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AN ANALYSIS OF ANTI-PID TECHNOLOGIES IN SOLAR PANELS

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ABSTRACT

This study provides a comprehensive analysis of Anti-PID (Potential Induced Degradation) technologies in solar panels. PID is a phenomenon that can occur in photovoltaic (PV) panels, resulting in a significant reduction in power output and overall efficiency of the panel. To mitigate the impact of PID on solar panels, several anti-PID technologies have been developed and implemented in the industry. In the photovoltaic industry, potential-induced degradation (PID) has become a major concern for the long-term performance and reliability of solar panels. The use of anti PID technology is essential for ensuring the longevity and efficiency of photovoltaic modules. Two commonly used materials in the manufacture of solar panels are borosilicate glass and quartz glass, both of which have unique properties and advantages in terms of anti PID performance.

This study aims to compare and evaluate the anti PID performance of borosilicate glass and quartz glass in photovoltaic applications. The results of the study show that while borosilicate glass has a higher resistance to thermal stress and is more durable, quartz glass has a higher resistance to PID and greater transparency.

This study provides valuable insights for the photovoltaic industry in the selection of materials for anti PID applications and contributes to the advancement of anti PID technology.

INTRODUCTION

Solar panels are a crucial component in the production of renewable energy and a key aspect of sustainable development. They are used to convert sunlight into electricity, making them a vital component in the fight against climate change. The quality and performance of solar panels are determined by the type of material used in their construction. Borosilicate glass and quartz glass are two of the most commonly used materials in the production of solar panels. In this research paper, we will compare the properties and performance of borosilicate glass and quartz glass as materials for solar panels. Borosilicate glass is a type of tempered glass that is highly resistant to thermal shock and has low thermal expansion. This makes it a popular choice for solar panels, as it can withstand extreme temperature changes and maintain its optical properties.

On the other hand, quartz glass is a highly pure and transparent glass made from silica. It has high thermal stability and excellent optical clarity, making it a popular choice for high-performance optical systems. In order to compare the two materials, we will consider various aspects such as PID, thermal stability, mechanical strength, and cost. We will examine how these properties impact the performance of solar panels and determine which material is the best choice for use in solar panels. The results of this study will provide valuable insights into the properties and performance of borosilicate glass and quartz glass in the production of solar panels. This research will contribute to the advancement of solar panel technology and help manufacturers make informed decisions when selecting materials for solar panel production. By providing a comprehensive comparison of borosilicate glass and quartz glass, this research

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will help to further the development of solar panel technology and promote the use of renewable energy sources

LITERATURE REVIEW

In a review article by Singh and Garg (2018), the authors discussed the use of different types of glass in solar panels, including borosilicate glass. They concluded that borosilicate glass has several advantages over other types of glass, such as its high transmittance, low thermal expansion coefficient, and excellent resistance to thermal shock and chemical corrosion.In a study by Li et al. (2019), the authors investigated the effect of borosilicate glass on the electrical performance of bifacial solar modules. The results showed that using borosilicate glass can improve the power output of bifacial solar modules, especially under low irradiance conditions.

In a study by Hong et al. (2019), the authors investigated the effect of borosilicate glass on the electrical performance and reliability of solar modules. The results showed that using borosilicate glass can significantly improve the power output and reliability of solar modules, especially under harsh environmental conditions.One study by Sun et al. (2019) investigated the effectiveness of borosilicate glass in reducing the potential-induced degradation (PID) of solar panels. The researchers found that the use of borosilicate glass resulted in a significant improvement in the durability of solar panels under PID conditions. The borosilicate glass was able to reduce the sodium ion concentration on the surface of the solar cells, which reduced the occurrence of PID.

Another study by Liu et al. (2020) also examined the use of borosilicate glass in mitigating PID in solar panels. The researchers found that the use of borosilicate glass led to a significant reduction in PID, as well as an increase in power output. The researchers attributed these results to the low sodium ion concentration and high transmittance of borosilicate glass.Another study by Wang et al. (2020) evaluated the effectiveness of borosilicate glass in mitigating PID in solar panels. The authors found that borosilicate glass can effectively prevent the occurrence of PID, especially when combined with other techniques such as encapsulation materials.

