

Robust Ceramic Outer Tube-set

for Agilent 5000 Series ICP-OES torches



Minimizing downtime and fewer replacements

Agilent introduces the ceramic outer tube-set for both the semi- and fully demountable torches for the 5000 series ICP-OES, developed to address the challenges faced when analyzing samples that have high levels of total dissolved solids (TDS) or salts, especially lithium-ion battery samples rich in alkali metals, or chemically aggressive samples that attack and degrade the quartz outer tube.

Designed as a direct replacement for the conventional quartz outer tube-set, the ceramic outer tube-set delivers significantly improved durability and lifetime, helping laboratories maximize uptime, reduce maintenance frequency, and lower operating costs when working with demanding matrices.

Role of the tube-set in the ICP-OES torch

The ICP-OES torch typically consists of three concentric quartz tubes. The smaller internal diameter (id) tube in the center is the injector. The tube-set, which is a critical component of the torch, consists of an outer tube and an intermediate tube surrounding the injector. A relatively high flow of argon gas is introduced between the intermediate and outer tubes to confine the plasma and cool the torch. The argon gas is ionized by radio frequency (RF) energy, generated by the RF-coil that surrounds the torch outer tube-set, enabling formation of a stable, high temperature plasma (~10,000 °K). The sample aerosol, generated by the nebulizer is mass-filtered by the spray chamber and delivered into the plasma through the injector for atomization and excitation, allowing optical emission measurement. A smaller argon flow between the injector and the intermediate tube supports and positions the plasma above the injector, reducing deposition on the tip of the injector.

Key challenges with quartz outer tube-sets

In applications where samples are rich in total dissolved solids (TDS) or alkaline-earth metals (Li, Na, K, Ca, Cs, etc.) such as Li-ion battery materials, fusions, high-salt matrices, and aggressive acid digests, the elemental ions created within the plasma of the torch can diffuse into the surface of the quartz outer tube.

Quartz tube-sets are comprised of fused quartz (or fused silica) which is amorphous glass made from high purity silicon dioxide (SiO₂). With exposure to the alkali-metal ions at high-

temperature, the quartz rearranges its molecular structure, breaking Si-O bonds. Devitrification occurs as the foreign ions penetrate the quartz and "unlock" that structure, replacing or disrupting the Si-O bonds, resulting in a brittle structure. As devitrification occurs, the quartz becomes white or opaque in color (Figure 1), with many tiny cracks in the surface layer, which drastically reduces optical clarity, mechanical strength, and service life. This degradation is largely irreversible. Cleaning the torch can temporarily improve the appearance, but the devitrification will continue to occur. Eventually, the quartz will crack or shatter, so replacement of the part is required.



Figure 1. Devitrification of a quartz outer tube-set after 24 hours analyzing 1.5% TDS solution of Li, Na, Cs in 5% HNO₃.

Devitrification is the degradation mechanism that significantly limits the usable lifetime of a quartz outer tube-set. This is a key driver behind the development of alternative materials to resist devitrification, solarization, and thermally induced cracking under harsh operating conditions.

The Agilent ceramic outer tube-set solution

The Agilent ceramic outer tube-set has been engineered to withstand the harsh conditions that accelerate devitrification and degradation of the standard quartz outer tube. The robust ceramic outer tube is manufactured from silicon nitride (Si₃N₄), which prevents the alkali ions from penetrating the underlying bulk material. It is available in both Dual View (DV) and Radial View (RV) configurations and suitable for use with the Easy-fit semi- and fully demountable torches for the Agilent 5000 series ICP-OES.

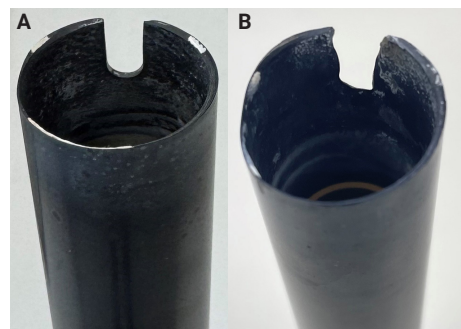


Figure 2. Ceramic outer tube after over 900 hours (A) analyzing 1.5% TDS solution of Li, Na, Cs in 5% HNO₃, and 1,792 hours (B).

Unlike quartz, the material properties of silicon nitride provide superior resistance to devitrification induced by the analysis of alkali-metals (Figure 2) as the free metal ions are unable to destabilize the Si-N bonds. Silicon nitride also offers greater tolerance to thermal shock when exposed to high-temperature plasma cycling. It is also recommended for the analysis of samples containing hydrofluoric acid (HF), which can etch and attack the quartz components. An inert alumina injector must also be used when analyzing samples containing HF, as quartz is not compatible.

Typically, a ceramic outer tube-set will last > 10x when compared to a quartz outer tube-set for lithium-ion battery samples or high-TDS applications.

