Technical Note: 43053

Radial Demountable Ceramic Torch for the Thermo Scientific iCAP 6000 Series ICP spectrometer

Key Words

- iCAP 6000 Series
- Radial Ceramic D-Torch
- High Matrix
- Organics

Key Benefits

- Fully demountable torch design for cost effective replacement of parts
- Durable long lasting ceramic material to handle the most demanding sample matrices and analysis regimes.

Introduction

Since the introduction of Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES), the main weakness of the technique has been the sample introduction system. The sample introduction system has a large influence on the analytical performance of a spectrometer and is the main area of the hardware that users interface with. One key component of this system is the ICP torch. The ICP torch is a relatively high cost consumable item which can require regular maintenance and replacement when performing more demanding applications.

Currently the majority of ICP torches are made from quartz which is a crystalline form of silicon dioxide (silica, SO_2). When a quartz ICP torch is heated (by the plasma) it can undergo a process known as devitrification (which means becoming less glass like). This is commonly observed in ICP torches when the region of the ICP torch that contains the plasma becomes translucent and then opaque, flaking of the internal surface of the torch can also occur (Figure 1a). This process occurs when the transition temperature (Tg) of the quartz (573°C) is reached and the covalent bonds of the quartz are broken and reformed incorporating impurities. These impurities are introduced to the quartz from the plasma and are typically elements with a valency of less than 4 such as sodium, potassium, calcium and lithium.

The process of devitrication can decrease the expected lifetime of the ICP torch and is commonly seen when samples are analyzed that contain the above mentioned elements at high concentrations (greater than 1000 mg/L). Typical sample types may include those prepared as a lithium metaborate fusions, sea waters and brines.

Quartz has a low thermal expansion coefficient which is important as the temperature gradient along the axis of the torch is large. The lowest temperature is at the base of the ICP torch where the gas is introduced, it increases rapidly just below the load coil, reaches a maximum within the load coil and then decrease slightly in the region above the load coil. Quartz is also relatively resistant to sudden temperature changes (such as when plasma ignition takes place). These two properties make quartz an ideal material for ICP torches which are designed for analyzing aqueous samples and this has been demonstrated over many years of practical use. However, it is when organic solvents are introduced into the plasma that the temperature gradient along the axis of the ICP torch increases more significantly. The main reasons for this increase in temperature gradient are as follows:

- Higher RF powers are typically used when analyzing organic solvents.
- Carbon based molecules will emit large amounts of infra-red (IR) light which is absorbed by the quartz increasing the temperature.

This increase in the temperature gradient can lead to premature failures of the quartz ICP torch (Figure 1b).

Whilst ICP technology has undergone considerable developments, little effort has been directed specifically at ICP torch design and the use of alternative materials to improve torch durability. This is despite the fact that both devirtrification and premature failures of quartz ICP torches are common problems.

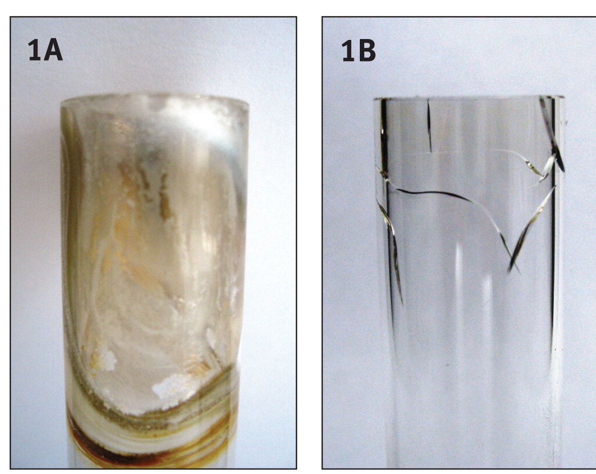

Figure 1. Examples of devitrification (1a) and premature failure (1b) of quartz ICP torches.

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Introducing the Ceramic D-Torch for the Thermo Scientific iCAP 6000 Series ICP spectrometer

The geometry of the Radial Ceramic D-Torch (Figure 2) is identical to that of the Radial Enhanced Matrix Tolerance (EMT) torch, consisting of three concentric parallel tubes; the outer tube, the intermediate or auxiliary tube and the centre or injector tube. The key differences between the EMT torch and the Ceramic D-Torch are the materials used for the outer tube and intermediate tube and that the Ceramic D-Torch is fully demountable where as the EMT torch is semi-demountable (the outer and intermediate tube are fused).

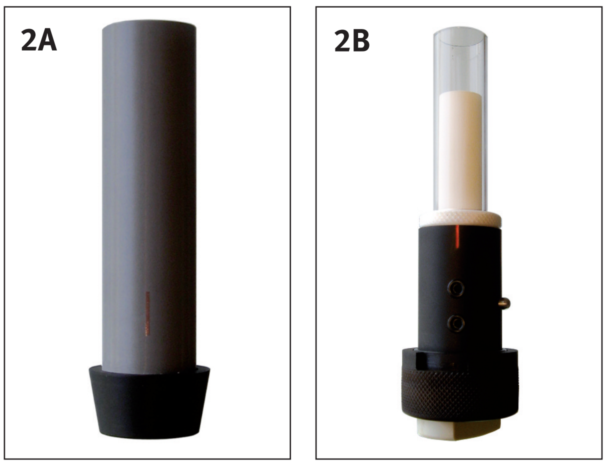

Figure 2. The radial D-Torch ceramic outer tube (2a) and the radial D-Torch, with a quartz outer tube to show the geometry of the intermediate tube (2b).

