

G4 ICARUS C/S

Why We're The Best Choice



Audience Poll



Did you know Bruker offers Carbon/Sulfur Analyzers?

- Yes
- No
- Somewhat



Webinar Schedule

C and S by Combustion Analysis



- Introduction of Speakers
- Why Analyze Carbon and Sulfur
- Typical Applications
- Sample Shapes
- The Principle of Combustion
- G4 ICARUS – Technical Overview
- Ease of Maintenance
- Instrument Specifications
- Benefits of the G4 ICARUS
- Question and Answer Session



Welcome!

Meet your speakers



Kristin Odegaard

Sr. Sales Engineer OES, CS/ONH
Bruker AXS LLC
Madison, WI



Christian Zühlke

Business Development Manager
Elemental Analysis CS/ONH
Bruker AXS GmbH
Karlsruhe, Germany

C & S by Combustion

Why Analyze Carbon and Sulfur – Steel Industry



Carbon

- Most alloying element in steel
- Influences hardness, wear resistance, workability, etc.
- Used in mineral processing
- Range: low ppm to high %

Sulfur

- Undesirable in steel
- Influences brittleness, conductivity, workability, formability, etc.
- Range: low ppm to high %



G4 ICARUS Series 2

Further examples



Material	C	S
Copper		X
Carbides	X	
Slag	X	X
Cement	X	X
Foundries	X	X
Automotive	X	X
Refractories	X	X
Welding	X	X
Minerals	X	X
Research Facilities	X	X



G4 ICARUS Series 2

Steel

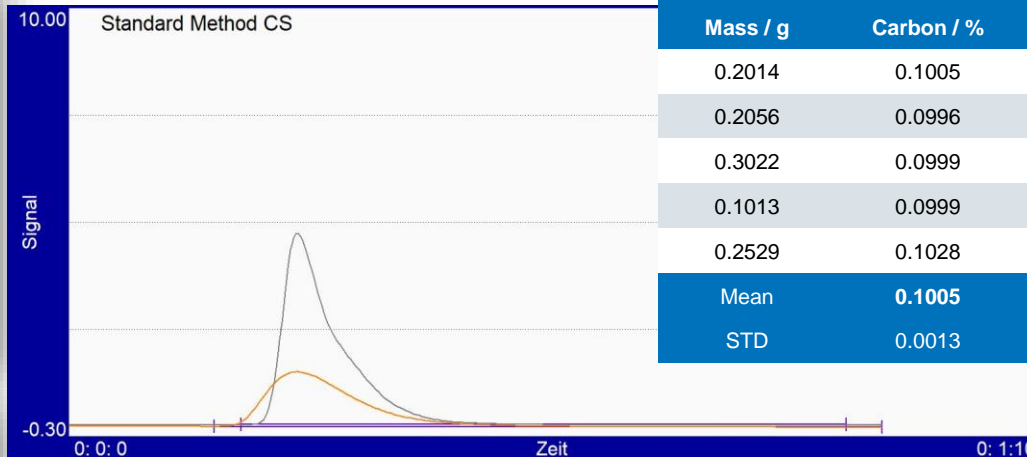


Iron, Steel, Co, Ni



Concentration ranges

- **C: 1 ppm to 1 %**
- **S: 1 ppm to 0.5 %**



CRM 286-1	certified values:	C: 0.100 (±0.005) %	S: 0.280 (±0.014) %
Mass / g	Carbon / %	Sulfur / %	
0.2014	0.1005	0.2854	
0.2056	0.0996	0.2732	
0.3022	0.0999	0.2844	
0.1013	0.0999	0.2820	
0.2529	0.1028	0.2842	
Mean	0.1005	0.2819	
STD	0.0013	0.0050	