Applications that can benefit from use of the ceramic outer tube-set

The key advantage of a ceramic (silicon nitride) outer tube-set is longer product life resulting in less unplanned downtime caused by maintenance, reducing the constant need to discard and replace worn quartz outer tube-sets. These are the typical application areas that can benefit from adopting a robust sample introduction system incorporating the ceramic outer tube-set to improve long-term durability, while ensuring stable performance that generates high-quality analytical data.

Li-ion battery

As lithium-ion and other battery technologies accelerate in production worldwide, there is continued research to drive the development of safer, longer-lasting battery technologies; Agilent ICP-OES plays a critical role across the battery value chain.

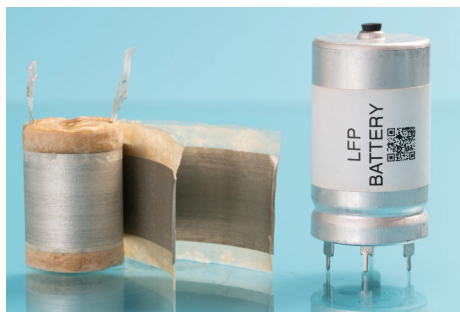


Figure 3. Battery technology.

From raw material qualification and quality control to product development and safety research, ICP-OES is used to analyze key materials including brines, anodes, and cathodes (LCO, NMC, NCA, LFP), electrolytes (LiPF₆, LiBF₄, and LiTFSI), separators, and process intermediates, and "black mass" recycling streams.

These chemically aggressive, high-matrix samples, are rich in alkaline-earth metals (Li, Na, K, Rb, Cs) that ionize easily and rapidly devitrify quartz torch components.

A strive for higher purity and stricter control of elemental contamination in battery materials are essential to prevent side reactions and degradation, requiring ICP analysis to be performed on neat, undiluted samples to achieve the low detection limits needed for safer, longer-lasting batteries.

Fusions and digests

A fusion digest is a sample preparation technique that involves dissolution of the sample in a molten flux to break down refractory or geological materials that may resist conventional acid digestion (e.g., silicates, oxides, minerals, or ceramics). The sample is first fused with a flux at high temperatures (typically 900 to 1,100 °C), which melts and breaks down the crystalline structure of the minerals. Common fluxes used are lithium metaborate (LiBO₂), lithium tetraborate (Li₂B₄O₇) or sodium carbonate (Na₂CO₃). The resulting homogeneous bead is dissolved in acid prior to analysis. The flux used for preparation introduces extra salts into the final digest, increasing the dissolved solids content and increasing the potential for interferences during analysis.

High TDS samples

Samples that contain up to 30% TDS, such as sea water or brines, aggressive acid digests (including hydrofluoric acid or 4 acid (which combines hydrochloric (HCl), nitric (HNO₃), hydrofluoric (HF), and perchloric (HClO₄)) digests), waste waters, or food/beverages with high salt/sugar content.

Environmental

For the analysis of environmental samples, an ionization buffer, commonly up to 2% cesium (Cs), is often introduced with the standards and samples to

suppress ionization interference from alkali metals (Na, K, Ca, Rb) that are easily ionized, shifting the ionization equilibrium in the plasma. Cs has a very low ionization potential and is used to flood the plasma with electrons helping to stabilize the plasma environment.

Organic solvents

When analyzing volatile and semivolatile organic solvents, conventional quartz outer tube-sets can suffer from solarization caused by intense deep ultraviolet (UV) radiation generated from the high plasma temperature. Impurities in the quartz, such as metals, absorb the UV energy, inducing localized devitrification. These effects weaken the quartz surface, leading to spider-web cracking (Figure 4) as the torch is heated and cooled. This means a shorter usable lifetime.

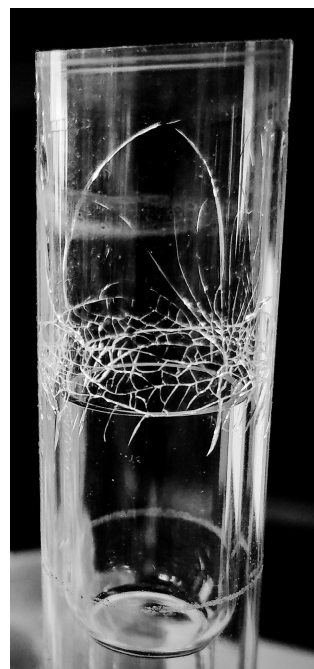


Figure 4. Spider-web cracking in a quartz vessel.

While Agilent offers a high-purity quartz tube-set specifically for analysis of organic solvents to combat web cracking, the ceramic outer tube-set offers superior resistance to solarization and longer service life.

Determining trace-level silicon

When determining trace-level silicon (Si), the achieved detection limit is restricted by leaching of Si from the sample introduction system. Using an inert sample introduction system can help, but there can still be issues with Si leaching from the torch components. Switching to the ceramic outer tube-set (which is made from silicon nitride) can reduce the leaching of Si from the torch, improving the detection limit performance (Figure 5).

This variance may be larger when analyzing more challenging sample matrices.

The alumina, inert, injector is made from alumina oxide (Al_2O_3) and will give a higher detection limit for aluminum (Al), when compared to a quartz injector.

