ARTICLE

IN-LINE PROCESS OPTIMIZATION WITH SPECTROSCOPY

INTRO

SMART MANUFACTURING: SPECTROSCOPY'S ROLE IN IN-LINE PROCESS OPTIMIZATION

Traditional manufacturing is undergoing a significant transformation due to rapid technological advancements. Modern data science is driving the emergence of 'smart manufacturing',[1] fundamentally changing how processes are developed, monitored, and assessed. Smart manufacturing aims to boost productivity, sustainability, and economic performance by seamlessly integrating all operational systems within industrial enterprises.

This article delves into the role of spectroscopy in revolutionizing smart manufacturing, highlighting how it helps foster improved product quality, consistency, and proactive process optimization.

In-Line Process Analytics

In smart manufacturing, accurate and timely data flow is crucial. Manufacturers aim to monitor each step of their processes to ensure optimal results. However, achieving precise control over manufacturing parameters, preventing defects, and maintaining adaptability in dynamic environments pose significant challenges.

In addressing these challenges, in-line process analytics plays a vital role.[2] This approach enables direct measurement of key parameters within each process in real-time, unlike traditional on-line analysis methods that rely on sampling loops. By providing continuous, real-time data, in-line process analytics allows manufacturers to swiftly adjust parameters, optimizing product quality, throughput, and yield.

SPECTROSCOPY: REVOLUTIONIZING MANUFACTURING

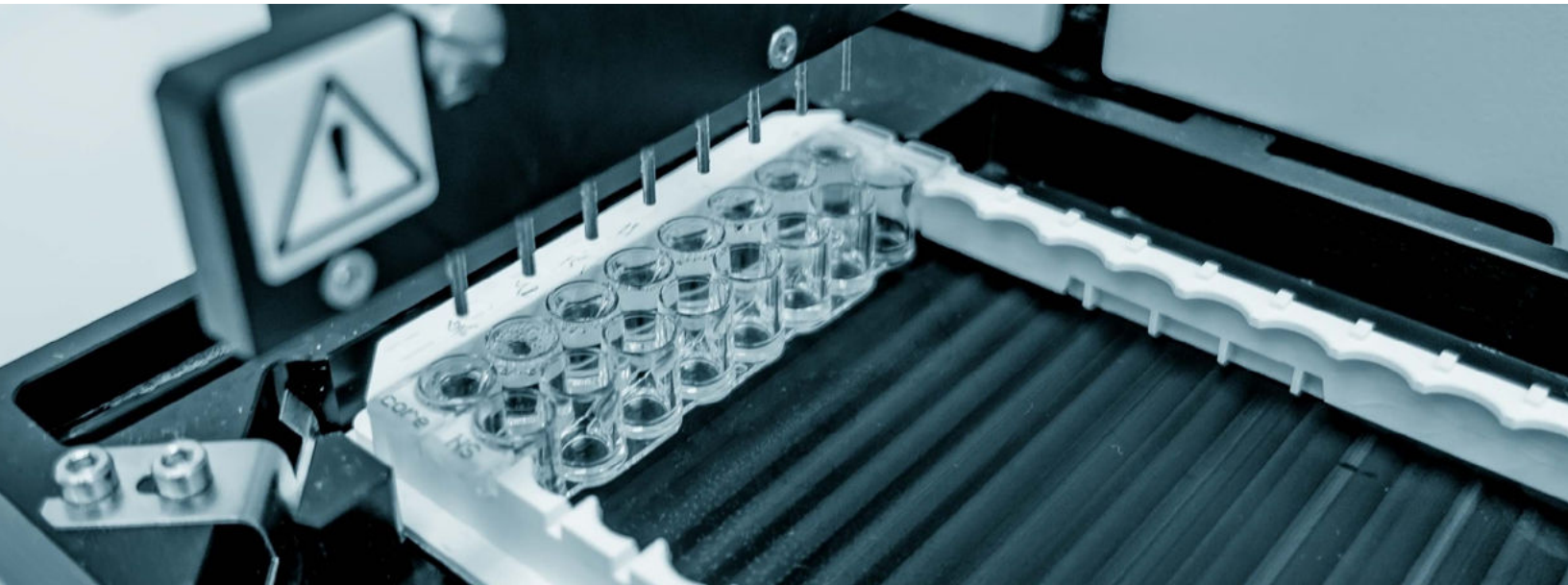
Over the last two decades, industries spanning pharmaceuticals, polymers, and semiconductors have increasingly embraced developing advanced in-line monitoring techniques for process analysis. Among the advanced sensing technologies driving in-line process analytics, spectroscopy stands out as a game-changer.

