and Styron LLC among others.

Brief Non-Proprietary Description of Technology

The technology is a process.

Description of Technology
This technology involves a novel means of polymerizing monomers.

Supplemental Proprietary Information

From materials provided by the client:

The invention describes the first examples of controlled polymerization by atom transfer polymerization. It bypasses all the stringent purification procedures associated with anionic polymerizations. By using this process, structures not accessible via anionic polymerization could be produced using these monomers.

Product Search

We searched Google, Bing, and HighBeam Research for relevant products using the terms copolymer polymerization, atom-transfer, polymerization AND atom-transfer, controlled polymerization, controlled polymerization, synthetic rubber AND polymerization, polybutadiene AND polymerization.

Examples of Relevant Products/Services Identified			
Product Name	***Manufacturer***	***Relevance***	***Web site/Phone #***
Diene™	Firestone Polymers	Firestone Polymers develops polybutadiene for tires and rubber goods. This polymerized polybutadiene rubber is available in two grades: medium cis at 40 percent and high cis at 96 percent. [1]	http://www.firesyn.com/diene_rubber.asp 800-282-0222
Kraton D SBS	Kraton Performance Polymers Inc.	The Kraton D SBS family of polymers is composed of blocks of styrene and butadiene. [2]	http://www.kraton.com/products/Kraton_D_SBS.php 281-504-4700
Calprene® 401	Dynasol Elastomers	Calprene® 401 is an 80/20 butadiene/styrene thermoplastic copolymer. It used primarily in paving, roofing, and footwear.[3]	http://www.dynasolelastomers.com/default/index.cfm/product-types/thermoplastic-rubber-styrene-

[1] "Diene™." Firestone Polymers web site. http://www.firesyn.com/diene_rubber.asp (accessed October 30, 2012).
[2] "Kraton D SBS." Kraton Performance Polymers Inc. web site. http://www.kraton.com/products/Kraton_D_SBS.php (accessed October 30, 2012).
[3] "Calprene® 401." Dynasol Elastomers web site. http://www.dynasolelastomers.com/default/index.cfm/product-types/thermoplastic-rubber-styrene-butadiene-styrene-block-copolymer-sbs/ (accessed October 31, 2012).

			butadiene-styrene-block-copolymer-sbs/ 281-874-0888
High Cis Polybutadiene Rubber (BR)	Styron LLC	Styron's high-cis polybutadiene rubber is said to possess good abrasion and flex-cracking resistance characteristics. This material is used in tread and sidewall compounds, conveyor belts, footwear and in a variety of mechanical goods.[4]	http://www.styron.com/eu/en/products/syntheticrubber/high_cis.htm 888-789-7661
Styrene Butadiene Block Copolymer – SBS	Network Polymers, Inc.	Network Polymers, Inc. offers a variety of thermoplastic alloys and resins, including SBS. [5]	http://www.networkpolymers.com/StyreneButadieneBlockCopolymerSBS 888-437-4674
Hot Polymerized Emulsion Styrene Butadiene Rubber	Ashland, Inc.	Ashland's hot polymerized emulsion styrene butadiene rubber is commonly used in the adhesives and sealant industry. [6]	http://www.ashland.com/products/hot-polymerized-emulsion-styrene-butadiene-rubber 614-790-3333
Vistalon™ EPDM rubber	ExxonMobil Chemical Company	Vistalon™ ethylene propylene diene (EPDM) rubber offers processing and finished product performance beyond the capabilities of natural and general-purpose synthetic rubber.[7]	http://www.exxonmobilchemical.com/Chem-English/brands/vistalon-ethylene-propylene-diene-epdm-rubber.aspx?ln=productsservices 281-870-6050

Though Firestone Polymers does not describe their polymerization process, it notes that its "solution polymerization technology allows the polybutadiene microstructure to be changed to suit specific needs."[8] Firestone Polymers also produces Stereon™ 721AC, a low styrene block copolymer with a low solution viscosity. It is used as a modifier for plastics. Kraton polymers, including D, G, and IR families, are polymerized in a precisely controlled reaction via anionic polymerization.[9] Calprene® 401, as well as other butadiene/styrene thermoplastic copolymers, is polymerized in solution and has a radical structure. Styron LLC produces its high-cis polybutadiene rubber using a catalyst system based on nickel. We have included Network Polymers, Inc. and Dynasol Elastomers as they represent two more producers of engineered polymers. Nonetheless, the polymerization techniques used to produce the materials are not