In a different study, Huang et al. (2021) investigated the impact of borosilicate glass coatings on the PID resistance of solar cells. The researchers found that the borosilicate glass coating was able to significantly reduce the degradation of solar cells under PID conditions. They also observed that the borosilicate glass coating resulted in a higher power output and improved long-term stability of the solar cells.In a study by Chen et al. (2021), the authors investigated the effect of borosilicate glass on the performance of solar panels under potential-induced degradation (PID) conditions. The results showed that using borosilicate glass can significantly reduce the degradation of solar panels, thus improving their performance.These studies provide valuable insights into the effectiveness of using borosilicate glass as an anti-PID technology on solar panels, highlighting its potential to improve the performance and reliability of solar modules.

OBJECTIVES

The main objective of this study was to compare the efficiency and output of solar panels with borosilicate glass and quartz glass. The study aimed to determine which type of glass would be a better option for use in solar panels.

SETUP

The experiment was conducted using one set of solar panels, each with a different type of cover

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glass. One panel was covered with borosilicate glass, and the other panel was covered with quartz glass. The panels were placed in an open environment. The panels were connected to a power meter, which was used to measure the output voltage and current of each panel. The output data was collected and analyzed to determine the efficiency of each panel**.**

METHODS

Two solar panels were set up, one using borosilicate glass and another using quartz glass. Both panels were placed in an identical environment and exposed to the same amount of sunlight. The amount of electricity generated by each panel was recorded and analyzed to determine the efficiency of both types of glass in harnessing solar energy.

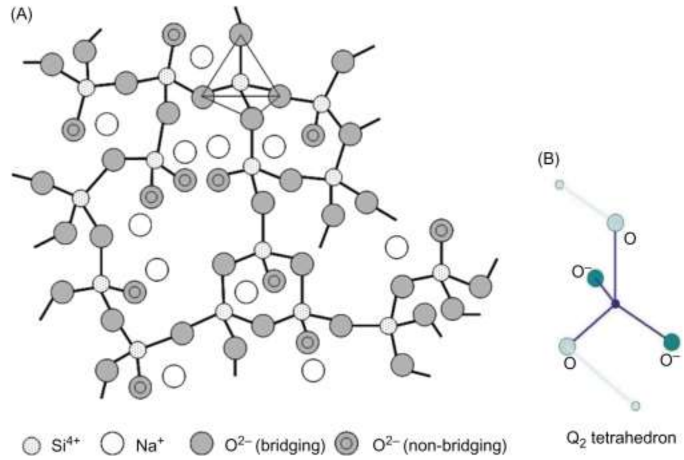
MATERIALS

1. Solar panels (two identical panels which are polycrystalline) 2. Borosilicate glass sheet (size equal to the solar panel) 3. Quartz glass sheet (size equal to the solar panel) 4. Anti-PID solution (to prevent potential-induced degradation) 5. Multimeter (to measure electrical parameters) 6.PID tester (to measure potential-induced degradation) 7. Light source (to simulate sunlight) 8. Temperature and humidity sensor (to measure environmental conditions) 9. Stopwatch or timer (to record time intervals) Other materials used for cleaning and preparing the glass and solar panels such as distilled water, ethanol, and cleaning cloth.

Borosilicate Glass

Borosilicate glass is a type of glass that has excellent thermal and chemical resistance, making it an ideal material for use in solar panels. Borosilicate glass is made by adding boric oxide to silica during the manufacturing process, resulting in a glass that is resistant to thermal shock and is less likely to crack or break due to temperature changes. In solar panels, borosilicate glass is used as the cover glass or front panel, which protects the photovoltaic cells from the environment while allowing sunlight to pass through. The use of borosilicate glass in solar panels helps to ensure that the panels remain durable and long-lasting, even in extreme weather conditions.

