TRUMPF Optimizes Ion Exchange System with Reliable and Continuous Data from Real-Time Arsenic Analyzer

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ABSTRACT: Faced with high ion exchange (IEX) process waste disposal costs, TRUMPF, a manufacturer of laser diodes made from Gallium Arsenide substrates (GaAs) wafers, undertook efforts to optimize the IEX process and produce less hazardous waste. One of the process improvements included the installation of the MetalGuard™ Arsenic online arsenic analyzer to continuously measure influent and effluent arsenic levels in real-time, providing TRUMPF with a stream of accurate and reliable arsenic data to measure the performance of its IEX system and ensure regulatory compliance. Timely and accurate arsenic results enabled TRUMPF to optimize rinse water reuse as well as to optimize and reduce IEX backwash frequencies, increasing media performance and reducing hazardous waste generation. These process improvements have resulted in an annual cost savings of approximately $150K for the facility.

INTRODUCTION

TRUMPF Photonics, Inc., (TRUMPF) in Princeton, N.J., is a manufacturer of laser diodes made from Gallium Arsenide substrates (GaAs) wafers. The GaAs wafers must be thinned as part of the product requirements, a process that allows arsenic to dissolve into the wastewater stream creating hazardous waste that must be treated prior to discharge.

In 2019, TRUMPF implemented a new wafer thinning process to move away from lapping, a low capability process, as compared to grinding, a high capability process. Deionized water (DI) is used in the grinding operation to serve as a lubricant and as a carrier vehicle for the grinding wheel to pull the Gallium Arsenide particles away from the grinding wheel and into the waste stream. While both lapping and grinding create a wafer with a thinness of 110 um while generating 1-2 kg of GaAs waste per week, the grinding process creates 30 times more hazardous wastewater by volume than the lapping process requiring treatment.

The lapping process generated (12) 55-gallon drums of wastewater per week with associated treatment costs averaging $185K per year while the grinding process was predicted to produce (346) 55-gallon drums a week, a severe logistical constraint for TRUMPF given the facility cannot accommodate that large amount of waste, at an estimated cost of $5M per year to treat. This became a point of concern for TRUMPF as its goal was to develop a practical and cost-effective wafer thinning wastewater treatment process to support the new high capability grinding process.

WASTEWATER TREATMENT APPROACH

To ensure a cost-effective wastewater treatment solution for its new wafer thinning technology and high capability grinding process, TRUMPF undertook a threefold treatment approach, including: remove particles through cartridge filtration; remove the dissolved ionic arsenic through ion exchange; and contain, measure, reduce trace arsenic particle amounts in wastewater, and release compliant wastewater to the city sewer.

Following a third-party engineering report to determine a suitable IEX treatment method, TRUMPF implemented a multi-stage treatment approach including 1- and 5-micron cartridge filtration (CF) to remove GaAs particulates, followed by IEX filtration system composed of one carbon filter for organic removal, and two arsenic resin tanks and two mixed-bed resin tanks to remove dissolved ionic (free) arsenic.

TRUMPF must meet a regulatory requirement of 500 parts per billion (ppb) or less of arsenic to be discharged to the local municipal treatment facility. However, the wafer thinning process generates untreated influent wastewater with arsenic levels of 42.1 parts per million (ppm).

To ensure compliance of the process wastewater so that it can be safely discharged, TRUMPF needed to attain reliable and continuous measurements of arsenic concentrations in its wastewater. As a result, TRUMPF selected the novel online Arsenic monitor, MetalGuard™ Arsenic, manufactured by AMS, which uses Anodic Stripping Voltammetry (ASV) technology to measure arsenic concentrations in real-time.

The installation of the online arsenic analyzer was completed in the winter of 2018 and it supports the entire treatment process at TRUMPF by providing continuous and reliable data on real-time arsenic levels at various stages including untreated/post cartridge filters, partially treated post arsenic resin tank 1, and fully treated post arsenic resin tanks 1 and 2 (Figure 1). The fully treated waste stream is measured at the storage tote continuously while the untreated and partially treated samples are pulled manually and introduced to the online arsenic analyzer using the grab port. The analyzer provides high-frequency real-time data on arsenic levels in less than 30 minutes with a sensitivity down to 1 ppb.

