

Assessment of Attitudes and Expectations of Switchable Glass Among United States Window Manufacturers

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ABSTRACT

Over the past several years, a growing amount of scientific data has been collected to examine various performance characteristics of switchable glass technologies. However, very little marketing-related information has been assembled to assist business managers in the development of new product strategies pertaining to switchable glass. This paper focuses on the results of a set of interviews of executives and managers involved in new product planning or product development at United States window manufacturers. The survey examined attitudes and expectations for switchable glass window products. Having obtained these measurements, business managers and strategists can more accurately understand and plan for the needs and desires of a key segment of firms involved in the delivery of switchable products to the market.

This paper initially describes the methodology used to collect the data. Following that, it examines awareness and knowledge levels of switchable glass technology, the perceived importance of various product attributes to end-users, expectations for the adoption of the technology by window manufacturers and end-users, and estimates of price sensitivity among window manufacturers. The paper concludes with an assessment of the pace of new product launches among window manufacturers and a discussion of the implications for managers interested in furthering the development of the market for switchable glass.

INTRODUCTION

Switchable glass is a class of technologies that uses electrical voltage to control the amount of light passing through glass. The technology can be used in numerous applications, including windows and interiors partitions, automotive mirrors and sunvisors, eyewear, flat panel displays and advertising signage. Various types of switchable glass technology exist, including electrochromic (EC), liquid crystal (LC) and suspended particle device (SPD). As a whole, this class of technologies has received substantial attention recently due

to many factors, including consumers' growing needs for energy efficient products, products that provide greater privacy and security, and products that are technology-enabled. Windows that include switchable glass, often described as "smart" windows, can serve each of these needs.

In an effort to identify and benchmark important attitudes related to switchable glass technology for windows, a marketing research study of United States window manufacturers was commissioned by Research Frontiers Incorporated (Woodbury, NY) during the summer of 2000. Research Frontiers is a developer and licensor of suspended particle device technology. Using a probability sampling procedure followed by statistical analyses of the data, various attitudinal measures were developed and are presented. Segmentation of the respondents into selected independent groups is subsequently conducted and hypothesis tests are performed to highlight commonalities and differences based on the nature of the responding companies. Finally, a predictive model is developed to forecast manufacturers' interest in offering smart window products with switchable glass in the future.

METHODOLOGY

The research methodology included a series of stages designed to optimize the study's validity and reliability. A structured survey instrument was designed using input from several sources including industry professionals and trade publications. The instrument was pre-tested prior to formal data collection. A contact list of 493 unduplicated window manufacturers in the United States was assembled (SIC 344202). Although this was the largest compilation practically available at the time of the study, the list may not have been totally exhaustive due to a variety of factors such as mergers, divestitures and other issues inherent to the due course of business. Data were collected by telephone, and survey respondents were screened to include only those involved in new product development

or product planning at their respective companies. Respondents were most likely to include those serving in engineering, research and development, and marketing positions. Representative titles include: Manager of Engineering and Quality, R&D Manager, and Vice President of Marketing and Planning.

From the master list of 493 window manufacturers, calls were made to 174 different companies. Fifty interviews averaging 25 minutes in length were completed. This yielded an overall response rate of 28.7%, and a margin of error ($\alpha=0.05$) of +/- 13.9%.

DESCRIPTIVE RESULTS

Awareness and Knowledge

Awareness of switchable glass technology for windows is strong, with 71.7% of those surveyed claiming some level of awareness of the technology. As Table 1 indicates, awareness of specific types of switchable glass technology is notably lower. [1]

Table 1. Total Awareness and Awareness of Specific Switchable Glass Technologies

Category	% Aware*
Switchable Glass	71.7%
Liquid crystal (LC)	45.2%
Electrochromic (EC)	32.6%
Suspended particle device (SPD)	24.6%

* Aided awareness obtained using the category term as a prompt.