G4 ICARUS Series 2

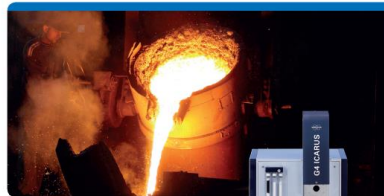
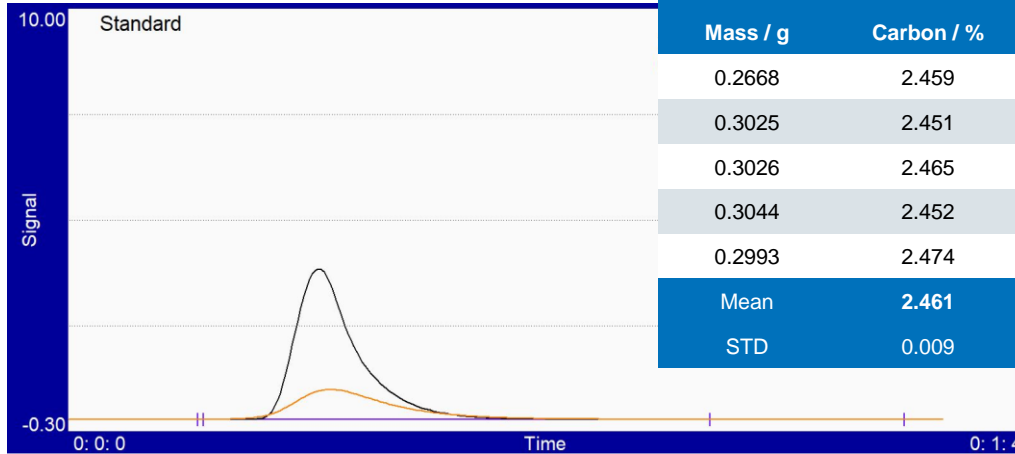
Cast iron



Concentration ranges

- **C: 0.1 to 5 %**
- **S: 10 ppm to 0.1 %**

CRM 483-1	certified values:	C: 2.463 (±0.012) %	S: 0.103 (±0.002) %
Mass / g	Carbon / %	Sulfur / %	
0.2668	2.459	0.1032	
0.3025	2.451	0.1030	
0.3026	2.465	0.1039	
0.3044	2.452	0.1039	
0.2993	2.474	0.1053	
Mean	2.461	0.104	
STD	0.009	0.001	



Lab Report CS/ONH 22

G4 ICARUS Series 2

- Fast and reliable Carbon and Sulfur Determination in Cast Iron

Introduction

The importance of the element carbon in iron and steel making is well known. Properties like hardness, ductility, ductility and brittleness depend to a large extent on the content of carbon in the material. That makes carbon the main alloying element in cast iron with typical levels greater than 2%. In the iron matrix, carbon can be present in different forms, e.g. dissolved in the matrix, bound to other elements as carbides, or elementary as free graphite.

Sulfur in contrast is typically an unwanted, contaminant element in cast iron. It can e.g. prevent the graphite formation in cast iron and thus impact the mechanical properties and its workability. Quality and Process-Control require the fast and accurate analysis of the carbon and sulfur content in cast iron and casted products. This Lab Report shows the simplicity, speed and reliability of carbon and sulfur determination by the G4 ICARUS Series 2 using a high-frequency (HF) induction furnace.