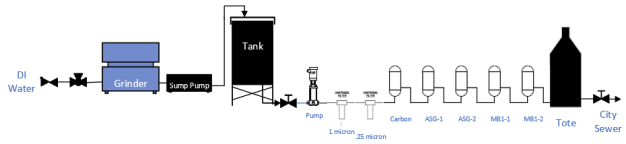

Figure 1- Open Loop Waste Treatment at TRUMPF With Online Arsenic Analyzer

MEASURING ARSENIC LEVELS IN REAL-TIME: TOTAL ARSENIC DETERMINATION BY ASV

The electroanalytical method of ASV is a concept that is well suited to provide unattended automated trace metal analysis field units. It has high sensitivity and selectivity to arsenic species. The ASV measurement process involves two major stages: sample preparation and voltammetric measurement.

During the sample preparation stage, the sample undergoes reduction process during which all dissolved arsenic species are converted into the measurable arsenite form. Further, the pretreated sample is taken into a measurement detector where resulted arsenic (arsenite) is analyzed as total arsenic using a proprietary voltammetric detector with self-regenerated probe.

ASV measurement involves two sequential steps; arsenic accumulation and stripping. During the accumulation step, arsenite specie is electroplated onto working electrode surface as elemental arsenic to increase probe sensitivity. During the second step, stripping, the accumulated arsenic is oxidized and stripped from probe surface during anodic scan. The voltammetric signal is proportional to analyte concentration in the solution and can be calibrated (Figure 2).

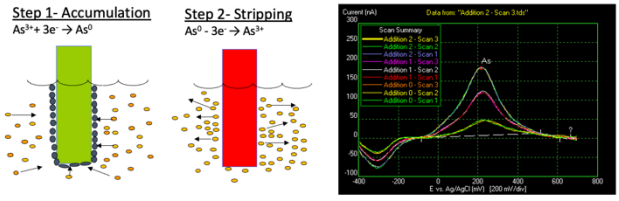

Figure 2- Total Arsenic Determination by Anodic Stripping Voltammetry (ASV)

This analytical approach employs a sensor self-generation mechanism that makes the probe less susceptible to gradual contamination from impurities or byproducts from the electrochemical process. As a result, the detector is capable of maintaining its sensitivity and calibrated status for an unlimited timeframe while operating reliably regardless of sample matrix conditions.

The monitor ensures sample stability compared to manual sample preparation and analysis that carries a high risk of inconsistency and human error. As a fully automated technology, the entire sample preparation and measurement processes provides a high accuracy and repeatability of the measurements and ensures lowest detection limits, selectivity down to 1 ppb total arsenic species. Also, flexible sample preparation routine allows speciation of different arsenic forms such as As(III), As(V) and total As. The system also allows for manually collected samples to be analyzed via a grab port.

Software controls the entire measurement process and allows process operators to access valuable data in near real-time manner. Thousands of continuous measurements can be performed in unattended manner by online arsenic analyzer without any operator interference.

THE VALUE OF REAL-TIME ARSENIC DATA TO TRUMPF

The analyzer continuously measures influent and effluent arsenic levels in real-time, providing TRUMPF with a stream of accurate and reliable arsenic data to measure the performance of its IEX system and ensure regulatory compliance. The data from the online arsenic analyzer was in excellent agreement with external lab results and provided TRUMPF with an extremely high degree of confidence (Figure 3).

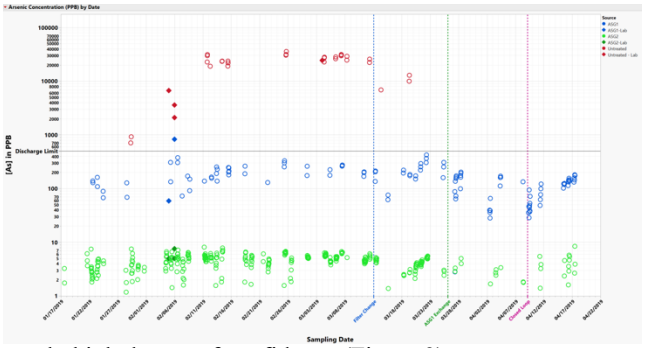

Figure 3- Analytical Results from Untreated and Fully Treated Wastewater with Lab and Online Arsenic Analyzer

