GLASS EXPANSION
Quality By Design

EXAMINING THE BENEFITS OF A CERAMIC TORCH FOR ICP

The classic ICP torch consists of three concentric fused quartz tubes sealed together, creating a single-piece torch. The outer tube of the ICP torch contains a plasma that can reach temperatures in excess of 6000°C. Contaminating impurities can have a detrimental affect on the life of fused quartz material. Alkaline metals, including Na and Li, act as a flux, accelerating devitrification at temperatures around 1000°C. At this temperature, impurities from samples can become imbedded within the quartz, starting the devitrification process. The disadvantage of the single-piece torch is that it is a relatively high cost consumable item that requires regular maintenance and replacement, particularly with more demanding samples, such as hydrofluoric acid (HF), organic solvents and high dissolved solids.

The D-Torch is a revolutionary new torch design, providing the benefits of a demountable torch at a significantly lower cost without sacrificing performance. In this report we will introduce the benefits of the D-Torch and investigate the use of a ceramic outer tube in place of a quartz outer tube for difficult matrices and reduced plasma gas (coolant) flow rates.

The D-Torch is available for a range of ICP-OES and ICP-MS instruments. It provides the analyst with an outer tube which can be replaced when it fails rather than replacing the entire torch. Interchangeable outer tubes made of quartz or ceramic are available for most D-Torch configurations. The ceramic outer tube is of particular benefit for the analysis of wear metals in engine oils and high salt samples, where quartz outer tubes often suffer from short lifetime. It is also beneficial for low level Si determinations, where quartz outer tubes can produce high background signals. In general, the ceramic outer tube has a much longer lifetime, greatly reducing interruptions and downtime due to torch failure. In addition to an interchangeable outer tube, the D-Torch also features an interchangeable injector. This allows the analyst to have a specific injector for each application whether aqueous, organics, high dissolved solids or HF. Injectors made from high quality quartz, alumina and sapphire are available in a variety of internal diameters to suit your application needs. The D-Torch also incorporates a ceramic intermediate tube for greater robustness. An example of the D-Torch and its components is shown in Figure 1.

Base and inner tube | Ceramic outer tube | Quartz outer tube | Quartz injector | Alumina injector | Sapphire injector

*Products shown above are available for the Thermo iCAP 6000 series Radial ICP, ceramic outer tube not available for all ICP models.

Figure 1: D-Torch components with a selection of outer tubes and injectors to best suit your application needs.

The ceramic outer tube of the D-Torch is made from sialon, which is a ceramic material derived from silicon nitride. Sialon is one of the most durable and robust ceramic materials known and maintains its properties at high temperatures. A combination of high temperature and salt deposit causes a quartz torch to devitrify. Higher concentrations of salt in the samples lead to more rapid devitrification. By contrast, the ceramic outer tube of the D-Torch does not devitrify and is not affected by salt deposits. The quartz torch in Figure 2a, was run for only 6 hours with samples containing 10% NaCl and is already badly degraded. The ceramic D-Torch in Figure 2b was run for the same period and with the same samples as the quartz torch, but shows no degradation at all. In general, the ceramic outer tube has a much longer lifetime, greatly reducing interruptions and downtime due to torch failure. Sialon is also beneficial for low level Si determinations, where quartz outer tubes can produce high background signals.

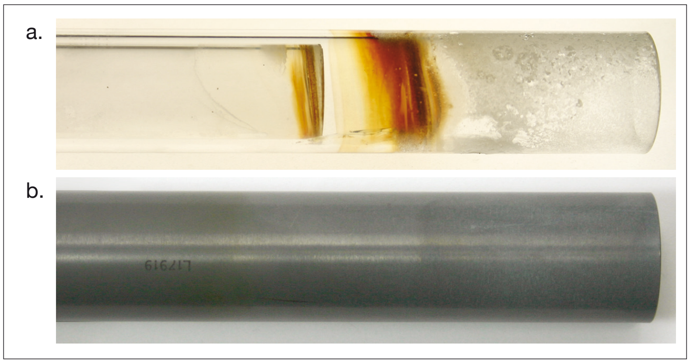

Figure 2: Quartz torch (a) and ceramic torch (b) exposed to 10% NaCl for 6 hours.