Agilent ceramic outer tube-set design

The Agilent ceramic outer tube-set has been engineered to have a demountable design, consisting of a ceramic (silicon nitride) outer tube and a quartz intermediate tube (Figure 6).

The demountable design allows the ceramic outer tube to be removed and cleaned independently from the intermediate tube. This is especially beneficial when analyzing organic matrices where there can be a build-up of carbon deposits on the outer tube from excessive carbon in the sample. The ceramic outer tube (only) can be removed and placed into a muffle furnace to burn off any carbon build-up.

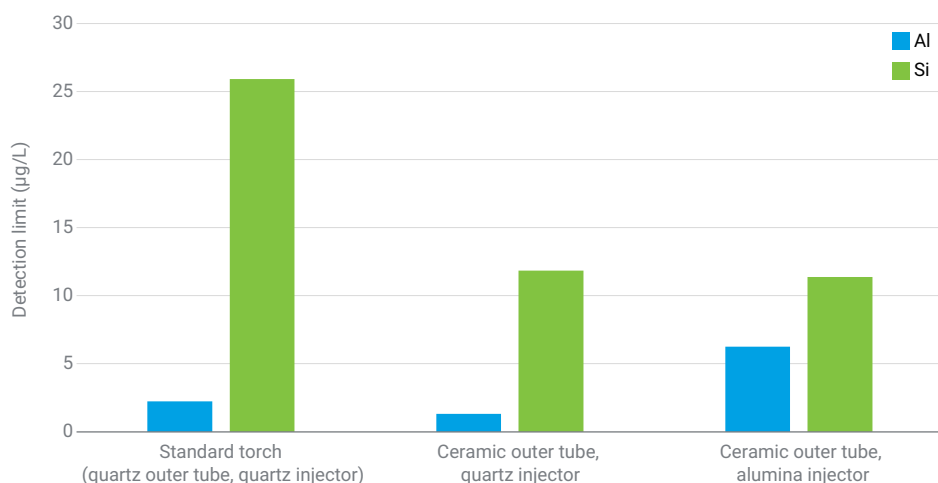


Figure 5. Comparison of detection limits: quartz versus ceramic.



Figure 6. Ceramic outer tube (A) and quartz inner tube (B) of the Agilent tube-set.

Disassembly and re-assembly of the ceramic tube-set is easily accomplished. Scan or click the QR code to watch a video illustrating the process, or refer to the Easy-fit Torch ICP-OES user guide (publication number [5994-8863EN](#)).

Injectors for the torch – factors to consider

Agilent offers a choice of quartz or inert, alumina injectors for use with the fully demountable torch for the 5000 Series ICP-OES (and the one piece and semi-demountable torches are also available with different injectors). Injectors are available in four inner diameters: 0.8, 1.4, 1.8, and 2.4 mm. The quartz injector is the most economical, whereas the alumina injector offers longer life and easier cleaning with most matrices.

When using a quartz injector with aggressive acid or high-matrix samples, the tip of the injector can also suffer from devitrification from exposure to the matrix. The quartz loses its polished finish, enabling salts from the high matrix samples to bind to the surface. With continued use and repeated cleaning, the build-up occurs at an ever increasing rate, which means shorter run times before cleaning is required. The increased frequency of maintenance means more downtime. In the worst case, the injector will need replacement.

The inert, alumina injector provides excellent resistance to devitrification and corrosion when used with high matrix samples. The inert, alumina injector is recommended when analyzing matrices that are rich in alkali metals, including Li-battery materials, or HF digests.

[Learn more about the range of injectors.](#)

Summary

The Agilent ceramic outer tube-set for Agilent 5000-series ICP-OES Easy-fit torches has been developed to address the fundamental material limitations of conventional quartz outer tube-sets when operating under high-matrix and chemically aggressive conditions.

Quartz outer tube-sets are prone to devitrification, solarization, and thermally induced cracking when exposed to these high-matrix samples, leading to loss of mechanical integrity and premature failure. The result is reduced torch lifetime, increased maintenance frequency, and unplanned instrument downtime.

The ceramic outer tube-set provides superior resistance to devitrification caused by alkali-metal attack and thermal shock, and deep-UV-induced solarization. In applications involving elevated total dissolved solids (TDS), alkali-metal-rich matrices (such as lithium-ion battery samples), aggressive acid digests, or organic solvents, the ceramic outer tube-set provides up to > 10x longer service life, alongside improved silicon background.

Compatible with both Dual View and Radial View configurations, the ceramic outer tube-set provides a robust, low-maintenance solution that improves uptime, analytical reliability, and total cost of ownership for demanding ICP-OES applications.

Learn more about the fully demountable torch from Agilent flyer [5994-1572EN](#).

Alternatively, visit the product pages:

- [Torches for 5100/5110 and 5800/5900 ICP-OES](#), or
- [Outer Tube for ICP-OES torches](#)

If you would like additional advice combined with tips and tricks to help ensure you are able to achieve the best performance, refer to the [ICP-OES Resource Hub](#).

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