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An Analyst's Perspective:

ICP-QQQ in the Semiconductor Industry

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Introduction

The control of metal impurities in process chemicals and on the surface of silicon wafers is extremely important in the semiconductor industry. Metal impurities of several ng/L in process chemicals or several pg on a 200 mm wafer surface can lead to defective devices. Wafer processing tools are therefore regularly monitored to determine the process performance with regards to metal contamination. This is done by processing non-product blank wafers and then analyzing the contaminants using vapor phase decomposition (VPD) ICP-MS.

During VPD analysis, the wafer is exposed to HF vapor that decomposes the SiO_2 present on the surface ($SiO_2 + 6HF \longrightarrow H_2SiF_6 + 2H_2O$). Any residual metal-ion contamination is collected in a droplet of an aqueous solution of 1% HF and 6% H_2O_2, which is scanned over the surface of the wafer. This solution is then analyzed using ICP-MS. H_2SiF_6 present on the surface will also be collected in the scanning droplet, so the solution will contain a few ppm of Si. This makes trace analysis of some elements difficult due to the formation of Si-based polyatomic ions e.g. ^{30}SiH on ^{31}P and $^{28}Si^{16}O^{19}F$ on ^{63}Cu.

In 2014, an Agilent 8800 Triple Quadrupole ICP-MS was installed at NXP Semiconductors. This article describes some of the results achieved using the ICP-QQQ for the analysis of surface contamination of silicon wafers.

Experimental

Instrumentation

An Agilent 8800 ICP-QQQ (semiconductor configuration, option #200) with integrated auto sampler was used. Sample introduction consisted of a 100 µL self-aspirating PFA nebulizer, PFA spray chamber, end cap, and connector tube, quartz torch with 2.5 mm sapphire injector, and Pt sampling and skimmer cones. MS/MS mode (where Q1 and Q2 both operate as true mass filters) was used throughout, and Table 1 summarizes the tune modes and mass pairs (*m/z* for Q1 and Q2) used for all of the analyzed elements. In cool plasma mode, the plasma power was reduced to 600 W. [1]

Table 1. DL and BEC of blank scan solutions

Element	Tune	Mass Pair Q1 m/z → Q2 m/z	DL ppt	BEC ppt
Li	Cool + H_2	7 → 7	0.08	0.02
Na	Cool + H_2	23 → 23	1.3	1.4
Mg	Cool + H_2	24 → 24	0.70	0.12
Al	Cool + H_2	27 → 27	1.8	0.43
P	Hot + H_2	31 → 35	35	101
K	Cool + H_2	39 → 39	0.48	0.47
Ca	Cool + H_2	40 → 40	4.7	2.6
Ti	Hot + O_2	48 → 64	0.31	0.10
V	Hot + O_2	51 → 67	0.31	0.27
Cr	Cool + H_2	52 → 52	0.77	0.10
Mn	Cool + H_2	55 → 55	0.33	0.03
Fe	Cool + H_2	56 → 56	2.5	0.32
Co	Cool + H_2	59 → 59	0.32	0.04
Ni	Cool + H_2	60 → 60	0.56	0.06
Cu	Hot + O_2	63 → 63	0.94	0.58
Zn	Hot + O_2	66 → 66	1.6	0.56
Ga	Cool + H_2	71 → 71	0.24	0.04
As	Hot + O_2	75 → 91	1.5	1.7
Rb	Cool + H_2	85 → 85	0.36	0.03
Sr	Cool + H_2	88 → 88	0.23	0.05
Y	Hot + O_2	89 → 105	0.09	0.01
Zr	Hot + O_2	90 → 106	1.9	0.04
Mo	Hot + O_2	95 → 127	0.30	0.09
In	Hot	115 → 115	0.07	0.01
Sn	Hot	118 → 118	0.58	0.27
Sb	Hot + O_2	121 → 121	0.61	0.17
Cs	Hot + O_2	133 → 133	0.06	0.03
Ba	Hot + O_2	137 → 137	0.58	0.25
Ta	Hot + O_2	181 → 213	0.24	0.02
W	Hot + O_2	182 → 214	0.53	0.15
Pb	Hot	208 → 208	0.60	0.40

Sample preparation

In order to determine the presence of any Si matrix interferences, solutions containing 5, 10, 25 and 50 ppm silicon were prepared by etching a silicon wafer in a mixture of 19% Tamapure AA-10 HF and 23% double subboiled HNO_3. This mixture was diluted with ultrapure water (<1 ppt metal impurities) until the desired Si concentration was achieved. A blank scanning solution (1% HF, 6% H_2O_2) was prepared by diluting Tamapure AA-10 HF and Tamapure AA-10 H_2O_2 with ultrapure water. All experiments were performed in a class 10 cleanroom.

