

Customer

INDUSTRY

Renewable Energy

ORGANIZATION PROFILE

- **Founded in 2001**
- **Listed on NASDAQ since 2006**
- **HQ in Ontario, Canada**

Case Summary

CHALLENGE

One of the world's largest solar technology and renewable energy companies needed to control the thickness of the silicon nitride film to improve the solar cells' surface energy efficiency levels after it was discovered that some of the films being produced were not meeting internal standards.

SOLUTION

Using the powerful charting and analysis tools included in Minitab® Statistical Software and Minitab Engage™, the company was able to pinpoint and rectify the causes for the differences in film thickness. This improved the energy efficiency of the final solar panels by 7%, from 81% to 88%, resulting in an overall revenue increase of more than \$100K annually.

Minitab helps leading solar power company increase energy efficiency and annual revenue by more than \$100K/year

The Minitab® client is one of the world's largest solar technology and renewable energy companies. For more than 20 years, it has been a leading manufacturer of solar PV modules and a provider of solar energy solutions. The company strives to deliver competitive, clean electricity to large energy buyers, and prides itself on its sustainability efforts. It has been listed on the Nasdaq Stock Exchange since 2006 and was named No. 1 Top Bankable Manufacturer rated by Bloomberg New Energy Finance (BNEF) in 2020.



INTRODUCING QUALITY CONTROLS BASED ON POWERFUL STATISTICAL ANALYSIS

Using Minitab Statistical Software and Minitab Engage helped the solar energy company gain control of the thickness of its silicon nitride film, after variations occurring somewhere along the manufacturing process were discovered. Using fishbone diagrams and other Minitab Engage brainstorming tools, the team was able to narrow down the possible causes of the variation. Capability analysis and control charts were then used to quickly determine the ideal conditions for manufacturing. Using Minitab's powerful statistical analysis, the team was able to take targeted and accurate measures to remediate the thickness problem, ultimately increasing the energy efficiency of the final solar panels by 7%, from 81% to 88%, resulting in an overall revenue increase of more than USD 100K per year.

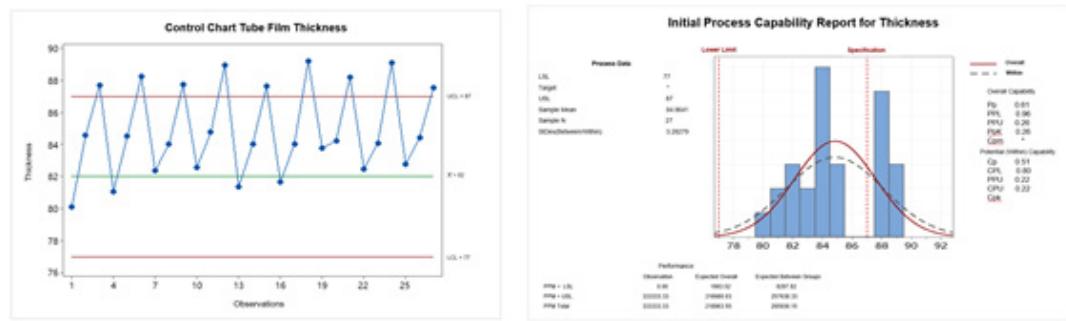
In the past, we used continuous blind testing, and now we finally can quantitatively test our hypotheses. Minitab has provided us with tremendous help."

R&D Manager in charge of Technology Improvement and New Product Development

The Challenge

Inconsistencies in manufacturing process due to unidentified factors.

The Research and Development manager at a solar power company location in Shanghai, China had a problem. His team discovered that their manufacturing process was producing unacceptable levels of variability in the thickness of their silicon nitride films. They needed to control the thickness of the film to improve the solar cells' surface energy efficiency levels and to meet internal standards. The ideal film thickness is between 77 – 87nm.



As illustrated above, from the initial process, the team found that the film thickness exceeded the upper limit as seen in the control chart, and there were issues with the process. Most of the data fell above the average, and the process capability was relatively low. As a result, the defect rate in the current process was very high.



MINITAB TOOLS USED



Minitab®

To look at current and past data to discover trends, find and predict patterns, and uncover hidden relationships between the variables.



Minitab Engage™

Visual brainstorming tools were used to hypothesize about causes of variance to narrow down the possibilities.

The Solution

The project team needed to analyze the reasons for the large variation of the film thickness and screen out the possible factors.

FINDING THE ROOT CAUSE ALONG THE PRODUCTION LINE

The team wanted to determine whether the measurement system or process errors were causing the discrepancies in film thickness. They used the Topcon product testing platform, an industry-standard testing equipment, to measure the film thickness and refractive index.