G4 ICARUS Series 2

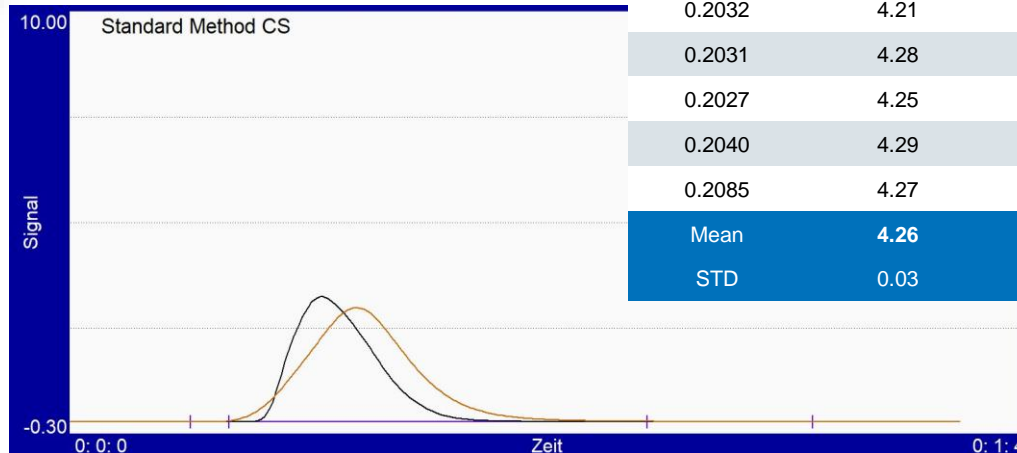
Ores & Minerals



Concentration ranges

- **C: up to 15 %**
- **S: up to 50%**

GS310-7	certified values:	C: 10.92 (±0.47) %	S: 4.16 (±0.17) %
Mass / g	Carbon / %	Sulfur / %	
0.2032	4.21	10.81	
0.2031	4.28	10.60	
0.2027	4.25	10.74	
0.2040	4.29	10.59	
0.2085	4.27	10.76	
Mean	4.26	10.71	
STD	0.03	0.09	



Lab Report CS/ONH 23
G4 ICARUS Series 2

- Fast and reliable Carbon and Sulfur Determination in Ore Concentrates, Metal-Bearing Ores and related materials

Many metals occur naturally in form of sulfide minerals like Pyrite (FeS₂), Chalcocite (Cu₂S), Argentite (Ag₂S), Galena (PbS), Sphalerite (ZnS) and many more. Since the amount of economically important metal relative to the ore is small, a first step in the metal extraction process is the separation of target minerals from unwanted rock, gangue and waste minerals. The result, called ore concentrate, is a mixture of the target metal sulfide ores, other sulfide minerals and some gangue.

The sulfur level of the concentrate provides an estimation of the metal-in-concentrate and is used as a quality control measure, determining the efficiency of the concentration process.

In the metal recovery process, determining the carbon and sulfur levels in metal-bearing ores is a necessary step for the mine operation to control the metallurgical process kinetics and to assess environmental aspects of the process waste. This is possible due to the fact that most metal-bearing

Innovation with Integrity

Elemental Analysis

G4 ICARUS

Typical samples



Inorganic solid samples

Examples: steel, copper, titanium, cast iron, refractories, carbides, minerals/mining, cement, metal powders (AM), ceramics



Pieces



Drillings/Chips

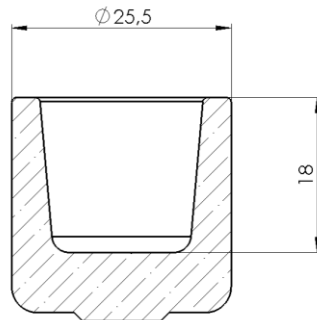


Coarse powders



Fine powders

Up to 1 g



Ceramic crucible G4 ICARUS

- The Principle of Combustion

G4 ICARUS Series 2

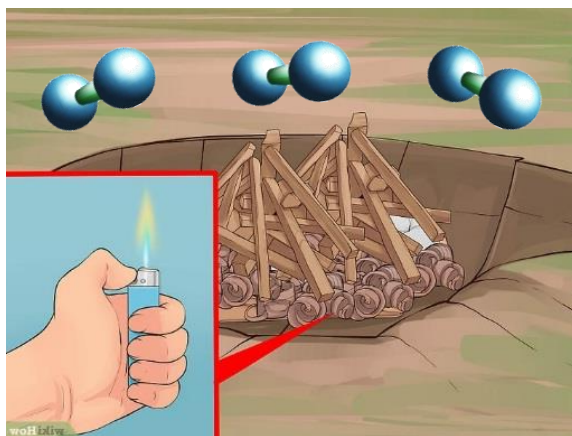
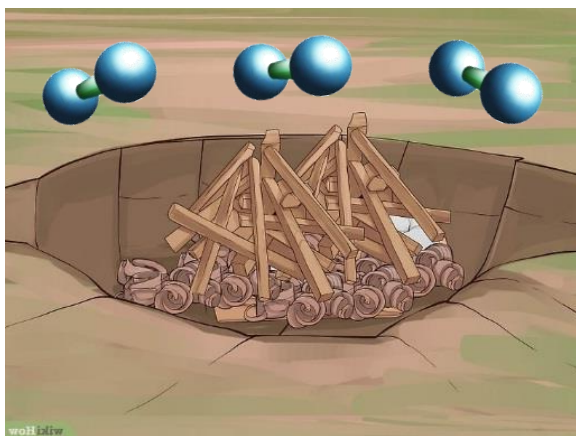
The principle of combustion



Combustion

[kuh m-buhs-chuh n]

the act or process of burning.