Results and Discussion

Figure 1 shows the apparent Cu concentration in HF/HNO_3 solutions spiked with silicon, measured in cool plasma mode with H_2 cell gas and hot plasma mode with O_2 cell gas. On-mass measurement (Q1 and Q2 both set to *m/z* 63) was used in both tune modes. In the presence of a Si matrix, the apparent Cu concentration increased significantly in cool plasma/H_2 mode compared to hot plasma/O_2 mode. This indicates that an on-mass interfering species was present at *m/z* 63 in cool plasma mode; most likely $SiOF^+$. No interference was present in hot plasma/O_2 mode, suggesting that the interference was successfully decomposed in the more robust hot plasma, and/or removed by reaction with the O_2 cell gas. In MS/MS mode, the quadrupole before the reaction cell (Q1) rejects all non-target (off-mass) ions before they can enter the cell. This ensures that no new reaction product ion interferences can be created in the cell. $^{47}Ti^+$ for

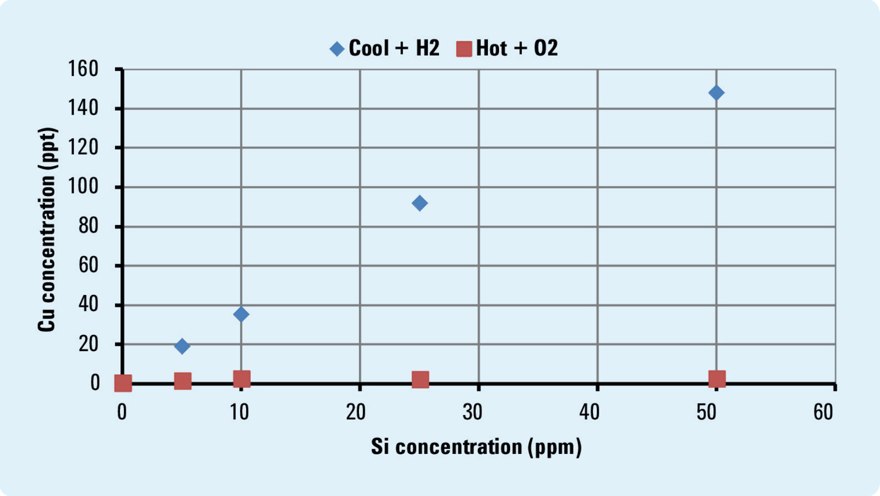

Figure 1. Cu concentration in HF/HNO_3 solutions spiked with Si

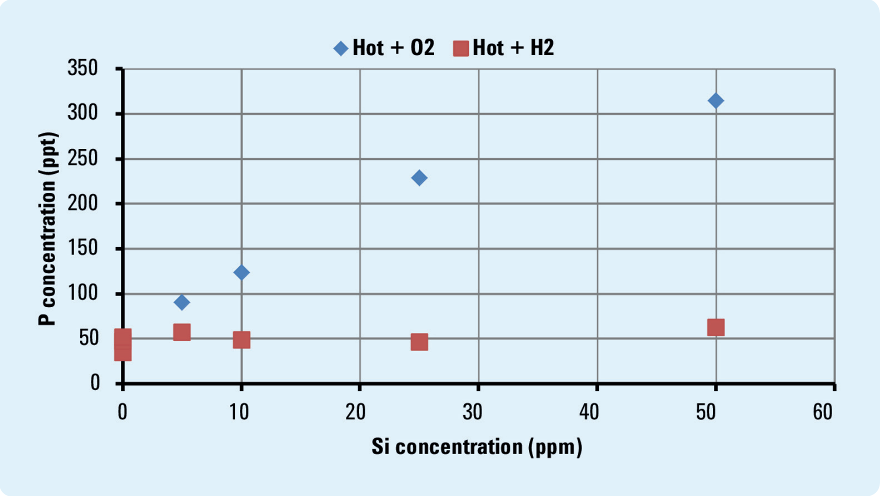

Figure 2. P concentration in HF/HNO_3 solutions spiked with Si

example would react with the O_2 cell gas to form $^{47}Ti^{16}O^+$, which would overlap Cu^+ at *m/z* 63 if the Ti^+ was not rejected by Q1.