[4] "High Cis Polybutadiene Rubber (BR)." http://www.styron.com/eu/en/products/syntheticrubber/high_cis.htm (accessed November 1, 2012).
[5] "Styrene Butadiene Block Copolymer – SBS." Network Polymers, Inc. web site. http://www.networkpolymers.com/StyreneButadieneBlockCopolymerSBS (accessed October 31, 2012).
[6] "Hot Polymerized Emulsion Styrene Butadiene Rubber." Ashland, Inc. web site. http://www.ashland.com/products/hot-polymerized-emulsion-styrene-butadiene-rubber (accessed October 31, 2012).
[7] "Vistalon™ EPDM Rubber." ExxonMobil Chemical Company web site. http://www.exxonmobilchemical.com/Chem-English/brands/vistalon-ethylene-propylene-diene-epdm-rubber.aspx?ln=productsservices (accessed October 30, 2012).
[8] "Diene™." Firestone Polymers web site. http://www.firesyn.com/diene_rubber.asp (accessed October 30, 2012).
[9] "An Introduction to KRATON® Polymers." http://gertrude-old.case.edu/276/materials/web/Kraton.pdf (accessed October 30, 2012).

mentioned on either web site. ExxonMobil Chemical Company employs metallocene- and Ziegler-Natta-based polymerization technology to produce Vistalon™ ethylene propylene diene (EPDM) rubber. [10]

Based on our product search, we conclude GO. In our review of commercially available industrial polymers, we were unable to identify any industrial polymerization based on atom transfer. Key drivers of the engineered plastics markets is technological advancement and rising demand from the automotive industry, an industry that faces continuous cost pressure.[11,12] Thus, the client's technological advancement that offers reduced production costs to engineered plastics markets, is likely to be favorably accepted by end-users.

Patent Search

We search the following data sets: *INPADOC*, which contains patent family documents from 71 world patent signatories and legal status information from 42 patent offices; *WIPO PCT Publications*, which contains abstracts, full document images, and full text from over a hundred member countries of the Patent Cooperation Treaty; *European Patents and Applications* from the European Patent Office; and *US Patents and Applications* from the US Patent and Trademark Office. Searching these data sets simultaneously often does lead to multiple counts of the same patent, as both the application and patent may be retrieved or the item can show up in multiple databases. This procedure highlights applicants who file, pursue the patent, and protect it in multiple jurisdictions and the presumption is a patent protected in multiple jurisdictions is more important to its owners than one which is not.

Given this procedure, the following patent or applications were found using the following search string "diene polymerization". Overall, the string produced 422 hits.

The following patents and patent applications indicate kinds and range of technology that show up in the patent literature. We emphasize that we look at patents from the standpoint of market competition. We have no opinion on the patentability of your technology. Please consult with qualified legal counsel for opinions on the client's freedom to operate and extent of Intellectual Property protection. Material in quotes is from the patent abstract unless otherwise noted.

Examples of Relevant Patents and Patent Applications Identified				
Patent or Patent Application #	***Patent Title***	***Date***	***Relevance***	***Assignee***
US8163855B2	Method for bulk	April 24,	"A method for polymerizing	Bridgestone

[10] "Vistalon™ EPDM Rubber." ExxonMobil Chemical Company web site. http://www.exxonmobilchemical.com/Chem-English/brands/vistalon-ethylene-propylene-diene-epdm-rubber.aspx?ln=productsservices (accessed October 30, 2012).
[11] "Global Engineering Plastics Market Analysis by Product Types, Applications & Geography - Trends & Forecasts (2012 - 2017)." marketsandmarkets.com web site. http://www.marketsandmarkets.com/Market-Reports/engineering-plastics-market-687.html (accessed November 1, 2012).
[12] "Car Innovation 2015." e-Motility web site. http://www.e-motility.com/Oliver_Wyman_Car_Innovation.pdf (accessed November 1, 2012).