Combustion in chemistry:

- rapid oxidation accompanied by heat and, usually, light.

G4 ICARUS Series 2

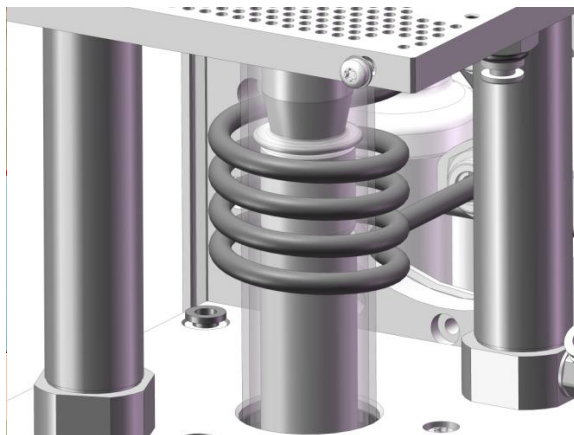
The principle of combustion



combustion

[kuh m-buhs-chuh n]

the act or process of burning.



Combustion in chemistry:

- rapid oxidation accompanied by heat and, usually, light.

G4 ICARUS Series 2

Chemistry of combustion



Solid sample + accelerator
in ceramic crucible



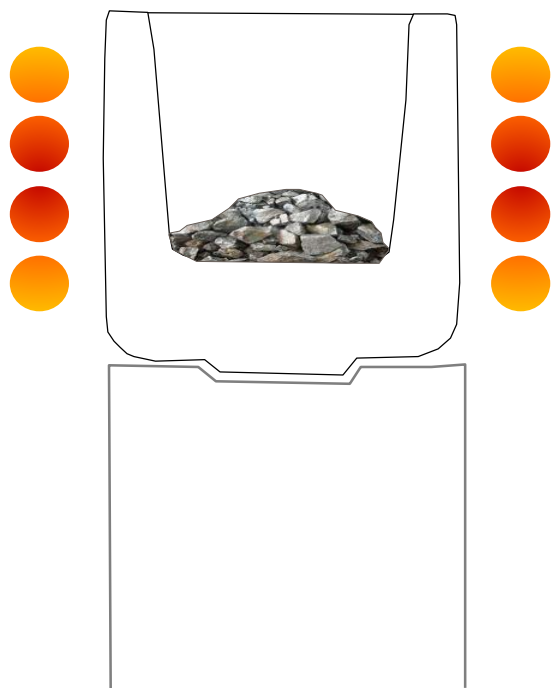
G4 ICARUS Series 2