Figure 2 shows the apparent P concentration in HF/HNO_3 solutions spiked with silicon under hot plasma conditions with O_2 and H_2 cell gases. A significant increase in the apparent P concentration is seen in O_2 mode. P^+ reacts with O_2 to create PO^+, which is detected at *m/z* 47. However, SiH^+ also reacts with O_2 and creates $SiOH^+$ which is also detected at *m/z* 47, so the apparent P concentration increases with the Si matrix level. With H_2 cell gas, there is no increase in the apparent P concentration with an increase in the Si matrix. P^+ reacts with H_2 to create PH_4^+, but SiH^+ does not react with H_2. H_2 gas can therefore be used to analyze P without suffering from Si-based interference.

Blank scan solutions were used to determine the Background Equivalent Concentration (BEC) and Detection Limit (DL) for 31 elements, and the results are shown in Table 1. Most elements show BEC and DL levels below 1 ppt. Some elements have a significantly higher DL than BEC (e.g. Al, Fe, Zr). This is probably because the BEC/DL calculations were based on the measurement of a large number of separate blank solutions; contamination of a few blank solutions would increase the standard deviation (SD) of the measurement (and therefore the DL) without significantly altering the mean blank concentration (BEC) calculated from all the samples.

Conclusions

The results show that the 8800 ICP-QQQ is able to measure metal impurities in Si wafer scan solutions, and minimize interferences by either removing the interfering species or shifting the mass of the analyte to an *m/z* value free of interference. By having an additional quadrupole mass analyzer situated before the reaction cell, unwanted ions can be excluded from the reaction cell and so no unwanted side reactions occur. This enables the analysis of metal impurities at ultra-trace levels in spite of the silicon matrix.

Reference

1. Katsuo Mizobuchi and Masakazu Yukinari, Ultra trace measurement of potassium and other elements in ultrapure water using the Agilent 8800 ICP-QQQ in cool plasma reaction cell mode, Agilent publication (2014), 5991-5372EN

Characterization of Nanoparticles in Consumer Products and Water Samples using CE-ICP-MS

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Introduction

Nanoparticles (NPs) are increasingly used in consumer products despite a lack of knowledge about their potential impact on human health and the environment. Analytical methods are required to determine NPs in real samples, which are often complex in nature.

Here we describe a method using capillary electrophoresis (CE) separation coupled to ICP-MS for the identification and accurate size characterization of NPs in consumer products and environmental water samples. The data provides multi-dimensional information on the chemical composition and size distribution of multiple NPs, together with the level of ionic species in a sample, all acquired in a single run.

Concept

A polydisperse mixture of NPs is separated according to size and from the sample matrix by CE, and the chemical composition of the NPs is characterized by ICP-MS. The CE peaks reflect the size distribution of the NPs, so accurate sizes of the NPs can be obtained by the Gaussian fitting of the peaks. This approach allows both multi-element chemical analysis and size distribution measurement of multiple NPs in a single run, without any complicated sample preparation procedures.

Experimental

Standard and sample prep

Consumer products were purchased from a local market. The samples were filtered through a 0.22 µm nylon filter membrane and then diluted in the running buffer solution before analysis by CE-ICP-MS.

Instrumentation

An Agilent HP 3D CE system was coupled to an Agilent 7500ce ICP-MS using an Agilent CE-MS spray kit interface (G1607A). The CE separation was performed using a fused silica capillary (Yongnian Optical Fiber Company, Hebei, China). The running buffer consisted of 10 mM tris, 10 mM H_3BO_3, and 10 mM $Na_2B_4O_7$ (pH 9.0). CE-ICP-MS operating parameters are given in Table 1.

Table 1. CE-ICP-MS operating parameters

Capillary	75 µm id × 60 cm
Voltage	25 kV
Temperature	25 °C
Sample Injection	Hydrodynamic 50 mbar, 15 s
Pre-analysis rinse	0.1 M NaOH (2 min) DI water (2 min) Running buffer (3 min)
Post-analysis rinse	0.1 M NaOH (2 min) DI water (2 min)
Plasma power	1550 W
Carrier gas	1.10 L/min
Make up gas	0.10 L/min
Sample depth	8 mm

Data analysis

The measured migration time (from the CE-ICP-MS electropherogram) was converted into NP diameter by normalization using a minimum of three standards containing NPs of different nominal sizes. The mean and standard deviation (SD) of each NP size was obtained through the Gaussian fitting of the electropherogram peaks using OriginPro8 software (OriginLab, Northampton, MA).

Method validation

Size distribution

To confirm the accuracy of size measurement using the CE-ICP-MS method, commercially available Ag NPs (citrate-coated) were analyzed and the results were compared to data obtained using dynamic light scattering (DLS) and transmission electron microscopy (TEM) (Table 2).