It is likely that awareness of at least one of these technologies, suspended particle device (SPD) technology, has increased since this study was conducted. Research Frontiers has licensed this technology to various companies including Hankuk Glass Industries, Korea's largest glass manufacturer. In January 2001, Hankuk established a separate subsidiary, SPD Inc., devoted exclusively to the production of SPD film and end-products. Mass production of SPD products at SPD Inc.'s plant in Incheon, Korea began in February 2002. This major series of events in the history of switchable glass technology has attracted significant press coverage in the United States, Asia and other parts of the world. The associated publicity likely has heightened the awareness level of SPD technology particularly and switchable glass technology as whole.

Knowledge of the properties inherent to switchable glass technology is very limited. For most respondents, the level

of knowledge in this area is restricted to two items: 1.) switchable glass products control the amount of light transmitted through glass, and 2.) the actual control function is accomplished through the integration of an electrical interface into the product. Very few respondents were able to share any technological or performance information about either LC, EC or SPD switchable glass specifically.

End-users' Interest in Switchable Glass Products

Respondents were asked to rate the expected level of interest in switchable glass products among residential and commercial end-users within the next three years. To obtain this information, respondents were first asked to identify whether their company offered window products to the residential market or to the commercial market. Fully 96% reported that their company offers window products to residential homes, while 66% said their company offers products to commercial buildings.

Among those whose companies serve the residential market, 17.2% believe that residential homeowners will be "very interested" in switchable glass products over the next three years, while 45.2% claim that residential homeowners will be "very interested" or "somewhat interested" in such products over the next three years. Only 8.3% claim that homeowners will be "very disinterested" in these products over the next 3 years. Among individuals whose companies serve the commercial market, 34.2% believe commercial developers will be "very interested" in switchable glass products within the next three years. Almost seventy percent (69.4%) feel that commercial developers will be "very interested" or "somewhat interested" in switchable glass products within this time period. Just 9.1% believe that commercial developers will be "very disinterested" in switchable glass products over the next 3 years.

Importance of Various Attributes to End-Users

The individuals interviewed for the study were asked to rate the level of importance that various attributes of switchable glass technology would have to end-users (i.e. prospective window buyers). These attitudes reflect an impression that the needs of potential consumers are highly functional in nature, with durability, the reduction of glare and heat, the ability to be used with low-e glass and the control of daylight as the most important product attributes. Respondents were asked to rate each item using a 1 to 4 scale, where 4 was "very important" and 1 "very unimportant." The average importance scores for each of the attributes examined are presented in descending order in Table 2. [1]

Table 2. Perceived Importance of Various Switchable Glass Attributes to End-Users

Rank	Attribute	Mean
1	Durable	3.8
2	Reduce glare and heat	3.5
3	Ability to be used with low-e	3.4
4	Control of daylight	3.4
5	UV protection	3.3
6	Offer range of light transmission	3.3
7	Eliminate need for window coverings	2.9
8	Increase security	2.8
9	Aesthetic benefits	2.8
10	Manual & automatic adjustment	2.5

Importance of an Almost Instantaneous Tint Change to End-Users

Scientific research indicates that switchable glass technologies vary in terms of the speed of their tint change. Some technologies change almost instantly, while others are significantly slower to change tint. Further variation exists in terms of the range of light transmission available, with some technologies offering just “clear” and “light scattering” (but not light blocking) states, and others offering, in effect, an unlimited number of transmission levels. Respondents were asked to rate the importance of an almost instantaneous tint change to end-users. Respondents whose companies serve the residential market were asked to assess the attitude of residential window customers, while those serving the commercial market were asked to assess the commercial window market.