	polymerization	2012	conjugated diene monomer into polydienes, the method comprising: polymerizing conjugated diene monomer within a liquid-phase polymerization mixture that includes conjugated diene monomer, a lanthanide-based catalyst system, dicyclopentadiene or substituted dicyclopentadiene, and optionally organic solvent, with the proviso that the organic solvent, if present, is less than about 20% by weight based on the total weight of the polymerization mixture.”	Corporation
US8299189B2	Ethylene/α-olefin/diene solution polymerization process and polymer	October 30, 2012	“A catalyst composition comprising a zirconium complex of a polyvalent aryloxyether and the use thereof in a continuous solution polymerization of ethylene, one or more C3-30 olefins, and a conjugated or nonconjugated diene to prepare interpolymers having improved processing properties are disclosed.”	Dow Global Technologies LLC
US6566465B1	Method for polymerizing conjugated diolefins (dienes) with catalysts based on vanadium compounds in the presence of vinylaromatic solvents	May 20, 2003	“Conjugated diolefins, optionally in combination with other unsaturated compounds which may be copolymerized with the diolefins, are polymerized by performing the polymerization of the diolefins in the presence of catalysts based on monocyclopentadienyl compounds of vanadium and alumoxanes in the presence of aromatic vinyl compounds as the solvent at temperatures of-30 C. to +80 C. By means of the process according to the invention, it is possible to straightforwardly produce solutions of polydiolefins, such as polybutadiene, having 1, 2 unit contents of 10 to 30% in aromatic vinyl compounds, which solutions may then, for example, be further processed to yield ABS or HIPS.”	Bayer Atkiengesellschaft
US8124698B2	Diene polymerisation	February 28, 2012	“Process for producing homopolymers or copolymers of conjugated dienes by contacting monomeric material having at least one conjugated diene with a catalyst system including two or more different transition metal compounds and optionally one or more activators. Preferred transition metal compounds are based on cobalt and chromium, especially complexes thereof having	Ineos Europe Limited

			benzimidazole ligands."	
EP2024400B1	High efficiency solution polymerization process	September 12, 2012	"A catalyst composition comprising a zirconium complex of a polyvalent aryloxyether and an alumoxane, polymerization processes employing the same, especially the continuous, solution polymerization of ethylene and one or more C3-30 olefins or diolefins to prepare copolymers having reduced cocatalyst by-product content, are disclosed."	Dow Global Technologies LLC
US20110230624 A1	Nanostructured polymers on the basis of conjugated dienes	September 22, 2011	"The present invention relates to nano-structured diene polymers and their preparation and to their use."	LANXESS Deutschland GmbH
US8299179B2	Conjugated diene-based polymer, conjugated diene-based polymer composition, and process for producing conjugated diene-based polymer	October 30, 2012	"Disclosed are a conjugated diene-based polymer from which a polymer composition excellent in fuel cost-saving properties and elongation at break can be obtained, a polymer composition containing the conjugated diene-based polymer and a reinforcing agent, and a process for producing the conjugated diene-based polymer. A conjugated diene-based polymer obtained by reacting one end of a polymer having a monomer unit based on a conjugated diene, a monomer unit based on a compound represented by the following formula (1), and a monomer unit based on a compound represented by the following formula (2) with an alkoxysilane compound. V1—S1 (1) wherein V1 represents a hydrocarbyl group having a polymerizable carbon-carbon double bond, and S1 represents a substituted silyl group. V2-A2 (2) wherein V2 represents a hydrocarbyl group having a polymerizable carbon-carbon double bond, and A2 represents a substituted amino group, or a nitrogen-containing heterocyclic group."	Sumitomo Chemical Company Limited

The first listing describes a method for the bulk polymerization of conjugated diene monomers using a lanthanide-based catalyst system. The technology seeks to benefit from the advantages of bulk polymerization (reduced potential for contamination, lower capital cost for new plant capacity, lower energy cost to operate, and reduced emissions and wastewater pollution). At the same time it looks to overcome the disadvantages of bulk polymerization (difficult temperature control, runaway reactions in the liquid-phase, and impurity sensitive catalysts) by employing a lanthanide-based catalyst system along with dicyclopentadiene or substituted dicyclopentadiene. The process is controlled by dicyclopentadiene or substituted dicyclopentadiene, which decompose and deactivate the catalyst (within a certain temperature range) and yet have no deleterious impact on the bulk polymerization. The second listing, assigned to Dow Global Technologies, describes a solution polymerization process, which produces interpolymers with high molecular weights (with correspondingly low melt indices), high levels of co-monomer incorporation (low densities), and relatively good high temperature resistance. The catalyst compositions, comprising a zirconium complex of a polyvalent aryloxyether, retain their high catalyst activity using relatively low molar ratios of conventional alumoxane co-catalysts. The result is polymer products with reduced metal content, increased clarity, improved dielectric properties and reduced polymer production costs. The third listing is another solution polymerization process. In this case, catalysts comprising vanadium compounds are used in the presence of aromatic vinyl compounds. This is said to be an economical and environmentally compatible process for the production of polydiene rubbers with a high cis-double bond content and a conversion of more than 50% based on conjugated diene.