Table 2. Size distribution of Ag NPs obtained using different techniques

Technique	Nominal and measured Ag NP mean diameter and range [nm]		
	10	20	40
DLS	12.8	26.7	48.2
TEM	9.5±2.1	21.1±2.8	42.9±4.6
CE-ICP-MS	8.2±4.3	20.2±5.7	42.0±7.2

The CE-ICP-MS results agreed well with those obtained by TEM, with the DLS data being slightly higher in all cases. A possible reason for this discrepancy is that the diameters obtained from DLS are the apparent diameters of dynamic hydrated particles, which are often slightly larger than the true diameters.[1] Some artifact sources, such as dust, may also interfere with the DLS results. In contrast, CE-ICP-MS can distinguish between dust particles and NPs, eliminating false positive results.

Polydisperse NPs

The CE-ICP-MS method can also distinguish between the smallest NPs and the dissolved ionic component, which can be problematic for direct single particle analysis methods. A

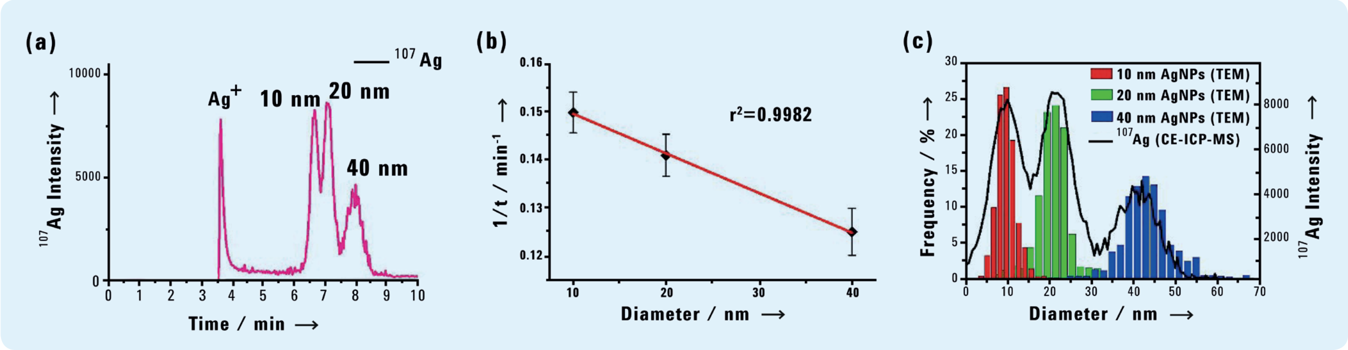

Figure 1. (a) Typical electropherogram of a mixture of Ag NPs; (b) relationship between the reciprocal of the migration time and Ag NP diameter; (c) size distribution generated by CE-ICP-MS and TEM.

mixture of ionic silver and three kinds of Ag NPs (nominal diameters of 10 nm, 20 nm, and 40 nm) was analyzed in a single CE-ICP-MS run. As shown in Figure 1a, the ionic silver was easily distinguished from the different-sized Ag NPs. Figure 1b demonstrates the linear relationship between the diameter of the Ag NPs and the reciprocal of their migration time. The size characterization results of Ag NPs from CE-ICP-MS were consistent with the results from TEM (see Figure 1c), demonstrating the CE-ICP-MS method as an accurate method for characterization of polydisperse NP mixtures.

Multiple NPs

To test the universality of the method, it was applied to the characterization of gold nanoparticles (Au NPs), another widely used type of NP. A mixture of 10, 20, and 40 nm Ag NPs (with citrate coating), 10 and 20 nm Au NPs, and gold and silver ionic species was analyzed. Identification and characterization of the different Ag and Au NP sizes, and separation of the particles from the dissolved component could be achieved in a single run (Figure 2) due to the specificity and multi-element capability of ICP-MS.

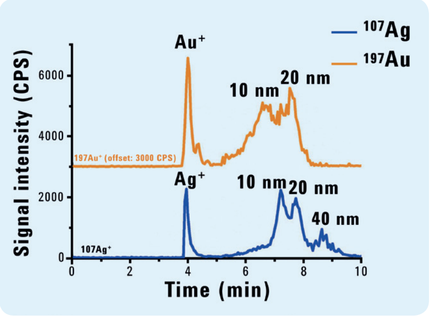

Figure 2. Electropherograms of Ag (Ag$^+$, 10 nm, 20 nm and 40 nm) and Au (Au$^+$, 10 nm and 20 nm) species by CE-ICP-MS.