The analytical performance of the Thermo Radial EMT quartz torch was compared to the Radial ceramic D-Torch for the analysis of aqueous and high salt samples.[i] The geometry of the two torches is identical, the key differences are the materials used for the outer tube and intermediate tube and that the ceramic D-Torch is demountable. The detection limits in an aqueous matrix for selected elements obtained with the EMT torch and the ceramic D-Torch are compared in Table 1. The results show little difference between the detection limits obtained with the two torches. A key indicator of ICP torch performance is stability. Figure 3 shows a plot of selected elements at 0.5 mg/L in a 3% NaCl matrix. The stability exhibited by the ceramic D-Torch over a period of 5.5 hours in this high matrix sample is excellent. The ceramic D-Torch provides equivalent analytical performance to the standard EMT torch with the added advantage of resistance to devitrification and premature failures with specific sample matrices, including organics and high dissolved solids samples such as fusions.

	Detection Limit µg/L	
Element (λ)	Radial EMT Torch	Radial Ceramic D-Torch
Al 167	1.6	1.1
Ba 455	0.07	0.12
Cu 324	0.88	0.62
K 766	25.5	11.7
Mg 279	0.05	0.05
Mn 257	0.36	0.25
Ni 221	1.6	1.3
P 177	5.1	5.0
Zn 213	0.23	0.28

Table 1: Comparison of detection limits for EMT Torch and Ceramic D-Torch.[i]

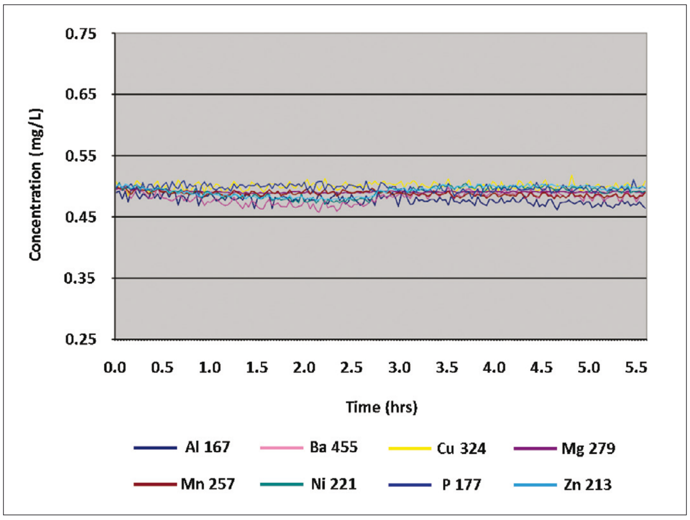

Figure 3: Stability of elements in 3% NaCl solution using ceramic D-Torch.[i]

ARGON CONSERVATION

A stream of argon gas between the outer and intermediate tubes of the ICP torch is required to provide a cooling sheath to prevent the torch from melting in the 6000°C plasma. Quartz can require flow rates as high as 20 L/min in order to provide an adequate cooling sheath. This high consumption of argon can constitute a significant cost of up to several thousand dollars per year. In contrast to quartz which has a lower melting point, sialon has a melting point above 2100°C and therefore needs much less cooling. To examine the performance of the D-Torch at a reduced plasma (coolant) gas flow, detection limits were compared at 16L/min and 10L/min in matrices consisting of 2% HF and 2% HNO_3. The operating conditions are listed in Table 2.