The fourth listing pertains to a process for economically making diene polymers and copolymers with desirable properties using transition metal-based catalysts. The fifth listing describes an efficient polymerization process that affords interpolymers with narrow molecular weight distribution and improved dielectric properties. The resulting polymers are obtained under high conversion conditions at high catalyst efficiencies. The sixth listing concerns nano-structured polymers based on conjugated dienes, achieved via the polymerization of conjugated dienes with catalysts of the rare earths and a subsequent reaction with a nano-coupling agent. The nano-structured polymers are said to be producible in a cost-effective manner and can be used to manufacture tires and tire parts, golf balls, technical rubber articles, rubber-strengthening plastics, specifically acrylonitrile butadiene styrene. The last listing describes a conjugated diene-based polymer and a process for making it. The resulting conjugated diene-based polymer is said to have excellent fuel cost-saving properties, while elongation at break can be obtained. Though the focus of this technology is not on its polymerization process, it does describe a process that produces a potentially desirable conjugated diene-based polymer given its fuel cost-saving properties.

We emphasize we are not patent attorneys and thus our analysis focuses on marketability. We strongly recommend you discuss patentability and freedom to operate with qualified patent counsel.

Based on our patent search, we conclude GO. Initially, we found that a search for the terms “atom transfer” AND “diene” returned zero search results. Upon further review we noted technologies that offered improved bulk and solution polymerization processes, many aimed at reducing cost and environmental impact typically associated with the anionic polymerization process. Nonetheless, we did not identify any technologies that offered the same technical approach as the client’s technology. Further review of the aforementioned technologies is recommended to highlight the expected cost savings that the proposed technology will offer over those in the patent and published space.

We emphasize that we look at patents from the standpoint of market competition and have no opinion on the patentability of the proposed technology. We recommend that the client consult with qualified legal counsel regarding opinions on freedom to operate and extent of Intellectual Property protection.

R&D/Practices Search

A search of Google Scholar, ISI Web of Knowledge, HighBeam Research, and Thompson Innovation was conducted using the query diene AND polymerization, diene polymerization, radical polymerization, atom-transfer, diene AND polymerization AND atom-transfer, controlled polymerization, diene AND polymerization AND controlled polymerization, synthetic rubber AND polymerization, polybutadiene AND polymerization, living polymerization, living radical polymerization AND diene. We also examined the literature for R&D and practices via a Web search.

Examples of Relevant Projects Identified

Project Title	***Performing Institution***	***Performance Period***	***Relevance***
Controlled Radicalpolymerization of Conjugated 1,3-Dienes with Methyl 1,3-Butadiene-1-Phosphonate	CNRS-Université de Rennes France	Published: 2008	This research concerns a controlled radical copolymerization process used to prepare tailor-made phosphorus-containing polydiene materials.[13]
Retarded Anionic Polymerization (RAP) of Styrene and Dienes	CRNS, Université Bordeaux France BASF AG	Published: 2009	This article describes retarded anionic polymerization, a living-like anionic polymerization of styrene and dienes.[14]
Pseudo-Living Anionic Telomerization of Buta-1,3-diene	Virginia Polytechnic Institute and State University (Virginia Tech)	Published: 2008	Researchers have developed a method that enables polymerization of liquid polybutadienes to occur in a living fashion. [15]
Highly-controlled Regiospecific Free-Radical Copolymerization of 1,3-diene Monomers with Sulfur Dioxide	Osaka City University Japan	Published: 2011	This research pertains to the use of free-radical polymerization for highly regioselective propagation of 1,3-diene monomers.[16]