Real sample analysis

To demonstrate the applicability of the method for the rapid screening of NPs in complex samples, two consumer products, an antiseptic kitchen cleansing spray and a nano-silver antibiotic lotion for gynecological care, were measured using CE-ICP-MS. Silver ion species were found at a concentration of 623.8 mg/L in the antiseptic kitchen cleansing spray, but no Ag NPs were detected. In the antibiotic lotion, two sizes of Ag NPs (7.8±4.8 nm and 33.5±2.6 nm) were detected and the results were verified using TEM (Figure 3).

The CE-ICP-MS method was also applied to the analysis of complex environmental samples, including river water and wastewater samples. Good recoveries of Ag NPs were obtained (88.2–95.2%) with a slight aggregation of Ag NPs (Table 3). NP concentrations in consumer products and environmental or clinical samples are normally very low. Commonly used techniques such as TEM and DLS cannot be used to identify the NP composition or measure dissolved ionic species, whereas the CE-ICP-MS method provides a more sensitive tool for this purpose.

Table 3. Recoveries, precision (n = 3) and size characterization of Ag NPs in river water and wastewater samples

Ag NP spiked	River water		Waste water	
	Recovery (%)	Measured particle size (nm)[a]	Recovery (%)	Measured particle size (nm)[a]
10 nm Ag NPs	92.9±1.6	16.4±12.1	95.2±2.1	15.9±10.3
20 nm Ag NPs	91.6±2.2	28.3±8.8	89.6±2.4	22.4±17.2
40 nm Ag NPs	88.2±2.9	51.8±6.4	91.5±3.2	49.4±11.3

a) The mean particle sizes measured by CE-ICP-MS were slightly larger than the nominal sizes of the spiked Ag NPs, indicating that slight aggregation of Ag NPs occurred in these water samples induced by the complex sample matrices.

Conclusions

A new CE-ICP-MS method has been developed that provides multi-element capability, accurate size and concentration data in real samples, identification of ionic species, and the ability to distinguish smaller size NPs than is possible with existing single NP methods, particularly in the presence of a high concentration of the dissolved element.

The methodology is suitable for the rapid screening of NP-containing products, quality control of NPs in commercial products, investigating polydisperse NP systems, the characterization of NPs in environmental samples and for “nano” research and standardization.

Reference

1. M. Hassellçv, J.W. Readman, J. F. Ranville, K. Tiede, Ecotoxicology 2008, 17, 344 – 361.

More Information

For a full account of this work, see publication: *Identification and Accurate Size Characterization of Nanoparticles in Complex Media* by Lihong Liu et al. Angew. Chem. Int. Ed. 2014, 53, 14476 –14479.

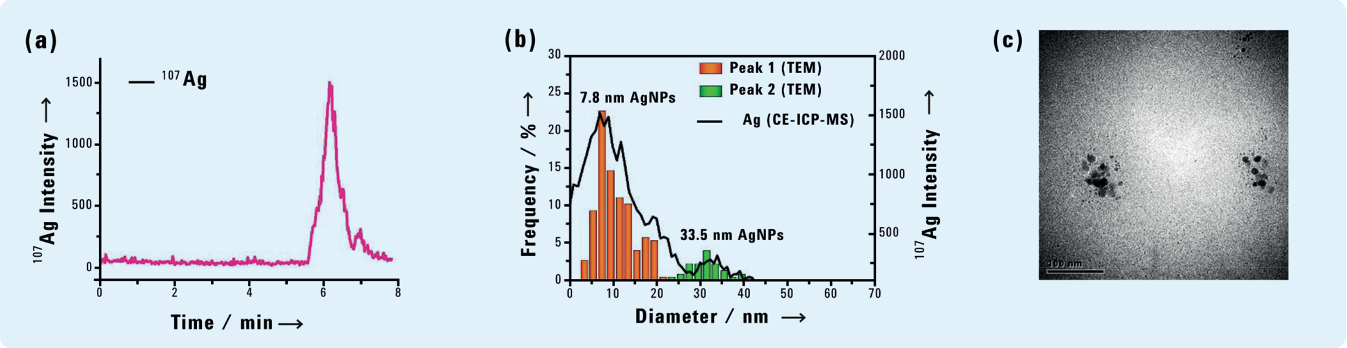

Figure 3. (a) Electropherogram and (b) size distributions obtained from CE-ICP-MS and TEM measurements of Ag NPs in a commercial nano-Ag antibiotic lotion for gynecological care, and (c) the corresponding TEM image (scale bar=100 nm).