ICP Parameter	2% HF		2% HNO_3	
	Standard	Low Flow	Standard	Low Flow
RF Power (W)	750	750	750	750
Auxiliary gas flow (L/min)	0.50	0.50	0.50	0.50
Nebulizer gas flow (L/min)	0.75	0.70	0.65	0.65
Plasma gas flow (L/min)	16	10	16	10
Sapphire injector ID (mm)	2.0	2.0	2.0	2.0
Solution flow rate (mL/min)	2.0	2.0	2.0	2.0

Table 2: iCAP operating conditions for 2% HF and 2% HNO_3 work

The detection limits for both matrices listed in Table 3 were calculated using the standard deviation of 7 replicates and the student T value for a 98% confidence level. The wavelengths examined show little difference in the detection limits obtained between a plasma gas flow rate of 16 and 10L/min. The HF stability data shown in Figure 4 also shows there is no sacrifice in plasma stability running the plasma gas flow rate at 10L/min. The average RSD for a number of wavelengths collected over 3 hours was less than 1.5%. The results show that an analyst who is not dealing with a difficult matrix such as high dissolved solids, can also benefit from utilizing a fully ceramic D-Torch by greatly reducing argon consumption and costs.

The D-Torch also provides the durability of being able to handle difficult matrices such as HF, high dissolved salts, and organic solvents without sacrificing analytical performance at both standard and low flow plasma gas

	2% HF Detection Limit µg/L		2% HNO_3 Detection Limit µg/L	
Element (λ)	16 L/min	10 L/min	16 L/min	10 L/min
Al 167	1.18	4.90	1.35	1.54
Ba 455	1.21	3.26	0.23	0.05
Cd 214	0.31	0.16	0.12	0.31
Co 228	0.44	0.16	0.31	0.46
Cr 267	0.52	0.40	0.86	0.93
Cu 221	1.03	1.41	0.78	1.57
K 766	1.08	1.23	0.64	1.30
Mg 279	0.26	0.50	0.53	0.64
Mn 257	0.07	0.16	0.15	0.28
Ni 221	0.97	0.70	0.56	2.59
Pb 220	2.42	1.95	1.77	6.88
Zn 213	0.52	1.74	0.23	0.54

Table 3: Detection limits obtained with a fully ceramic D-Torch at 16L/min and 10L/min.

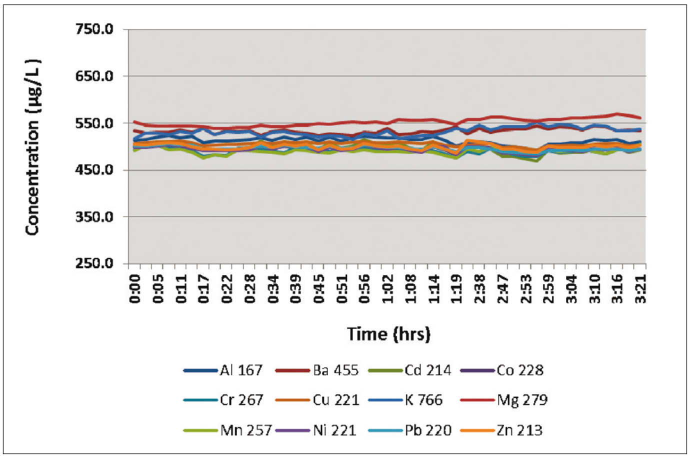

Figure 4: Stability with HF at plasma gas flow rate of 10L/min with fully ceramic D-Torch.

Conclusions

In summary, the ceramic D-Torch, in comparison to quartz, provides the analyst with reduced argon consumption, a more robust plasma, and longer life. The expected lifetime of the ceramic D-Torch is at least 5 times that of a quartz torch when dealing with difficult matrices, making the ceramic D-Torch a cost effective solution to reduce some of the traditional consumable costs associated with ICP. Additionally the ceramic D-Torch provides the analyst with the ability to run the ICP at a reduced plasma gas flow with no loss in performance.

Reference

i. Thermo Scientific Technical Note #43053, *Radial Demountable Ceramic Torch for the Thermo Scientific iCAP 6000 Series ICP spectrometer*, 2010.