Looking at the data collectively, open circles are representative of data from the online arsenic analyzer, and the closed diamonds are from an external lab. Red data points are from manually sampled wastewater that was filtered but untreated. Blue data points are from manually sampled wastewater from the first arsenic resin tank (ASG-1) that was filtered and partially treated. Green data points are from manually sampled wastewater from the second arsenic resin tank (ASG-2) resin that was filtered and completely treated. All of the partially

treated samples (blue) and completely treated samples (green) scored below the arsenic discharge limit of 500 ppb. While partial treatment could have tighter distribution, all of the online arsenic monitoring data falls between the external lab values providing TRUMPF with confidence in the monitoring accuracy of the analyzer. All fully treated samples, post ASG-2, had values below 10 ppb (1.5 orders of magnitude below the discharge limit), enabling TRUMPF to release wastewater into the city sewer.

The implementation of the online arsenic monitoring system to sample, measure, and analyze data in real-time internally saved both time and money for the facility.

The high frequency of arsenic data enabled TRUMPF to operate its IEX to treat actual arsenic levels, not dated values produced from standard analytical methods that can take up to two weeks to produce results. With the online arsenic analyzer, TRUMPF obtained measurement results in 30 minutes to better understand the effect of the different treatment stages on arsenic within the wastewater management system.

With the high frequency of data, TRUMPF was able to trend results at multiple stages in the wastewater remediation system to identify patterns and develop learning opportunities. The timely and accurate arsenic results enabled TRUMPF to optimize rinse water reuse as well as reduce IEX backwash frequencies, increasing media performance and reducing hazardous waste generation.

The online analyzer also afforded TRUMPF the flexibility to monitor performance of the wastewater remediation system while the grinder is running product or in stand-by. The real-time arsenic data also eliminated the requirement for TRUMPF to store treated wastewater until lab results were returned and confirmed regulatory compliance.

With a reliable method to continuously measure performance of the arsenic remediation system in real time, TRUMPF was able to move to close-looped system within months, instead of years. The high frequency of accurate and reliable results from the online arsenic analyzer gave TRUMPF the confidence to recirculate the treated water back to the grinder as the DI source input reducing its water consumption by 90%.

By treating and recirculating the wastewater, the overall DI water consumption of the grinding process was reduced to a lower level than the lapping process. All combined, this allowed TRUMPF to not only minimize costs, but ensure that it operates in a greener, more sustainability-focused and environmentally responsible manner.

The three-fold wastewater treatment approach undertaken by TRUMPF to ensure a cost-effective solution for its new wafer thinning technology and high capability grinding process has resulted in process improvements that have provided an estimated annual cost savings of approximately $150K with a return on investment of less than one year (Table 1).

The closed-loop system designs leave open the opportunity to possibly reclaim the Gallium from the GaAs left in the particle filters, which would bring TRUMPF an additional estimated $3K annually.

Status	Process	Annual Spend or Return			
		Waste Drum Expense	Filters & Ion Tank Exchange	Gallium Reclamation (Est.)	Total Waste Expenses
New Process	Grind &Polish	($17,443)	($15,350)	$3,000	($29,793)
Historic Process	Lap& Polish	($181,810)	$0	$0	($181,810)
				Annual Waste Savings	$152,017

Table 1- TRUMPF Costs Analysis: New vs. Historic Process

CONCLUSIONS

1. TRUMPF implemented an in-line IEX to capture the dissolved Arsenic in the waste stream.

2. MetalGuard Arsenic, a novel online arsenic monitor based on ASV technology, was installed to enable measurement of the IEX system performance and ensure regulatory compliance.

3. The use of the online MetalGuard Arsenic analyzer provided confidence and the ability to create trend data to evaluate the effectiveness of the waste treatment system as it was being used and refined.

4. The arsenic abatement system was converted to a closed loop system which resulted in 90% effective water conservation system over the open loop system.

5. The use of the online MetalGuard Arsenic analyzer and IEX systems delivered process knowledge and cost savings (over $150K) compared with the prior drum and contain system.