Chemistry of combustion



Solid sample + accelerator
in ceramic crucible

Induction heating of the sample
Excess O_2 provided to sample



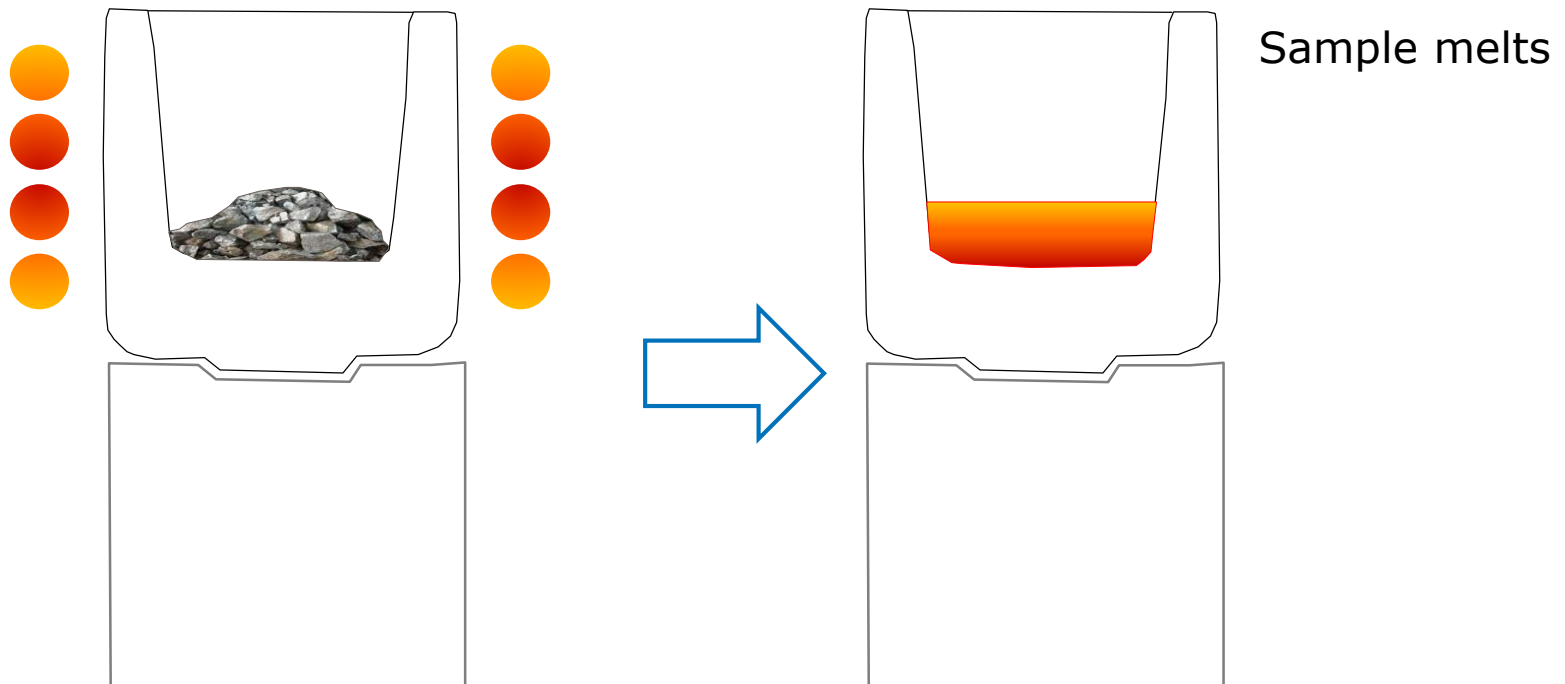
G4 ICARUS Series 2

Chemistry of combustion



Solid sample + accelerator
in ceramic crucible

Induction heating of the sample
Excess O_2 provided to sample



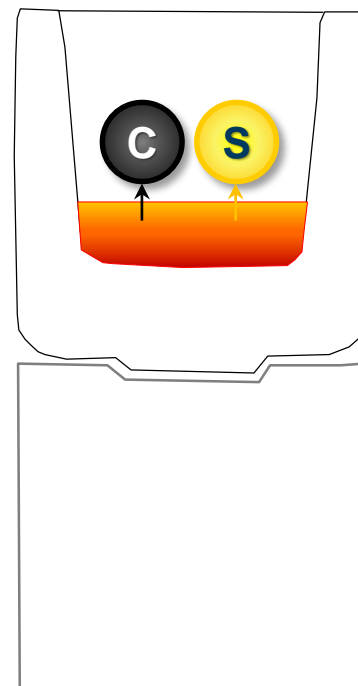
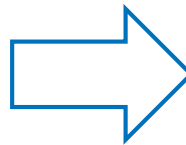
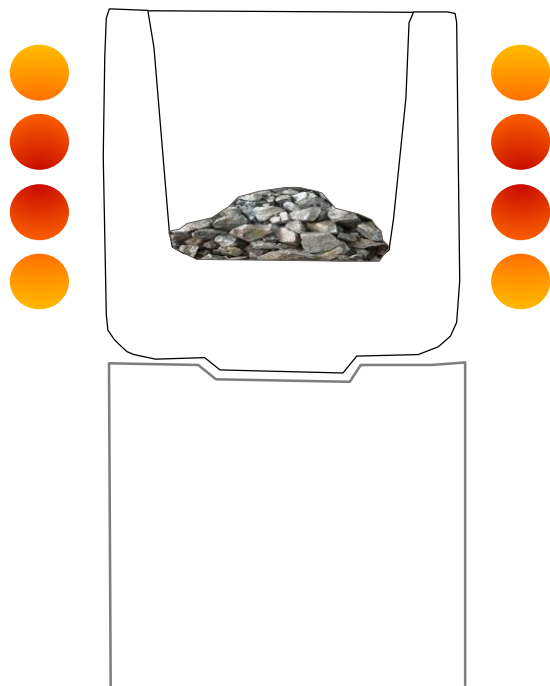
G4 ICARUS Series 2