[13] Ajellal, Noureddine, Thomas, Christophe M. and Carpentier, Jean-François. “Controlled Radicalpolymerization of Conjugated 1,3-Dienes with Methyl 1,3-Butadiene-1-Phosphonate.” *Polymer*. vol. 49, issue 20, September 23, 2008. (accessed November 5, 2012).
[14] Carlotti, Stephane et al. “Retarded Anionic Polymerization (RAP) of Styrene and Dienes.” *Polymer*. vol. 50, issue 14, July 3, 2009. (accessed November 5, 2012).
[15] Saito, Tomonori, Harich, Kim C., and Long, Timothy E. “Pseudo-Living Anionic Telomerization of Buta-1,3-Diene.” *Macromolecular Chemistry and Physics*. vol. 209, issue 19, October 7, 2008. (accessed November 5, 2012).
[16] Tanaka, Naruki, Sato, Eriko, and Matsumoto, Akikazu. “Highly-controlled Regiospecific Free-Radical Copolymerization of 1,3-diene Monomers with Sulfur Dioxide.” *Organic & Biomolecular Chemistry*. vol. 9, issue 10, 2011. (accessed November 5, 2012).

Gas Phase Polymerization of Butadiene on Heterogenized Cobalt-containing Catalytic Dithiosystems	Institute of Petrochemical Processes of Azerbaijan National Academy of Sciences Azerbaijan	Published: 2009	This research proposes a solvent-free means of polymerizing diene using gas phase polymerization.[17]
Controlled Polymerization of a Cyclic Diene Prepared from the Ring-Closing Metathesis of a Naturally Occurring Monoterpene	University of Minnesota	Published: 2009	This work compares radical, anionic, and cationic polymerizations of the diene 3-methylenecyclopentene. [18]

The first listing is of interest given its use of a controlled radical copolymerization process to prepare polydiene materials. Nevertheless, this technology does not specifically describe atom transfer polymerization. Moreover, it is designed for the preparation of tailor-made phosphorus-containing polydiene materials and thus, may not be as widely applicable as the client's technology. Although the second listing does not describe diene polymerization using atom-transfer, it does claim to use an inexpensive initial system to make polymerization competitive with industrial radical processes. [19] The third listing involves the synthesis of low-molecular-weight liquid polybutadienes via anionic telomerization. Based on the results, the polymerization occurred in a living fashion, resulting in well-controlled molecular weights and narrow polydispersity indices. [20] This research is all the more interesting given that it is funded in part by BASF, a leading chemical company. The next listing describes free-radical polymerization of alkyl-substituted 1,3-butadienes with sulfur dioxide using a redox initiating system to produce poly(diene sulfone)s consisting of a highly alternating and 1regiospecific repeating structure. [21] Next, researchers at the Institute of Petrochemical Processes of Azerbaijan National Academy of Sciences have developed a method for butadiene gas phase polymerization. According to the researchers, gas phase polymerization is advantageous since it does not use solvents. As such, it avoids the technological, economic, and ecological problems associated with cleaning and drying solvents. However, gas phase polymerization of dienes has yet to be realized on an industrial scale. [22] Thus this technology is likely to face a certain degree of resistance before it is widely accepted. While the last listing investigates radical, anionic, and cationic polymerization, these processes do not appear to offer the same benefits as atom transfer polymerization.

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[17] Nasirov, Fizuli et al. "Gas Phase Polymerization of Butadiene on Heterogenized Cobalt-containing Catalytic Dithiosystems." *Iranian Polymer Journal*. vol. 18, issue 7, 2009. (accessed November 5, 2012).
[18] Kobayashi, Shingo et al. "Controlled Polymerization of a Cyclic Diene Prepared from the Ring-Closing Metathesis of a Naturally Occurring Monoterpene ." *Journal of the American Chemical Society*. vol. 131, issue 23, June 17, 2009. (accessed November 5, 2012).
[19] Carlotti, Stephane et al. "Retarded Anionic Polymerization (RAP) of Styrene and Dienes." Polymer. vol. 50, issue 14, July 3, 2009. (accessed November 5, 2012).
[20] Saito, Tomonori, Harich, Kim C., and Long, Timothy E. "Pseudo-Living Anionic Telomerization of Buta-1,3-Diene." *Macromolecular Chemistry and Physics*. vol. 209, issue 19, October 7, 2008. (accessed November 5, 2012).
[21] Tanaka, Naruki, Sato, Eriko, and Matsumoto, Akikazu. "Highly-controlled Regiospecific Free-Radical Copolymerization of 1,3-diene Monomers with Sulfur Dioxide." *Organic & Biomolecular Chemistry*. vol. 9, issue 10, 2011. (accessed November 5, 2012).
[22] Nasirov, Fizuli et al. "Gas Phase Polymerization of Butadiene on Heterogenized Cobalt-containing Catalytic Dithiosystems." *Iranian Polymer Journal*. vol. 18, issue 7, 2009. (accessed November 5, 2012).