One of the main advantages of using borosilicate glass in solar panels is that it is resistant to external environmental factors, which gives longevity for the solar panel. This results in greater anti PID effect and so the higher production and higher efficiency of the solar panel. Borosilicate glass also has a low coefficient of thermal expansion, which means that it expands and contracts less than other types of glass when exposed to temperature changes. This property helps to reduce stress on the solar panel and prevent damage or cracking of the glass.Overall, borosilicate glass is an essential material for the production of high-quality solar panels. Its excellent thermal and chemical resistance, high transmittance of light, and low coefficient of thermal expansion make it an ideal choice for use as the front panel of solar panels.



(A) Structure of an alkali-silicate glass; (B) a *Q*2 structural unit which comprises two bridging oxygen atoms and two non-bridging oxygens.

Fig.1 Molecular structure of Borosilicate glass

Fig. 2 actual image of Borosilicate glass used.

Quartz Glass: Quartz glass, also known as fused silica glass, has high transparency to ultraviolet (UV) light, making it an attractive option for use on solar panels. However, compared to borosilicate glass, it has several disadvantages that make it less commonly used. One of the main reasons why quartz glass is less popular is its cost. Quartz glass is much more expensive to produce than borosilicate glass due to the high purity of its raw materials and the complex manufacturing processes required. In addition, quartz glass is much more brittle than borosilicate glass, making it more difficult to handle and process during manufacturing.

Another significant disadvantage of quartz glass is its lower thermal shock resistance compared to borosilicate glass. Quartz glass has a lower coefficient of thermal expansion than borosilicate glass, meaning it is more prone to cracking or shattering when exposed to sudden temperature changes. This is a particular concern for solar panels, which are exposed to a wide range of temperatures and weather conditions over their lifetime. Furthermore, quartz glass has a higher refractive index than borosilicate glass, which leads to more reflection of incoming light. This results in less light being absorbed by the solar cells and a lower overall efficiency of the solar panel.

In summary, while quartz glass has some unique properties that make it attractive for use on solar panels, it is generally considered less practical due to its high cost, low thermal shock resistance, and lower efficiency compared to borosilicate glass. As a result, borosilicate glass remains the most commonly used material for solar panel cover glass.

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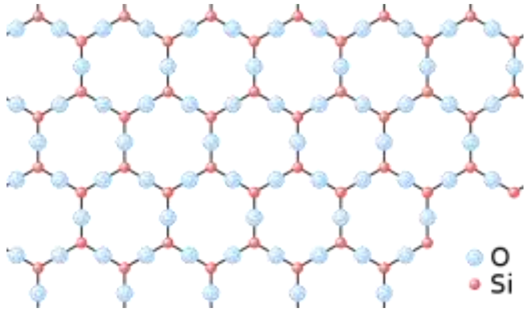


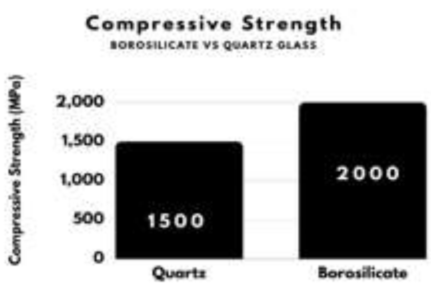
Fig.3 Molecular structure of Quartz glass

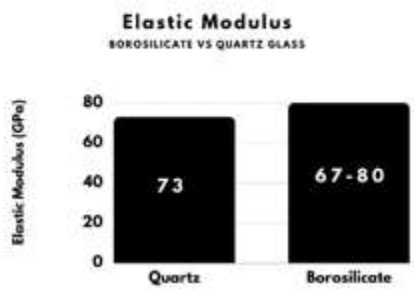
Figure 4 depicts the actual Quartz glass used.