Investigation of Aviation Gasoline for Contaminants by GC-ICP-MS

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Texas Raiders operates one of the few B-17 'Flying Fortresses' still in operation as part of the Commemorative (formerly Confederate) Air Force. Recently, there was suspicion that two of the aircraft's four fuel tanks had been contaminated with heavy naphtha or compromised in some other manner. The B-17 uses Aviation Gasoline 100 LL (low lead) which is one of the few fuels still allowed to contain the anti-knock additive tetraethyllead (TEL). 100 LL is a narrow boiling range alkylate that is primarily composed of branch chain alkanes and contains between 0.3-0.56 g/L TEL. Gas Chromatography (GC) was the natural choice for evaluating the hydrocarbon profiles of the fuel to determine if unusual compounds were present in the suspect tanks, while the known presence of lead offered an additional means for comparing composition. Both of these analyses could be done on a quantitative basis in a single run by GC-ICP-MS, measuring ^{13}C and ^{204}Pb/^{208}Pb in time resolved analysis (TRA) mode.

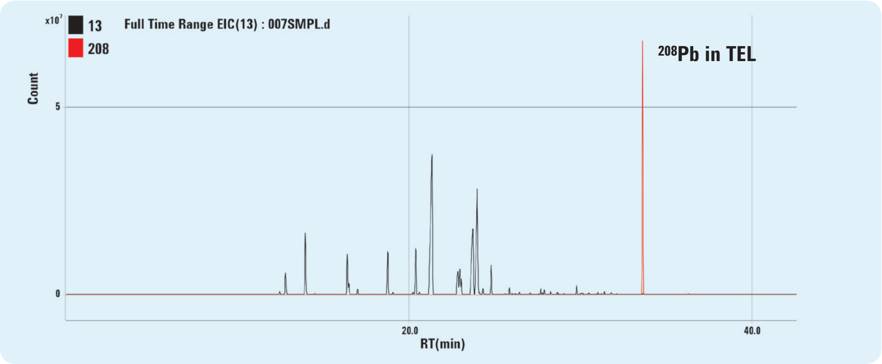


Figure 2. ^{13}C chromatogram of AvGas 100LL (black), ^{208}Pb chromatogram of TEL (red).

Experimental

Samples from the four tanks of the aircraft were analyzed along with a control sample of 100LL fuel using an Agilent 7890 GC coupled to an Agilent 7900 ICP-MS. Since there was some suspicion that the two tanks may have been contaminated with heavy naphtha, the initial screening test investigated this possibility. Though carbon isn't typically considered a practical analyte by ICP-MS, the high plasma temperature and freedom from interferences in the dry plasma enable carbon determination with excellent sensitivity, even for the minor ^{13}C isotope. As the overlaid chromatograms in Figure 1 show, no heavy naphtha was found to be present in the fuel.

Hydrocarbon and Pb profiles

The next step was to compare detailed hydrocarbon and elemental lead profiles of each fuel to determine if there were any significant compositional differences in the fuel contained in the four tanks. ICP-MS supports very rapid multi-element acquisition in TRA, so it is an excellent technique for measuring multiple analytes in a single injection, while also delivering accurate quantitative results. The chromatogram in Figure 2 shows that both the hydrocarbons and the TEL are easily resolved using GC-ICP-MS. As the summary in Table 1 shows, the bulk composition of fuel from all four tanks was essentially identical, especially considering that the tanks likely contained residual fuel from previous lots of gasoline. There was no statistically significant difference between the fuels in the four tanks.

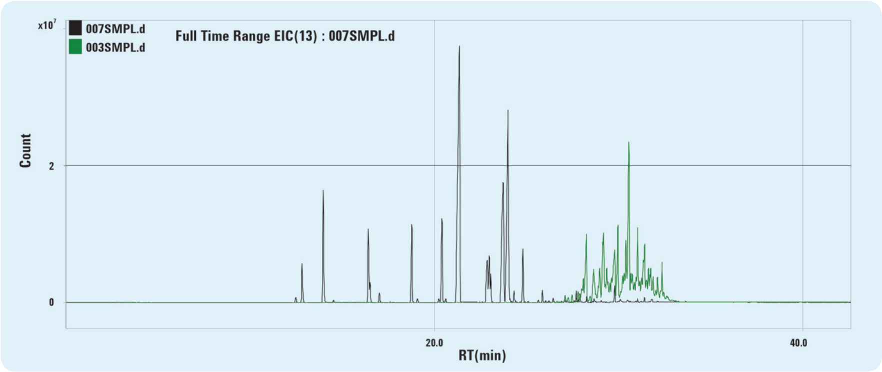


Figure 1. ^{13}C chromatogram of AvGas 100LL from suspect tank (black), overlaid with ^{13}C chromatogram of heavy naphtha (green).