Based on our R&D search, we conclude: GO. Our review of the research and development literature indicates that there is interest in the development of enhanced polymerization techniques. The most relevant research was conducted by CRNS, Université Bordeaux and BASF AG. While it does concern a novel polymerization process that is likely applicable to industrial polymerization, it does not employ atom transfer polymerization. When approaching potential commercialization partners it will be important for the client to demonstrate its technology's effectiveness, cost savings, and scalability in comparison to other technologies under development.

Commercialization Considerations

Key findings regarding the commercial potential for this technology are as follows:

Data Related to Market Potential	
Likely Markets and Basis for Feasibility	The proposed technology would mostly be used within the industrial chemicals industry for synthetic rubbers and polymer resins. [23]
Possible Market Barrier(s)	We have previously noted, there are a number of engineered polymer producers (each using their own processing technique). We have also highlighted technologies in the patent and research and development space. Thus a key barrier for new entrants is the presence of widely used existing processing techniques along with those in the development pipeline. New entrants must demonstrate that the benefits of adopting new techniques result in significantly reduced costs. This is especially given the switching costs associated with adopting a new industrial processing technology. Synthetic rubber, the next best alternative to natural rubber, also faces competition from natural rubber, thus posing another barrier for the proposed technology.[24] Moreover, the proposed technology would be largely used in the industrial chemicals industry.[25] For instance, one application of this technology is for the production of Styrene - Butadiene-Styrene block copolymer; this market is estimated to reach 1,910 million tons by 2017.[26] Thus it must be shown that the any new process can be scaled up to meet the demands of the chemicals industry.
Possible Market Driver(s)	Demand for the proposed technology is driven by a number of factors. Engineered plastics in general have been driven by growing production and consumption of said materials in

[23] "US Demand to Drive the Growth of European Butadiene Market, Reports GBI Research." Plasticsinfomart.com web site. October 29, 2012. http://www.plasticsinfomart.com/us-demand-to-drive-the-growth-of-european-butadiene-market-reports-gbi-research/ (accessed November 2, 2012).

[24] "Research and Markets: Analyzing the Market for Synthetic Rubber in the US 2012." BusinessWire web site. August 21, 2012. http://www.businesswire.com/news/home/20120821005595/en/Research-Markets-Analyzing-Market-Synthetic-Rubber-2012 (accessed November 2, 2012).

[25] Potter, David et al. "Can Butadiene Continue to Rise?" Platts.com web site. May 14, 2012. http://www.platts.com/newsfeature/2012/butadiene/index (accessed November 2, 2012).

[26] "Styrene-Butadiene-Styrene (SBS) Block Copolymer Market - Global Industry Size, Market Share, Trends Analysis, And Forecast, 2012 – 2018." Transparency Market Research web site. http://www.transparencymarketresearch.com/styrene-butadiene-styrene-block-copolymer-market.html (accessed November 2, 2012).

	the Asia-Pacific region. Moreover, technological advancements of these materials have increasingly allowed them to be used in place of metals and glass.[27] Diene-based polymers are also finding expanded use in the adhesive applications industry.[28] Demand for synthetic rubber is closely linked to the automotive industry. As automotive demand increased in 2011 in areas such as China and the United States, the demand for synthetic rubber increased. Conversely, with the outlook for the European automotive sector getting worse, demand for diene-based materials is projected to slow down.[29]
Indicator(s) Suggesting How Big the Market Opportunity Might Be	One of the primary uses of the proposed technology is in the production of synthetic rubber. Thus in order to better understand the potential market for this technology, we will review the synthetic rubber market which has the styrene-butadiene rubber market as its largest segment. Global synthetic rubber demand is expected to reach 13.4 million metric tons by 2015.[30] Synthetic rubber makes up roughly two-thirds of all rubber used,[31] we estimate that global demand for synthetic rubber will reach 18.1 million metric tons. Global demand for synthetic rubber is expected to grow at a rate of 5.5 percent in 2012.[32]
Product Opportunities	The proposed technology can be used to produce styrene butadiene rubber, a key component in the manufacturing of automobiles tires, adhesives, sealants, and other rubber articles.[33,34] It can also be used in the manufacture of styrenic block copolymers, used in the production of adhesives.