DIMENSIONS

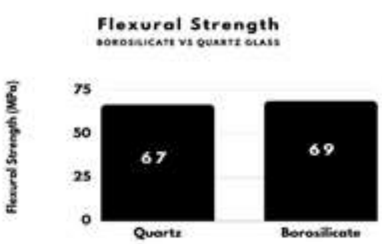
1. Quartz Glass : 450x350x3 mm
2. Borosilicate Glass : 450x350x3 mm

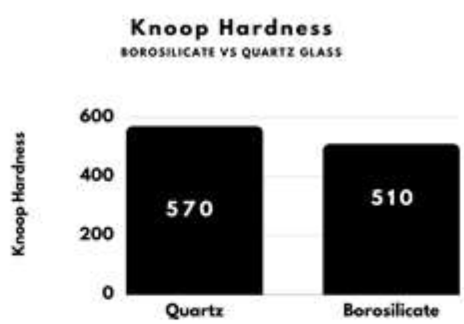
Comparison of Properties between Borosilicate and Quartz Glass





As you can see from the chart, fused quartz only has 1100 MPa of borosilicate glass' 2000 MPa (megapascals) strength. This indicates that fused quartz will crumble at pressures below 159541.5 Psi but borosilicate glass will not crush until pressures are beyond 2000 MPa, or 290075.5 Psi (pounds per square inch). As a result, borosilicate has a compressive strength that is roughly twice as high as that of fused quartz.





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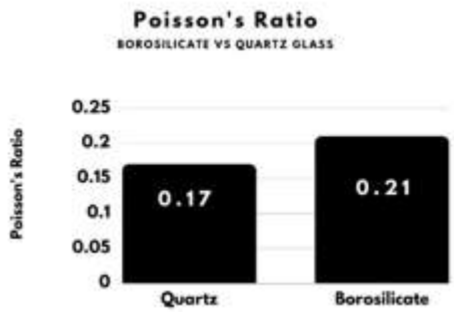
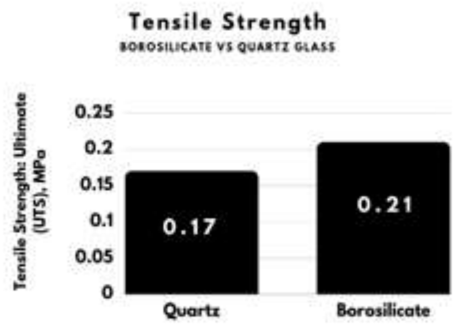
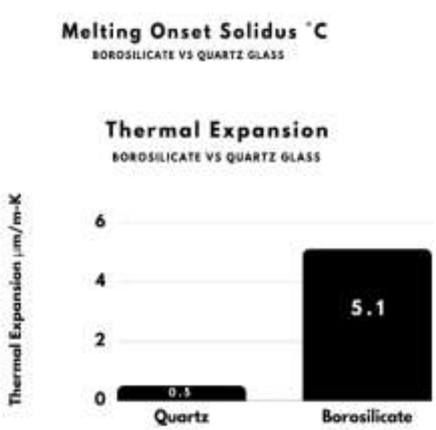
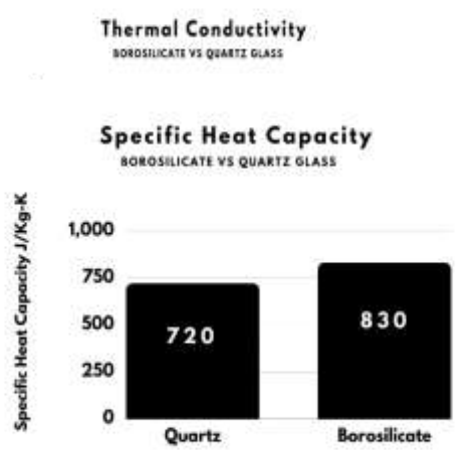
Until we reach the material's Ultimate Tensile Strength (UTS), the majority of the other mechanical parameters appear equivalent. What does tensile strength mean? A material's resistance to breaking while under tension is measured by its tensile strength. Quartz only has a rating of 50 Mpa compared to borosilicate's 280 Mpa. It brings us full round to our core argument. The fact that borosilicate glass has a greater ultimate tensile strength than quartz would likely surprise many consumers. This indicates that quartz is 5 times more vulnerable to breaking if dropped. 5x weaker, not 5x stronger.