As the data in Table 3 demonstrate, the perceived importance of an almost instantaneous tint change is far greater for the residential market than it is for the commercial market. In fact, 63.4% of those serving the residential market believe that an almost instantaneous tint change will be “very important” or “somewhat important” to end-users. Comparatively, 35.2% of those serving the commercial market believe commercial developers will feel that an almost instantaneous tint change is “very important” or “somewhat important.” Notably, the “top box” (“very important”) scores for this measure show somewhat dramatic differences in opinion. While 36.6% of respondents who serve the residential market claim that residential homeowners believe that an almost instantaneous tint change will be “very important”, just 16.6% of those whose companies serve the commercial market believe that commercial developers will feel this way. [1]

Table 3. Importance of a Tint Change That is Almost Instantaneous (Residential vs. Commercial End-Users)

Category	Residential	Commercial
Very Important	36.6%	16.6%
Somewhat Important	26.8%	18.6%
Somewhat Unimportant	29.4%	44.3%
Very Unimportant	7.2%	15.3%
Unsure/Don't know	0.0%	5.2%

Manufacturers’ Interest in Offering Switchable Glass Products

Window manufacturers’ interest in offering switchable glass products to either residential or commercial markets is fairly strong. Respondents whose companies offer window products to the residential market were asked to rate their firm’s interest in offering switchable glass products to that market over the next three years. Impressively, 31.0% said their company would be “very interested”, while 51.1% said their company will be “very interested” or “somewhat interested.” Just 9.6% of this group claimed their company will be “very disinterested.” Among those individuals whose companies serve the commercial market, 29.0% reported that their company will be “very interested” to offer switchable glass products to commercial developers over the next three years. Fully 57.0% said their company will be “very interested” or “somewhat interested”, while 12.4% of this group said their company will be “very disinterested.” [1]

Price Sensitivity

A perception exists that switchable glass for windows is a high-priced technology. Yet, interest levels are highly sensitive to incremental manufacturing costs. The study found that a firm’s likelihood of offering switchable glass technology increases as the incremental cost needed to produce the technology decreases. Hence, one can conclude that a classic downward sloping demand curve exists for switchable glass technology, with the slope of that curve reflecting price elasticity. Using a survey technique known as “laddering,” respondents were asked to indicate the likelihood of their company offering switchable glass windows if the incremental manufacturing cost (per square foot) were in various ranges. Question presentation began with the highest price given first. For respondents who claimed their company would offer switchable glass windows at that incremental price, it was assumed that the company also would offer windows with switchable glass at lower incremental prices as well. For those who would not offer switchable glass at the highest price, the next highest price was asked and the process continued. Cumulative “likelihood” totals are

presented in Table 4. The data indicate a small but not insubstantial percentage of window manufacturers (13.5%) will be interested in offering switchable glass products if the incremental manufacturing costs to produce such products are in the range of \$26 to \$50 per square foot. A much larger percentage, 47.4%, believe their respective company will be interested in offering switchable products if their incremental manufacturing costs are in the range of \$11 to \$25 per square foot. [1]

Table 4. Likelihood of Offering Switchable Glass Windows at Various Incremental Manufacturers' Prices per square foot

Price Ranges (per sf)	% Likely*
> \$50	6.8%
\$26 - \$50	13.5%
\$11 - \$25	47.4%
\$5 - \$10	80.6%
\$2.50 - \$4.99	88.6%
< \$2.50	89.2%

* Cumulative Totals

Expected Level of Market Penetration

As an emerging technology, switchable glass for windows is in the earliest stages of its product life cycle with only a very limited global presence at this time. In order to assess expectations for adoption of this class of technologies, respondents were asked to give their expected level of market penetration for the technology by 2005. Respondents whose companies serve the residential market give a median level of expected market penetration of switchable glass for windows (installed or retrofitted) of 3.6%, while those serving the commercial market expect a 6.2% level of market penetration. [1]

Expected Pace of New Product Launches

Finally, respondents were asked to rate their expectations for the pace of new product launches by window manufacturers over the next 5 years. The results indicate that overall, United States window manufacturers expect a moderately strong level of new product introduction through 2005, with 61.2% claiming they expect the pace of new product launches to be either "very strong" or "somewhat strong." Just 0.6% of those surveyed said that the pace of new product launches in the industry through 2005 will be "very weak." These results are summarized in Table 5. [1]