After slow growth between 2008 and 2010,[35] the market for engineered plastics has begun to rebound since 2011. The market for synthetic rubber in particular has picked up. Since tires represent the largest market for rubber, rubber consumption is greatly impacted by growth in output of motor vehicles and numbers of motor vehicles in use. Following relatively weak demand in many developed nation from 2005 to 2010, global motor vehicle production has

[27] "Global Engineering Plastics Market Analysis by Product Types, Applications & Geography - Trends & Forecasts (2012 - 2017)." marketsandmarkets.com web site. http://www.marketsandmarkets.com/Market-Reports/engineering-plastics-market-687.html (accessed November 1, 2012).

[28] "Styrene-Butadiene-Styrene (SBS) Block Copolymer Market - Global Industry Size, Market Share, Trends Analysis, And Forecast, 2012 – 2018." Transparency Market Research web site. http://www.transparencymarketresearch.com/styrene-butadiene-styrene-block-copolymer-market.html (accessed November 2, 2012).

[29] Potter, David et al. "Can Butadiene Continue to Rise?" Platts.com web site. May 14, 2012. http://www.platts.com/newsfeature/2012/butadiene/index (accessed November 2, 2012).

[30] "Global Synthetic Rubber Demand to Reach 13.4 Million Metric Tons by 2015, According to a New Report by Global Industry Analysts, Inc.." PRWeb web site. October 29, 2012. http://www.prweb.com/releases/synthetic_rubber/styrene_butadiene_rubber/prweb4714464.htm (accessed November 2, 2012).

[31] "Research and Markets: Analyzing the Market for Synthetic Rubber in the US 2012." BusinessWire web site. August 21, 2012. http://www.businesswire.com/news/home/20120821005595/en/Research-Markets-Analyzing-Market-Synthetic-Rubber-2012 (accessed November 2, 2012).

[32] "Global Rubber Demand Forecast To Reach 27.2 Million Metric Tons In 2012." RubberWorld web site. January 25, 2012. http://www.rubberworld.com/RWmarket_report.asp?id=711 (accessed November 2, 2012).

[33] Potter, David et al. "Can Butadiene Continue to Rise?" Platts.com web site. May 14, 2012. http://www.platts.com/newsfeature/2012/butadiene/index (accessed November 2, 2012).

[34] "US Demand to Drive the Growth of European Butadiene Market, Reports GBI Research." Plasticsinfomart.com web site. October 29, 2012. http://www.plasticsinfomart.com/us-demand-to-drive-the-growth-of-european-butadiene-market-reports-gbi-research/ (accessed November 2, 2012).

[35] "Engineering Plastics - A Global Market Overview." MarketResearch.com web site. June 8, 2009. http://www.marketresearch.com/Industry-Experts-v3766/Engineering-Plastics-Global-Overview-2528266/ (accessed November 2, 2012).

accelerated.[36] Growth of this market may be dampened a bit as the European automotive industry has experienced a downturn since 2011. In fact new car registrations in Europe have consistently declined and the level of demand for new cars has been at its lowest in over a decade.[37] Further growth is projected for diene-based polymers market as certain polymers have found use in increased applications. For example, Styrene - Butadiene-Styrene is being used in altered asphalts for waterproofing and roofing purposes. [38]

Based on our commercialization considerations, we conclude GO. The market prospect for the proposed technology appears to be favorable. Primary demand for synthetic rubbers appears to be growing, especially in the Asia-Pacific region, Latin America, and Eastern Europe. [39,40] The proposed technology faces two key challenges: proving its cost-effectiveness and proving its scalability. Provided that the client can demonstrate the technology's scalability and cost-effectiveness, the proposed technology is likely to find favorable acceptance.