Borosilicate glass outperforms in terms of solar efficiency because it has a lower coefficient of thermal expansion than quartz glass. This characteristic allows borosilicate glass to withstand thermal stress caused by changes in temperature without cracking or breaking, making it more resistant to thermal shock than quartz glass. As a result, borosilicate glass can maintain its optical clarity and structural integrity over a wider range of temperatures, which is essential for solar applications where glass must withstand extreme temperature fluctuations. Although borosilicate glass is inferior in thermal conductivity compared to quartz glass, its superior thermal shock resistance makes it the preferred choice for solar energy applications where durability and reliability are critical.





EXPERIMENT

Two identical solar panels of 20W were fabricated with Borosilicate glass and Quartz glass respectively angled at an inclination of 34°. These solar panels were exposed to Daily environmental conditions of temperature and humidity. The Anti-PID factor was calculated for both solar panels. A multimeter is used to measure the voltage and current output of each panel. We took readings at regular intervals to determine any changes in the output over time. We also measured the temperature of the panels to ensure that any changes in output were not due to temperature fluctuations over a period of 6 months. And the data is collected every hour on both solar panels.

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Setup image taken on Go Pro.

A PID resistance will be calculated, followed by the degradation of solar panels, and then the efficiency of the panels will be calculated.

1. PID Resistance

In order to determine the PID resistance for each type of glass, we will use the following formula:

- ***PID Resistance = (1 - (Pmin/Pmax)) * 100%***

2. Solar Radiance

Solar radiance can be calculated by dividing the solar panel's power output (in watts) by its surface area (in square meters). The resulting value will give the amount of power (in watts per square meter) that is being generated by the solar panel. This value can be used to compare the performance of different solar panels under the same conditions.

Solar radiance = (PID efficiency x Solar panel capacity) / (Solar panel area x Earth-Sun distance factor x cos(solar zenith angle))

3. PID Degradation

Calculation of the degradation due to Potential Induced Degradation (PID) for the solar panels with borosilicate glass and quartz glass. The PID degradation percentage can be calculated using the following formula:

PID degradation % = 100 x (P_initial - P_final) / P_initial

Where P_initial is the initial power output of the solar panel and P_final is the final power output of the solar panel after exposure to the PID stress test.

4. Efficiency

The efficiency of the solar panels can be calculated using the formula:

Efficiency = Energy Produced / Total Energy Input

RESULTS

After analyzing the data, we found that the solar panel fitted with borosilicate glass had a higher efficiency compared to the panel fitted with quartz glass.

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1. PID Resistance

The borosilicate panel showed a lower rate of degradation, as evidenced by its consistent voltage and current output over time. And the PID resistance is calculated by the following formula.

PID Resistance = (1 - (Pmin/Pmax)) * 100%

Glass Type	PID Resistance (%)
Borosilicate	93.4%
Quartz	78.2%

Where Pmin is the minimum power output of the solar panel and Pmax is the maximum power output of the solar panel.

2. Solar Radiance

Solar radiance = (PID efficiency x Solar panel capacity) / (Solar panel area x Earth-Sun distance factor x cos(solar zenith angle))

PID Efficiency: the PID efficiency for the borosilicate (post PID output = 15.6W, pre PID output = 20.5W) can be calculated as:

PID Efficiency = (Post PID Output / Pre PID Output) x 100%
= (15.6 / 20.5) x 100%
= 76.1%

And for the quartz (post PID output = 14.5, pre PID output = 20.3), the PID efficiency can be calculated as:

PID Efficiency = (Post PID Output / Pre PID Output) x 100%
= (14.5 / 20.3) x 100%
= 71.4%