The team then used Minitab's measurement system analysis to see if the variability was caused by the measurement system itself:

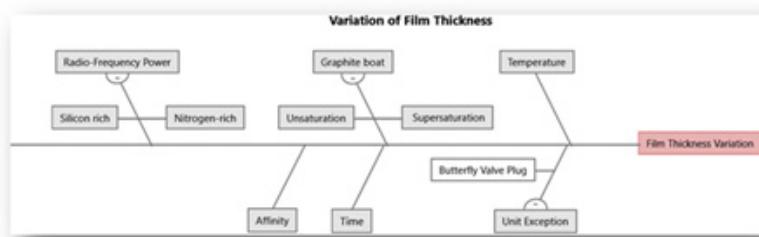
Gage Evaluation		
Source	Study Var StdDev (SD) (6 x SD)	%Study Var (%SV)
Total Gage R&R	0.0002956	9.16
Repeatability	0.0002694	8.35
Reproducibility	0.0001216	3.77
Operator	0.0001216	3.77
Part-To-Part	0.0032140	99.58
Total Variation	0.0032276	100.00

Number of Distinct Categories = 15

The analysis value of the measurement, Gage R&R, is 9.16, which is less than 10%, indicated that the Topcon measurement system met the requirements and was therefore not causing the issues.

NARROWING DOWN POSSIBILITIES WITH MINITAB BRAINSTORMING TOOLS

Still looking for possible influencing factors, the team used the fishbone diagram (also known as a cause-and-effect diagram) in Minitab Engage to brainstorm.



BACKGROUND ON THE CRYSTALLINE SILICON SOLAR CELLS

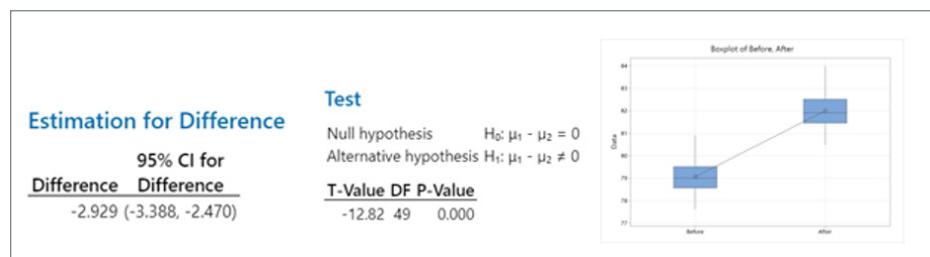
- In the production process it is essential to reduce the reflection on the front surface of the solar cell and passivate the silicon surface of the solar cell.
- The refractive index of crystalline silicon is usually 3.8. If the smooth silicon surface is placed in the air with a refractive index of 1, the reflectivity can reach 30%.
- In the manufacturing process, a light-transmitting dielectric film will be inserted between the silicon surface and the air, so that surface reflection can be reduced. Determining the correct thickness of the film is at the heart of this case study.

IDENTIFYING ONE CAUSE WITH SIMPLE HYPOTHESIS TESTING

Based on the fishbone diagram and the leader's previous experience, the team identified two possible reasons that a malfunction in the equipment or a process issue may cause a variation of the silicon nitride film thickness:

- Frequency of which the butterfly valve, which is a valve that regulates the flow of fluid, in the coating equipment is cleaned
- Furnace temperature and position of the silicon in the furnace

First, the team investigated whether the butterfly valve in the coating equipment cleaning was an issue. The team created a two-sample t-test in Minitab to confirm whether the frequency of the butterfly valve cleaning makes a significant difference to the film thickness.



After the analysis, the team found that the p-value is less than 0.05. This means that there is a significant difference in the film thickness before and after the butterfly valve is cleaned, which means that the cleaning of the butterfly valve also has a significant effect on the film thickness. Eureka!



PINPOINTING THE IDEAL TEMPERATURES WITH REGRESSION ANALYSIS

In order to test the second possible reason (furnace temperature and the relative position of the silicon in the furnace), the project team recorded the actual temperature and film thickness data from three different positions of the furnace: i) the furnace mouth, ii) the middle of the furnace, and iii) the bottom of the furnace respectively.

Analysis of Variance					
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	250.471	83.490	3556.84	0.000
Rel Temp	1	202.861	202.861	8642.25	0.000
Location	2	106.088	53.044	2259.78	0.000
Error	14	0.329	0.023		
Lack-of-Fit	10	0.144	0.014	0.31	0.939
Pure Error	4	0.185	0.046		
Total	17	250.800			

The team used Minitab's Regression Analysis, above, to test different positions and temperatures and their relative relationships.

Regression Equation

Location

$$\text{furnace bottom Thickness} = -116.54 + 0.41367 \text{ Rel Temp}$$

$$\text{furnace middle Thickness} = -116.54 + 0.41367 \text{ Rel Temp}$$

$$\text{furnace mouth Thickness} = -129.43 + 0.41367 \text{ Rel Temp}$$

With the regression model above, the team can see that the temperature and position of the silicon in the furnace are significant factors. Thus they set out to find the value between the temperature at the mouth, middle, and bottom of the furnace, and also the actual temperature to test out the relationships between the factors.