Table 5. Expected Pace of New Product Launches by Window Manufacturers/Next 5 Years

Category	%
Very Strong	18.1%
Somewhat Strong	43.1%
Somewhat Weak	31.4%
Very Weak	0.6%
Unsure/Don't Know	6.8%

RESULTS OF SELECTED HYPOTHESIS TESTS

Manufacturers' Interest in Offering Switchable Glass Windows

The contact list of United States window manufacturers included recent annual sales estimates. These were aggregated in a manner that grouped the participating companies into two categories based on their sales volumes: 1.) higher sales volume manufacturers, hereinafter referred to as "Tier I" companies, and 2.) lower sales volume manufacturers, described as "Tier II" companies. An objective of the study was to examine whether statistically significant differences exist in terms of manufacturers' interest based on sales volume status. A t-test of independent means was used to examine the null hypothesis that no significant difference exists between the two groups. Response categories were assumed to be interval in nature, and mean scores were derived using a 1 to 4 scale, where 1 is "very disinterested" and 4 "very interested." Table 6 summarizes the results for the residential market. These results indicate that individuals from Tier II (lower sales volume) companies have a much greater interest in offering switchable glass products than their counterparts at Tier I (higher sales volume) companies. Further, the statistical significance of this difference is very high ($p < 0.01$). From a commercialization perspective, it is important to note that both groups displayed, at minimum, mid-range levels of interest regardless of status.

Table 6. Manufacturers' Interest in Offering Switchable Glass Products/Residential Market Test of Independent Means

	Tier I	Tier II
Mean	2.000	2.952
Standard error	0.376	0.162
t	-2.463	
Significance (1-tailed)	p=0.009	

Similarly, a t-test of independent means was conducted to challenge the hypothesis that no statistically significant difference exists in manufacturers' interest in offering switchable glass products to the commercial market based on their annual sales volume. Once again, individuals from the smaller Tier II companies express a much greater level of interest in offering switchable glass products to the commercial market over the next three year. These results, which are summarized in Table 7, indicate that a statistically significant difference exists ($p < 0.1$) between Tier I and Tier II companies on this measure. Several additional items are observed. First, a directional difference is found regarding the attitude of Tier I companies toward offering switchable glass products to commercial developers. The data suggest that Tier I companies may be more interested in offering these products to the commercial market than to the residential market. Finally, regardless of status or market served, all companies have a mid-range level of interest or higher, on average, in offering switchable glass products to window manufacturers.

Table 7. Manufacturers' Interest in Offering Switchable Glass Products/Commercial Market Test of Independent Means

	Tier I	Tier II
Mean	2.375	2.929
Standard error	0.239	0.286
T	-1.495	
Significance (1-tailed)	p=0.073	

Respondents were asked to give the approximate percentage of window products (on a square foot basis) that their company produces for residential homes and also for commercial buildings. Responding companies whose percentage of windows offered to the residential market was equal to or exceeded the median of all responding companies were classified as "Group A" companies, while the remainder were classified as "Group B" companies. Hypothesis tests were conducted to challenge the belief that no statistically significant difference in manufacturers' interest in offering switchable glass exists based on the percentage of their total window products that are produced for the residential market. These data, summarized in Table 8, indicate with a moderate level of confidence ($p < 0.15$) that companies which offer a higher percentage of window products than others to the commercial market have a greater interest in offering switchable glass products to the residential market over the next 3 years.

Table 8. Manufacturers' Interest in Offering Switchable Glass Products/Residential Market Test of Independent Means

	Group A	Group B
Mean	2.269	2.650
Standard error	0.219	0.233
t	-1.181	
Significance (1-tailed)	p=0.1220	

A similar test was conducted to challenge the hypothesis that no statistical difference in manufacturers' interest in offering switchable glass exists based on the percentage of their total window products that are produced for the commercial market. Once again, a difference is observed between the two groups of companies, with companies that offer a higher percentage of products to the commercial market also expressing a higher interest in offering switchable glass products for windows. The statistical significance of this difference is moderate ($p < 0.15$).