Table 1. Comparison of hydrocarbon profile and TEL content for each tank

	Tank 1	Tank 2	Tank 3*	Tank 4*
	Wt.%	Wt.%	Wt.%	Wt.%
n-butane	2.01	1.88	1.92	2.13
Iso-pentane	5.92	5.65	5.74	6.08
2,3-dimethylbutane	4.84	4.77	4.78	4.91
3-methylpentane	0.51	0.49	0.51	0.51
2,4-dimethylpentane	4.20	4.23	4.19	4.26
2,3- dimethylpentane	5.08	5.24	5.04	5.16
2,2,4-trimethylpentane	28.91	28.78	28.97	28.89
2,3,4-trimethylpentane	13.58	13.77	13.80	13.61
2,3,3-trimethylpentane	17.46	17.49	17.71	17.37
2,2,5-trimethylpentane	2.84	2.90	2.88	2.84
2,3,5-trimethylpentane	0.48	0.50	0.48	0.49
TEL g/L	0.430	0.433	0.423	0.414

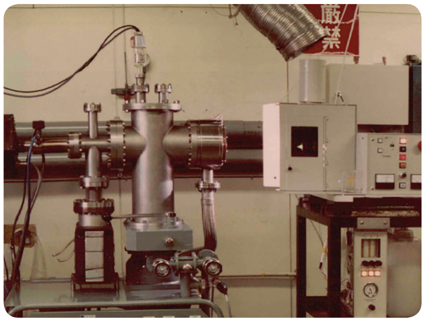
Conclusions

After performing the GC-ICP-MS analyses of the fuel samples, we were able to inform the Texas Raiders that:

- All four tank samples from their B17 were virtually identical to the 100 LL control sample
- There was no measurable heavy naphtha in the tanks

As there was no evidence of contamination, the historic aircraft was safe to fly!

Agilent ICP-MS: A History of Innovation Over Three Decades



Forerunner to the 7900: first experimental ICP-MS developed in Japan (1985)

At the recent UK ICP-MS User Group Meeting, Toshifumi Matsuzaki, General Manager of Agilent Tokyo Analytical Division (TAD), gave a personal account of 30 years of ICP-MS development at TAD's R&D facility.

The 1980s

Agilent (formerly Hewlett-Packard) and Yokogawa Electric of Japan had enjoyed a long-established joint venture when Toshifumi Matsuzaki joined Yokogawa in 1985. His first assignment was to begin work on the development of the first experimental ICP-MS system. The instrument had a number of limitations (including high random background and poor sensitivity) and was difficult to use, but despite this, two years later Yokogawa released their first commercial ICP-MS, the PMS (Plasma Mass Spectrometer) 100, for the Japanese market.

PMS100: First commercial ICP-MS with off-axis lens, hyperbolic quadrupole, and computer control (1987).

Ease-of-use was improved for the release of the PMS200 in 1988 and the PMS2000 in 1990 which resulted in increasing sales of each system respectively.

PMS200 released in 1988.

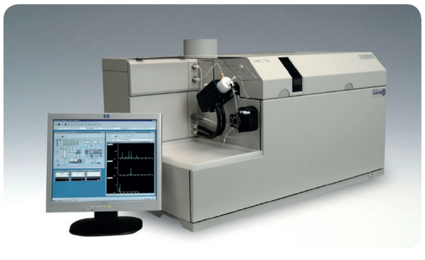
The 1990s

With sales of the PMS series limited to Japan, Yokogawa Analytical Systems Inc. was formed in 1992 to build the next generation ICP-MS for the world market. The objective was to combine Yokogawa's excellent ICP-MS product knowledge with HP's experience in benchtop mass spectrometers and international leadership in analytical technology. This led to the worldwide introduction of the world's first benchtop ICP-MS, the HP 4500 in 1994.

4500: The first ever bench top ICP-MS (1994).

The HP 4500 was to become a highly successful ICP-MS platform with more than 750 shipped over a five-year period, establishing HP as worldwide market leader in ICP-MS.

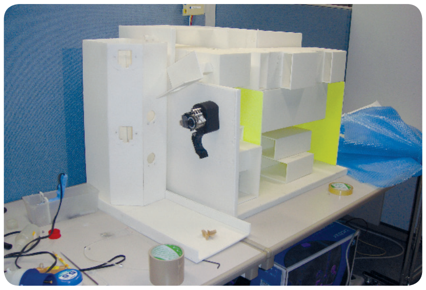
2000 onwards



Agilent 7500 - ever-evolving ICP-MS available from 2000-2009. Technology advancements included ORS and HMI.