THE FINDINGS

Using Minitab's capability analysis and control charts, the team identified the conditions needed to produce the ideal silicon nitride film thickness:

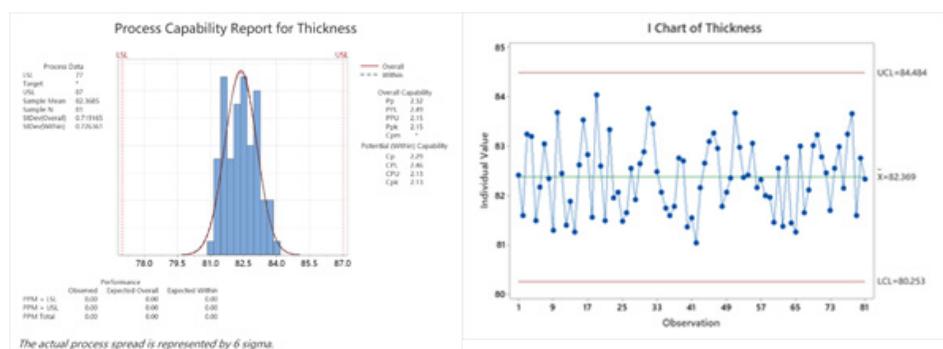
- Butterfly valves should be cleaned twice a day
- Determined the reasonable furnace temperatures. The process output showed the ideal temperature settings for the three respective furnace positions to be 500°C/932°F for the mouth of the furnace, 480°C/896°F for the middle, and 472°C/881°F for the bottom of the furnace

“ During the different various stages of discovery, testing the hypothesis, confirming and problem-solving, Minitab Statistical Software came through, not only shortening the time to solve problems but also improving the confidence of team members’ decisions.”

R&D Manager in charge of Technology Improvement and New Product Development

The Results

The team quickly found the ideal settings for the process parameters using statistical analysis. Inside Minitab’s regression model, the process parameters were adjusted, and the silicon nitride film thickness achieved a stable output. Using the adjusted parameter settings, the team implemented a verification analysis, and the process output showed a temperature settings of 500°C, 480°C, and 472°C for the three respective positions to be the most ideal. At the same time, the value of Cpk was greater than 1.67, and the process capability index was high, far exceeding the pre-set target.



Using Minitab’s powerful statistical analysis, the team was able to take very targeted and accurate measures . “In the past, we used continuous blind testing, and now we finally can quantitatively test our hypotheses. Minitab has provided us with tremendous help,” said the team manager. “During the various stages of discovery, testing the hypothesis, confirming and problem-solving, Minitab Statistical Software came through, not only shortening the time to solve problems but also improving the confidence of team members’ decisions.” By understanding and being able to control the thickness of the silicon nitride film, the team helped improve the energy efficiency of the panels by 7%, from 81% to 88%. According to current production estimates of 6,048 single tube capacity per day, this measure has increased the companies’ revenues by CNY 650,000 (USD 101,400) annually.



Accelerate Innovations:

MINITAB STATISTICAL SOFTWARE AND MINITAB ENGAGE

Minitab Statistical Software has the market's most trusted statistical tools available on the desktop or the cloud to get the most out of data, discover trends, find and predict patterns, uncover hidden relationships between variables, and create stunning visualizations to tackle even the most daunting challenges and opportunities.

Minitab Engage leverages powerful, proven, problem-solving methodologies and brainstorming, diagramming, and mapping tools, Minitab Engage is the only solution that enables the assignment, oversight, management and visibility of ideas and innovation projects to ensure successful execution.

With the power of statistics, industry-leading data analytics, and dynamic visualizations, the possibilities are endless.

ABOUT MINITAB

Minitab helps companies and institutions to identify trends, solve problems and discover valuable insights in data by delivering a comprehensive and best-in-class suite of data analysis and process improvement tools. Combined with unparalleled ease-of-use, Minitab makes it simpler than ever to get deep insights from data. Plus, a team of highly trained data analytic experts and services ensure that users get the most out of their analyses, enabling them to make better, faster and more accurate decisions.

For nearly 50 years, Minitab has helped organizations drive cost containment, enhance quality, boost customer satisfaction and increase effectiveness through its proprietary solutions. Thousands of businesses and institutions worldwide use Minitab® Statistical Software, Minitab Connect™, Salford Predictive Modeler®, Minitab Workspace®, Minitab Engage™ and Quality Trainer® to uncover flaws and opportunities in their processes and address them. Minitab Solutions Analytics™ is Minitab's proprietary integrated approach to providing software and services that enable organizations to make better decisions that drive business excellence.

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