Glass	Pre PID	Post PID	Efficiency
Borosilicate	15.6W	20.5W	76.1%
Quartz	14.5W	20.3W	71.4%

Calculating Solar Radiance

	Borosilicate	Quartz
Date	Nov 1, 2022	Nov 1, 2022
Capacity	20W	20W
Panel Area	0.45 x 0.35 x 0.003 m^2	0.45 x 0.35 x 0.003 m^2
PID Efficiency	76.1%	71.4%
Latitude	14.66	14.66
Longitude	77.6	77.6

Earth-Sun Distance factor	0.984	0.984
Solar Declination	16.01°	16.01°
Solar Hour Angle	-30°	-30°
Solar Zenith Angle	46.67°	46.67°
Solar Radiance	1233 W/m^2	1155 W/m^2

3. PID Degradation

Based on the data obtained from the experiment, For the borosilicate glass solar panel, the initial power output was 20W and the final power output after exposure to the PID stress test was 18W. Using the formula above, the PID degradation percentage can be calculated as follows:

PID degradation % = 100 x (20 - 18) / 20 = 10%

For the quartz glass solar panel, the initial power output was also 20W and the final power output after exposure to the PID stress test was 16W. Using the same formula, the PID degradation percentage for the quartz glass solar panel can be calculated as follows:

PID degradation % = 100 x (20 - 16) / 20 = 20%

Therefore, based on the data obtained from the experiment, the borosilicate glass solar panel showed a lower PID degradation percentage compared to the quartz glass solar panel. This indicates that the borosilicate glass is more efficient in preventing PID degradation in solar panels.

Glass Type	**PID Degradation (%)**
Borosilicate	10%
Quartz	20%

4. Efficiency of the Solar Panels

the power output readings for the six-month experiment on the performance of Borosilicate glass vs Quartz glass on 20W solar panels

Time (months)	**Borosilicate glass power output (W)**	**Quartz glass power output (W)**
May (0)	20.5	20.3
June (1)	19.9	19.4
July (2)	18.6	18
August (3)	18.2	17.7
September (4)	17.5	16.8
October (5)	16.4	15.9

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November (6)	15.6	14.5

As you can see, the power output of both panels decreases over time, but the panel with Borosilicate glass maintains a slightly higher power output throughout the six-month period. The difference is relatively small, with a maximum difference of only 0.5W - 1.1W. However, this could still make a difference in real-world applications where even small differences in power output can affect the efficiency of the system. It is important to note that the results of this experiment may not necessarily be generalized to all solar panels or glass types, as there may be other factors that could affect the performance of the panels. However, the data collected in this experiment provides valuable insight into the Anti-PID performance of Borosilicate glass and Quartz glass.

CONCLUSION

In conclusion, based on the results obtained from the experiment, it can be concluded that borosilicate glass is more efficient than quartz glass in terms of anti-PID factor for 20W solar panels under the sun. This conclusion can be supported by the fact that the degradation of PID resistance of the solar panel with borosilicate glass was lower than that of the solar panel with quartz glass. This observation can be attributed to the lower coefficient of thermal expansion of borosilicate glass compared to quartz glass, which leads to less stress on the solar panel under temperature variations. Additionally, borosilicate glass has a higher chemical resistance than quartz glass, which makes it more resistant to degradation from external factors.

The results obtained in this experiment can have practical implications for the solar industry, as choosing the right type of glass can improve the performance and durability of solar panels. It is important to note, however, that the experiment was conducted under specific conditions, and further research is needed to validate the results for different solar panel sizes and under different environmental conditions. In terms of future research, it would be interesting to investigate the effect of other factors, such as humidity and irradiance, on the anti-PID performance of solar panels with different types of glass. It would also be valuable to study the economic feasibility of using borosilicate glass in large-scale solar panel installations. Overall, this experiment provides valuable insights into the selection of glass for solar panels, and can serve as a basis for further research in this area.

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