Spectroscopy, a technique for analyzing the interaction between matter and electromagnetic radiation, plays a critical role in smart manufacturing, particularly in optimizing in-line processes for improved overall operational efficiency and product quality. Combined with machine learning, spectrometers can help predict and prevent defects. Manufacturers can achieve precise control over processes by harnessing spectroscopic techniques, ensuring optimal product quality and consistency.

One example of an application where the implementation of spectroscopic techniques is proving invaluable for quality control is the pharmaceutical industry. Using techniques such as Raman spectroscopy, it is possible to set up in-line monitoring for the manufacturing processes of therapeutics, such as monoclonal antibodies.[3] The measured spectra are used to determine the concentration and retrieve information, such as confirming the presence of any contaminants or active ingredients.

Other uses of spectroscopy in manufacturing include automated process optimization and control.[4] In this context, a spectrometer is utilized to detect the chemical signature of the desired product. By varying reaction conditions, such as temperature or pressure, the yield of specific product species can be observed. Feedback loops may also be established as needed. Employing optimization algorithms enables the identification of the most effective combination of reaction parameters for optimal production outcomes.

The information-rich nature of the data that can be collected with spectroscopic techniques on concentrations, sample purities, etc., means some parameters can be compared for sample-to-sample consistency as well as quality control.