The outer tube of the Ceramic D-Torch is made from sialon, which is a ceramic material derived from silicon nitride. sialon is one of the most durable and strongest ceramic materials known and maintains these properties at high temperatures. The intermediate tube is made form alumina which again has excellent properties for chemical and temperature resistance and has been proven as a material for ICP torches as it is commonly used for centre tubes. (Note: the standard range of EMT centre tubes for the iCAP 6000 Series ICP spectrometer can also be used with the D-Torch).

Increased Torch Life Time

When analyzing samples that contain elements that promote the devitrification process the Ceramic D-Torch does not suffer from effects of devitrification like the quartz torch. This is due to the sialon material which the Ceramic D-torch is made from. This can be seen in Figure 3, which compares a quartz ICP torch and the sialon outer tube of Ceramic D-torch; both have been used for the continuous aspiration of 10 % NaCl for a period of 10 hours. It can be noted that the top section of the quartz has begun to degrade due to exposure to the sample matrix, however, the sialon tube remains in a pristine condition.

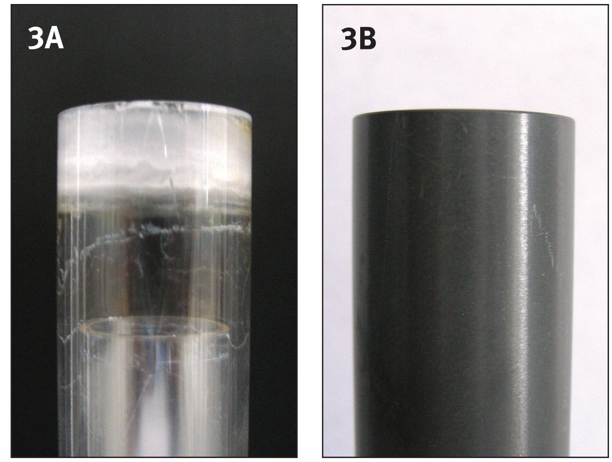

Figure 3. Quartz torch (3a) and the radial Ceramic D-torch (3b) after 10 hours continuous analysis of 10 % sodium chloride solution (after cleaning and drying).

The sialon material of the outer tube of the ceramic D-torch also eliminates premature failures of the torch when analyzing organic solvents. The sialon material has a thermal conductivity of 28 W/(m·K), meaning that heat is conducted more evenly along the axis of the torch. The temperature gradient from one end to the other of the ceramic is, therefore, lower when compared to quartz (thermal conductivity 1.4 W/(m·K)). This reduces the thermal stress on the torch which results in a lower failure rate.

Analytical performance

A number of studies have been carried out comparing the analytical performance of the EMT torch and the ceramic D-torch. Table 1 compares the detection limits of the EMT torch and the ceramic D-torch in an aqueous matrix for selected elements. The detection limits were calculated by running a series of calibration standards, then a blank solution with ten replicates. The standard deviation of these replicates was then multiplied by a factor of three to give the detection limit. There is little difference between the detection limits obtained from the two torches which have the same geometry but made from different materials.

	Detection limit µg/L	
Element & wavelength	**Radial EMT torch**	**Radial Ceramic D-torch**
Al 167.079 nm	1.6	1.1
Ba 455.403 nm	0.07	0.12
Cu 324.754 nm	0.88	0.62
K 766.490 nm	25.5	11.7
Mg 279.553 nm	0.05	0.05
Mn 257.610 nm	0.36	0.25
Ni 221.647 nm	1.6	1.3
P 177.495 nm	5.1	5.0
Zn 213.858 nm	0.23	0.28

Table 1. A comparison of detection limits between the radial EMT torch and the radial ceramic D-torch using default parameters for the plasma and sample introduction settings with 10 second integration times.

In addition to sensitivity (and the detection limit) another key indicator of ICP torch performance is stability. Figure 4 shows a plot of selected elements at 0.5 mg/L in a 3 % sodium chloride matrix over a period of 5.5 hours (a typical period of analysis). The stability exhibited by the Ceramic D-Torch in this high matrix sample is shown to be exceptional.

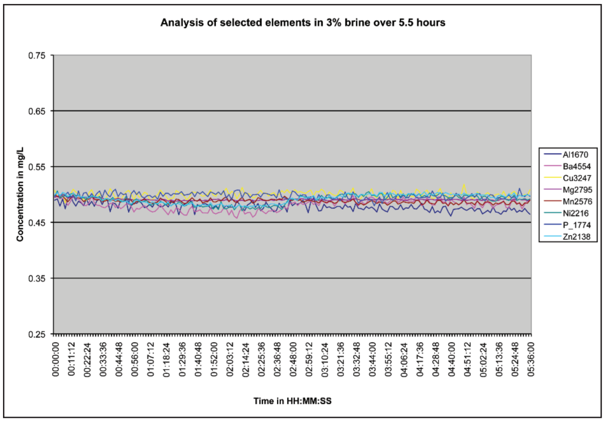

Figure 4. A plot of the stability run with the radial ceramic D-torch continuously analyzing a 3 % sodium chloride solution spiked at 0.5 mg/L with the elements of interest.

Conclusions

The ceramic D-torch provides equivalent analytical performance to the standard EMT torch but has the added advantage of resistance to devitrification and premature failures with specific sample matrices, including organics and high dissolved solids samples such as fusions. The expected life time of the sialon outer tube is at least 5 times that of a quartz EMT torch with the matrices mentioned, making the ceramic D-torch a cost effective solution to reduce some of the traditional consumable costs associated with ICP.

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