Chemistry of combustion



Solid sample + accelerator
in ceramic crucible

Induction heating of the sample
Excess O_2 provided to sample



Sample melts
C & S are released

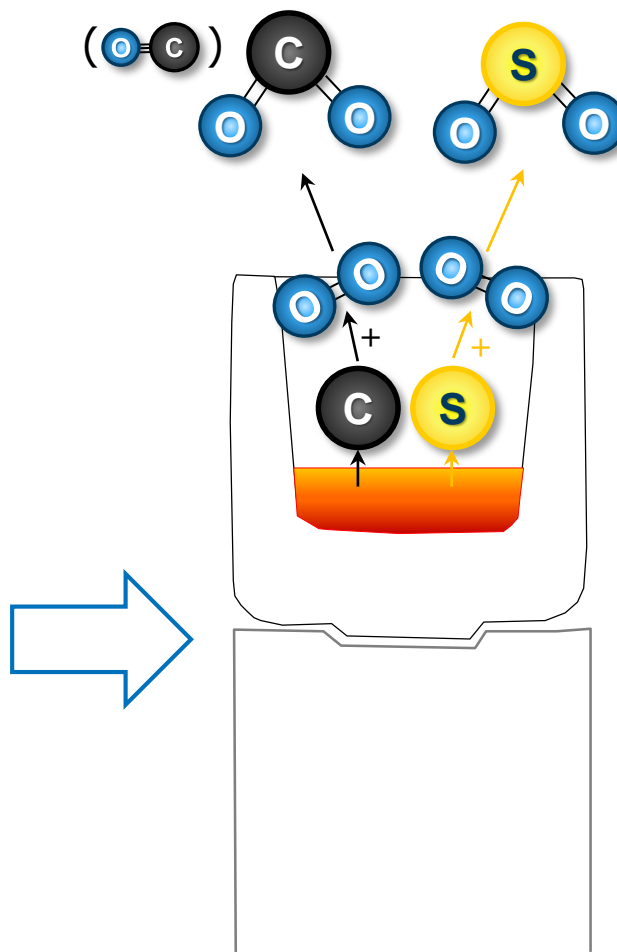
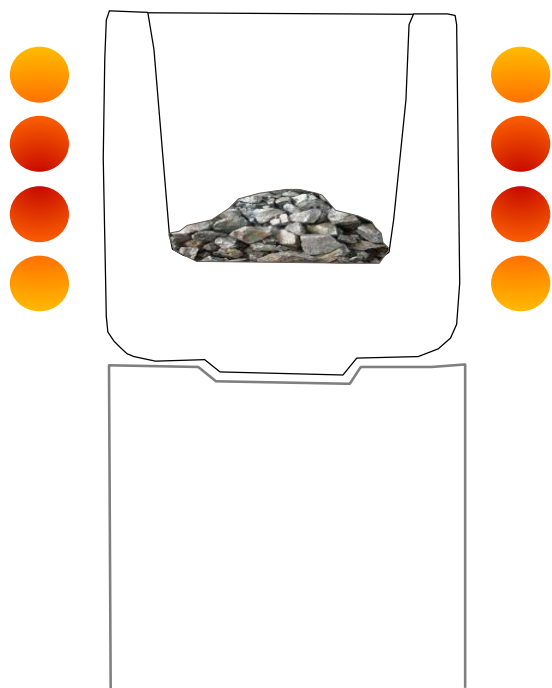
G4 ICARUS Series 2

Chemistry of combustion



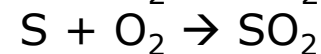
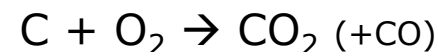
Solid sample + accelerator
in ceramic crucible

Induction heating of the sample
Excess O₂ provided to sample



Sample melts

C & S are released



CO is later oxidized
to CO₂ by oxidation
furnace (platinized
silica)