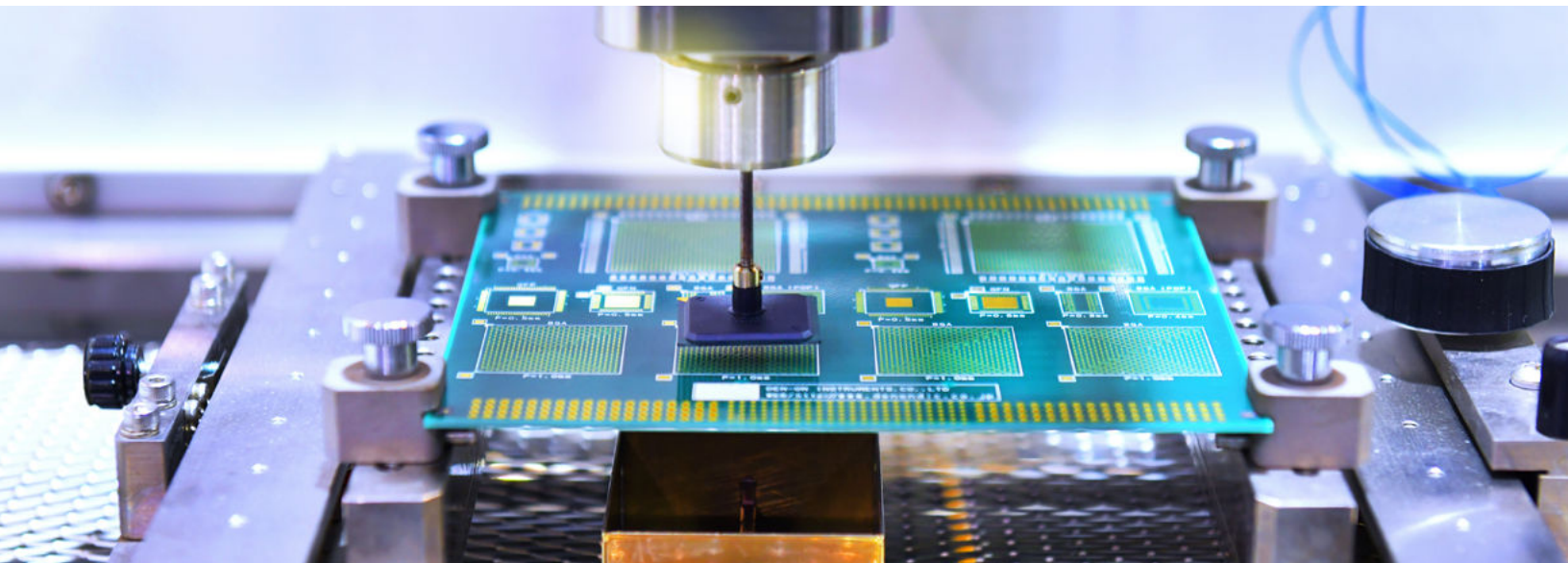
AVANTES' SPECTROMETER SOLUTIONS

Avantes offers a range of advanced spectrometers ideal for in-line process optimization, including its next-generation NEXOS™[5] and VARIUS™[6] devices. These spectrometers boast superior optical performance and customizable features, facilitating high-speed data transfer for high-precision monitoring and control of critical manufacturing parameters with real-time data provision.

The NEXOS™ Spectrometer is a lightweight, compact spectrometer that seamlessly integrates various sensors and devices within smart manufacturing systems. Users can select from multiple configurations of gratings and slits to align with specific requirements, along with different communication protocols such as USB2, direct interfacing, RS232, and SPI. This flexibility empowers manufacturers to make rapid adjustments based on real-time spectroscopic data, meeting varying product specifications.

Similarly, the VARIUS™ Spectrometer offers unparalleled flexibility, with a new magnetic connector cover for easier slit replacement and enhanced performance featuring an improved optical bench (patented technology). Available in standard compact and industrial (OEM) versions, VARIUS™ caters to both laboratory settings and industrial applications.

Both spectrometers can be seamlessly integrated with various sensors and devices in smart manufacturing systems, enhancing their functionality and versatility. This integration allows the spectrometer to gather comprehensive data from temperature sensors, pressure sensors, flow meters, and other monitoring devices commonly used in manufacturing, further enhancing precision and control. Designed for seamless integration into smart manufacturing systems, Avantes' compact spectrometers offer a completely tailored solution for in-line process optimization.



CASE STUDY: PLASMA ETCHING IN ELECTRONICS

Illustrating the practical application of Avantes' spectrometer solutions, a case study in plasma etching in the electronics industry sheds light on their effectiveness. Plasma processing is vital in manufacturing integrated circuits (ICs) and microelectronics. Engineers use plasma etching to create intricate patterns and features on semiconductor layers. However, real-time monitoring of this process is essential to ensure precise control over material removal, minimizing defects, and optimizing the quality of the final product.

Using an optical emission spectrometer such as Avantes' AvaSpec-ULS4096CL-EVO (the predecessor of the VARIUS), manufacturers were able to monitor the automated layer deposition and plasma etching processes in real time.[7] This gave the researchers precise control over removing material from the layers on the ICs, allowing them to know exactly when all unwanted material has been removed (the end-point). The result was a tightly controlled process generating products of high quality. Ultimately, by opting to integrate in-line spectrometers into this study, the researchers significantly improved the efficiency and precision of the plasma processing method, enhancing the overall level of quality assurance and manufacturing precision.

CONCLUSION

In-line spectroscopic tools are pivotal in optimizing processes in smart manufacturing operations, enhancing both efficiency and product quality while minimizing defects and waste. With Avantes' compact spectrometers leading the charge in this technological revolution, manufacturers can confidently navigate modern production's complexities, equipped with the tools necessary for success.

Contact a member of the Avantes team today to learn more about some of the spectroscopic tools they offer. Contact information can be found on the last page of this document.

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WE'RE HAPPY TO HELP

Curious how spectroscopy will help you reveal answers by measuring all kinds of material in-line, at your production facility, in a lab, or in the field? Visit our website or contact one of our technical experts. We are happy to help you!

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