Agilent Technologies was formed in 2000 when Hewlett-Packard realigned into two fully independent companies; in the same year, the Agilent 7500 Series was released. Toshifumi Matsuzaki believes that the development of Octopole Reaction System (ORS) cell technology with helium collision mode for the 7500 contributed to widening the acceptance of ICP-MS in many new markets. The 7500 Series went on to enjoy unprecedented commercial success during its 9 year production run.

Following the 7500, the challenge for Agilent's R&D for the next-generation ICP-MS began with a cardboard box and ended with the Agilent 7700 ICP-MS.



The cardboard box used at the design phase of the Agilent 7700

Not only was the 7700 ICP-MS the smallest ICP-MS on the market, it offered 9 orders detector dynamic range, lower detection limits, higher matrix tolerance, higher sample throughput and easier operation. Meanwhile, the R&D team was pursuing the idea of "ICP-MS/MS", which led to the release of the revolutionary Agilent 8800 ICP-QQQ in 2012.

Agilent 8800 ICP-QQQ - the only commercially available triple quadrupole ICP-MS provides unparalleled interference removal capability.

Then in 2014, Agilent redefined quadrupole ICP-MS performance with the release of the Agilent 7900.

Agilent 7900 ICP-MS with improved Signal to Noise, tolerance up to 25% NaCl brine solutions, 11 orders detector dynamic range, faster sample throughput, simplified operation.

The 100th Agilent ICP-MS in Turkey Goes to Leading Artworks Research Center

SEM's ICP-MS Product Specialists Evren Erdem (left) and Huseyin Tal (right) celebrate the installation of the 100th Agilent ICP-MS in Turkey at MSGSU and the opening of the new lab

The 100th Agilent ICP-MS in Turkey has recently been installed in a new facility within the Material Research Center for Cultural Property and Artworks that is part of Istanbul's Mimar Sinan Fine Arts University (MSGSU).

As a leading center for materials analysis in the field of conservation-restoration of cultural property and artworks, MSGSU's Central Research Laboratory is equipped with a broad range of advanced analytical instrumentation. Researchers investigate the properties of ancient and contemporary artifacts to identify the best restoration technique to apply to a particular item.

Agilent's distribution partner in Turkey, SEM Laboratuar Cihazlari, formed a close working relationship with the university's Prof. Dr. Meric Bakiler starting in the summer of 2010 while the lab was under construction. The installation of Agilent GC-MS, HPLC and ICP-MS instruments was completed towards the end of 2014 and the new facility was officially opened on December 10, 2014.

SEM Laboratuar Cihazlari has achieved remarkable sales success of Agilent chromatography and spectroscopy products in Turkey since its establishment in 1989, resulting in a landmark sales goal of 100 ICP-MS systems.

The 7700 ICP-MS will be used by MSGSU to determine trace elements in works of cultural importance by analyzing matrices such as paint, soil, rock and sediment etc.

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Join Agilent in Germany for the EWCPS 2015

Meet our team of atomic spectroscopy experts at the EWCPS 2015 in Münster, Germany, from February 22-26, 2015. Visit us at booth #A4 and complete your Agilent Tour!

- **Tuesday Feb 24th: Agilent Evening At the Museum** – join our atomic spectroscopy team for a unique evening event at Munster's LWL Museum, with dinner, dancing, museum guided tour and lots of surprises!
- **Wednesday Feb 25th: Agilent Workshop** – you can check out the agenda by clicking the link below.

Reserve your place now at: **www.agilent.com/chem/winter_plasma2015**
Attendance at the above Agilent events is free, but space is limited.

Conferences. Meetings. Seminars.

- **European Winter Conference on Plasma Spectrochemistry (EWCPS)**, February 22-26, 2015, Münster, Germany, **www.ewcps2015.org**
- **PDAC**, March 1-4, Toronto, ON, Canada, **www.pdac.ca/convention**
- **TMS**, March 15-19, Orlando, FL, US, **www.tms.org/tms2015/**
- **ACS**, Spring, March 22-25, Denver, CO, US, **www.acs.org/**
- **6th Pacific Winter Conference on Plasma Spectrochemistry (APWC)**, May 19-22, XiaMen, China, **www.apwc2015.xmu.edu.cn/**

- **Agilent Seminar Tours**
  - **ASTS Spectroscopy and Chromatography**, March 3-19, various US locations, **www.agilent.com/chem/ASTS-AtomicTour2015**
  - **ASTS Innovations in Elemental Analysis**, Feb 24-April 2, US and Canada, **www.agilent.com/chem/ASTS-AtomicTour2015-Canada**

Agilent ICP-MS Publications

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- **Application note:** Using heteroatoms as elemental labels in the analysis and quantification of active pharmaceutical ingredients by HPLC-ICP-QQQ, 5991-5445EN
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