Table 9. Manufacturers' Interest in Offering Switchable Glass Products/Commercial Market Test of Independent Means

	Group A	Group B
Mean	2.300	2.800
Standard error	0.396	0.200
t	-1.262	
Significance (1-tailed)	p=0.1085	

The results of these tests of independence are further supported by correlation analyses. Working with a company's annual sales volume as an ordinal variable, a correlation between annual sales volume and a manufacturer's interest in offering switchable glass can be determined. The Spearman correlation between company status and interest in offering products to the residential market is moderately negative (-0.447) with a high level of statistical significance ($p < 0.01$). This supports the earlier result which found that manufacturers' interest in offering switchable glass products to the residential market is inversely correlated with a company's annual sales volume. A weaker and less significant correlation is found for the commercial market (-0.286, $p < 0.10$). Thus, while interest exists among window manufacturers in both groups, interest increases among manufacturers who have lower annual sales volumes. The results imply that smaller

window manufacturers, likely serving specialty markets, may be among the first companies to offer switchable glass products to their customers.

Pearson correlation analyses also were conducted to examine the association between manufacturers' interest in offering switchable glass products and the percentage of their window products that are sold to residential markets. The association between the percentage of a manufacturer's window products offered to residential markets and a manufacturer's interest in offering switchable glass products to residential homeowners is moderately negative (-0.237), and somewhat statistically significant ($p < 0.10$). The association between the percentage of a manufacturer's window products offered to residential markets and a manufacturer's interest in offering switchable glass products to commercial developers is slightly negative (-0.148) and not significant ($p < 0.25$). Thus, to some degree, the data indicate that as window manufacturers' product mix shifts away from the residential market and toward the commercial market, interest in offering switchable glass products increases.

MULTIPLE LINEAR REGRESSION ANALYSIS

The previously completed hypothesis tests found that a window manufacturer's interest in offering switchable glass products over the next 3 years differs quite significantly based on the amount of the firm's annual sales volume and somewhat significantly based on the mix of a firm's sales to residential and commercial customers. The researcher wanted to use this information to develop models that predict a window manufacturer's likelihood of offering switchable glass products over the next three years to the residential market and to the commercial market. The technique employed is multiple linear regression. In this particular analysis, the dependent variable is "likelihood of offering switchable glass products over the next three years," and the independent (predictor) variables are "company sales volume" (Tier I versus Tier II) and the status as a company equal to/more likely or less likely than others to offer window products to the residential market (Group A versus Group B).

The data in Table 10 indicate that approximately one-fifth (17.8%) of the variation in manufacturers' interest in offering switchable glass products to residential homeowners over the next three years is explained by differences in their annual sales volume and by differences in the percentage of window products sold to the residential market. Further, the analysis results in a test statistic value (F) of 5.867 and a high level of statistical significance ($p < 0.01$).

**Table 10. Multiple Linear Regression Results
Dependent Variable: Interest in Offering Switchable
Glass Products to Residential Market/Next 3 Years**

Adjusted r-square	0.178
F	5.867
Significance	$p = 0.006$

Extending the regression analysis to focus on manufacturers' interest in offering switchable glass products to the commercial market over the next 3 years, the model has less predictive power. Just 3.7% of the variation in manufacturers' interest is explained by the independent variables. The statistical significance of this result also is quite low ($p < 0.25$).