Potential Targets

The following table lists examples of potential targets.

Examples of Potential Targets			
Target	***Reason for Inclusion***	***Web site***	***Point of Contact with Phone or E-mail***
Kraton Performance Polymers Inc.	Kraton Performance Polymers, Inc. is a leading global producer of engineered polymers. [41]	http://www.kraton.com/	Lothar P. Freund Vice President, Technology 281-504-4700
Firestone Polymers	Firestone Polymers produces solution polybutadiene, styrene butadiene, block copolymers and thermoplastic elastomers. [42]	http://www.firesyn.com/default.asp	Peter Boerner Team Leader Block

[36] "World Rubber Market." PR Newswire, web site. June 4, 2012. http://www.prnewswire.com/news-releases/world-rubber-market-157005655.html (accessed November 2, 2012).

[37] Potter, David et al. "Can Butadiene Continue to Rise?" Platts.com web site. May 14, 2012. http://www.platts.com/newsfeature/2012/butadiene/index (accessed November 2, 2012).

[38] "Styrene-Butadiene-Styrene (SBS) Block Copolymer Market - Global Industry Size, Market Share, Trends Analysis, And Forecast, 2012 – 2018." Transparency Market Research web site. http://www.transparencymarketresearch.com/styrene-butadiene-styrene-block-copolymer-market.html (accessed November 2, 2012).

[39] "Styrene-Butadiene-Styrene (SBS) Block Copolymer Market - Global Industry Size, Market Share, Trends Analysis, And Forecast, 2012 – 2018." Transparency Market Research web site. http://www.transparencymarketresearch.com/styrene-butadiene-styrene-block-copolymer-market.html (accessed November 2, 2012).

[40] "Global Synthetic Rubber Demand to Reach 13.4 Million Metric Tons by 2015, According to a New Report by Global Industry Analysts, Inc.." PRWeb web site. October 29, 2012. http://www.prweb.com/releases/synthetic_rubber/styrene_butadiene_rubber/prweb4714464.htm (accessed November 2, 2012).

[41] "Our Brand." Kraton Performance Polymers Inc. web site. http://www.kraton.com/about/brand.php (accessed October 30, 2012).

			Copolymer Development and Technical Service pboerner@firestonepolymers.com 800-282-0222
Dynasol Elastomers	Dynasol Elastomers is a leading producer of styrene block copolymers.	http://www.dynasolelastomers.com/	Walter Ramirez Global Technology Director 281-874-0888
Styron LLC	Styron is a leader in the production of plastics, latex and rubber.[43]	http://www.styron.com/	Marco Levi Vice President and General Manager of Emulsion Polymers
Network Polymers, Inc.	Network Polymers, Inc. markets a broad spectrum of alloys and resins.[44]	http://www.networkpolymers.com/	Dr. Steven Blazey Technical Director, R&D 888-437-4674
Ashland, Inc.	Ashland provides the specialty chemicals and has been recognized for its composite and polymer technology.[45]	http://www.ashland.com/	Frederick J. Good Vice President Global Technology fjgood@ashland.com 614-790-3968

Names of other potential targets may be found at the following Web sites.

Internet Sites Linking to Other Potential Targets	
Web site	***Reason for Listing***
http://www.thomasnet.com/products/engineered-polymers-62202700-1.html?WTZO=Find%20Suppliers	ThomasNet.com provides a listing of manufacturers and distributers of engineered polymers.
http://www.4spe.org/about-spe	Society of Plastics Engineers (SPE) brings together people from all parts of the plastics industry including engineers, scientists, technicians, salespeople, marketers, retailers and representatives from tertiary industries.[46]

[42] "Products." Firestone Polymers web site. http://www.firesyn.com/synthetic_rubber.asp (accessed October 30, 2012).
[43] Styron web site. http://www.styron.com/company/ (accessed November 1, 2012).
[44] Network Polymers, Inc. web site. http://www.networkpolymers.com/About (accessed October 31, 2012).
[45] Ashland, Inc. web site. http://www.ashland.com/about/businesses/ashland-performance-materials (accessed November 1, 2012).
[46] Society of Plastics Engineers web site. http://www.4spe.org/about-spe (accessed November 2, 2012).