**Table 11. Multiple Linear Regression Results
Dependent Variable: Interest in Offering Switchable
Glass Products to Commercial Market/Next 3 Years**

Adjusted r-square	0.037
F	1.562
Significance	$p = 0.228$

CONCLUSION

The 2000 study of United States window manufacturers offers business decision makers a unique perspective on the attitudes and expectations of these manufacturers toward switchable glass products. The study found strong levels of awareness of switchable glass technology in general, but substantially lower levels for selected types of switchable technologies. Since the completion of the research (summer 2000), commercialization activity and concomitant publicity and press coverage have grown markedly, particularly in the area of suspended particle device technology. This likely has increased awareness of SPD technology specifically and that of switchable glass technology in general. Knowledge of switchable glass technology also is quite limited and is primarily restricted to the fact that switchable glass can control the amount of light transmitted through glass, and that this control function is accomplished through the use of an electrical interface.

The study finds window manufacturers' expectation of end-user interest in switchable glass over the next three years is strong in both the residential and commercial markets. Further, manufacturers' interest in offering switchable glass window products is fairly strong as well.

A variety of attributes of switchable glass products were presented to respondents. Those surveyed cite durability, reduction of glare and heat, the ability to be used with low-e glass and control of daylight as the attributes they expect will be most important to end-users. A notable difference is observed regarding the importance of an almost instantaneous tint change. Respondents believe that an almost instantaneous tint change will be more important to the residential market than it will be to the commercial market.

Expectations for market penetration of switchable glass products vary by segment. Respondents serving the residential segment expect penetration of switchable glass in the residential market to be 3.6% by 2005 (installed or retrofitted), while those offering products to the commercial market anticipate a penetration rate in that market by that time of 6.2%.

Some degree of price sensitivity is observed regarding switchable glass products for windows, with nearly half of all respondents claiming their company would be likely to offer switchable glass products if the incremental manufacturing cost per square foot were in the range of \$11 to \$25. Nearly one-seventh (13.5%) said their company would be likely to offer these products at incremental manufacturing costs of \$26 to \$50 per square foot.

Finally, statistical testing revealed that significant differences exist in manufacturers' interest in offering switchable glass products to the residential or commercial markets over the next three years based on the size of a company's annual revenue. Individuals from smaller companies express a significantly higher level of interest in offering switchable glass products than do their larger counterparts. Individuals whose companies offer a lower percentage of window products to residential customers than other companies sampled also are more likely to claim their companies will be interested in offering switchable glass products over the next three years, although this result is only moderately statistically significant.

Integrating firm data regarding annual sales volume and the amount of window products offered to each market into a multiple linear regression analysis leads to several conclusions. The analysis finds that these two variables account for nearly one-fifth of the variation in manufacturers' interest in offering switchable glass products to the residential market over the next three years. This result is highly significant. Less predictive and less significant is the model's ability to forecast manufacturers' interest in offering switchable glass products to the commercial market over the next three years.

The information developed from this nationwide study of window manufacturers signals opportunities for companies involved in developing and marketing switchable glass products. Awareness levels are strong, and anecdotal evidence suggests this level may be rising due to a growing amount of related publicity. However, in-depth knowledge of specific switchable glass technologies and their inherent benefits is limited. Interest levels in the technology are fairly strong, as are the expectations for the technology's market penetration. However, these positive forces are somewhat offset by a degree of perceived price sensitivity regarding the technology that is exhibited by many of the window manufacturers surveyed. The study's findings indicate that incremental manufacturing costs of \$100 or more per square foot will meet with substantial resistance by window manufacturers. Even so, it is possible that price sensitivities may decline as end-user demand increases for switchable glass products. In the final analysis, optimal commercialization of switchable glass technology will occur when market demand ultimately warrants the incremental costs associated with the production and sale of switchable glass products, thus leading to an acceptable and sustainable return on investment for the companies involved.

REFERENCES

1. M.R. LaPointe and G.M. Sottile, "2000 Survey of Window Manufacturers on the Subject of Switchable Glass," *Proceedings of SPIE – The International Society of Optical Engineering, Solar and Switching Materials*, Vol. 4458, p.112, 2001.