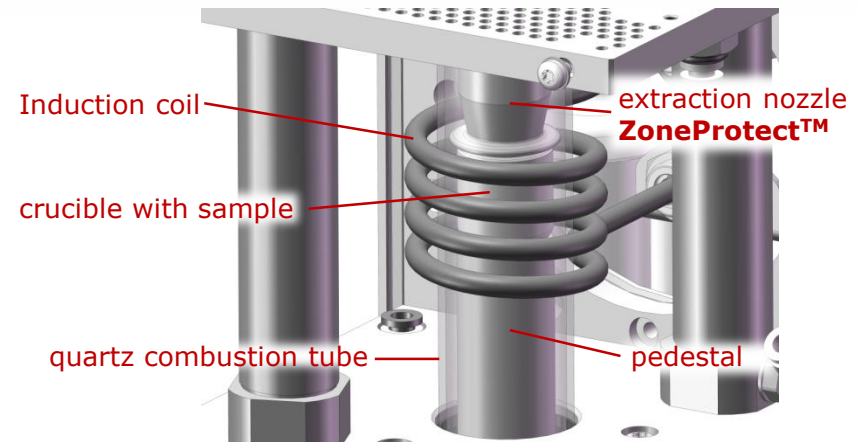
G4 ICARUS Series 2

HF Induction Furnace



Induction Heating:

- Heating of an electrically conductive material (e.g. metal) by induction
 - Application of AC power with high voltage & high frequency through induction coil
 - Alternating EM-field induces eddy currents in the sample
 - Electrical resistance leads to Joule-heating of the sample
- ⇒ Direct way of heating, short interaction time, $T > 1600$ dC possible



Accelerators

- conductive metal: **coupling** to the HF-field
- **Ignite** and "set-fire" to the sample; exothermic reaction, providing additional energy
- Act as **flux** to dissolve oxide layers and make melt thoroughly fluid (homogeneous melting)
- Different accelerators → different temperatures

Typical accelerators:
Tungsten, Tin, Iron, Copper



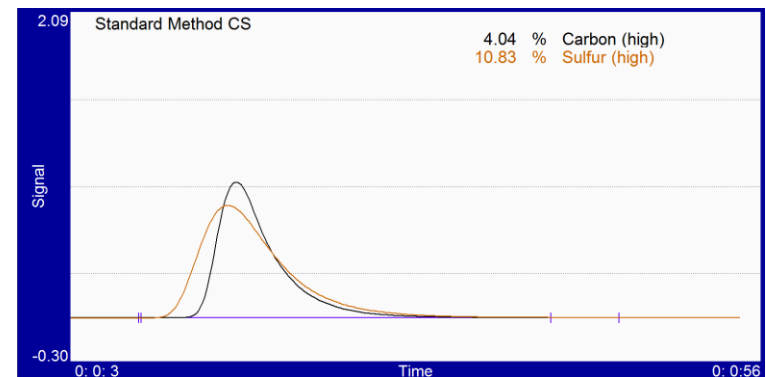
G4 ICARUS Series 2

Method Benefits



Combustion Analysis by HF-induction is:

- **Volumetric method**: Entire sample mass is analyzed
 - Also **applicable to difficult samples** with uneven distribution of elements (e.g. C in grey cast iron)
- Provides high **precision** and **accuracy**
- **Fast**: Analysis in ~60s
- Applicable over the **full concentration range** (from sub-ppm to 100%, by varying sample mass)
- **Flexible** in sample type, mass and form (powder, pieces, chips, drillings, etc.)
- **Easy** to operate



...if everything is designed the right way

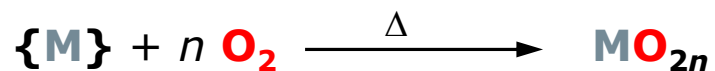
G4 ICARUS Series 2

A dirty affair...



The dark side of combustion

- Not only oxidation of C and S, but also of sample and accelerator
- ⇒ can create fine dust
- Fine dust can act as a column to retard or retain analyte delivery to the detectors dependent on amount and type of dust.
- Production of spraying particles and liquid metal splatters due to vigorous combustion
- ⇒ can damage quartz combustion tube



Metals/Minerals + O₂
= particulate oxides = **DUST**



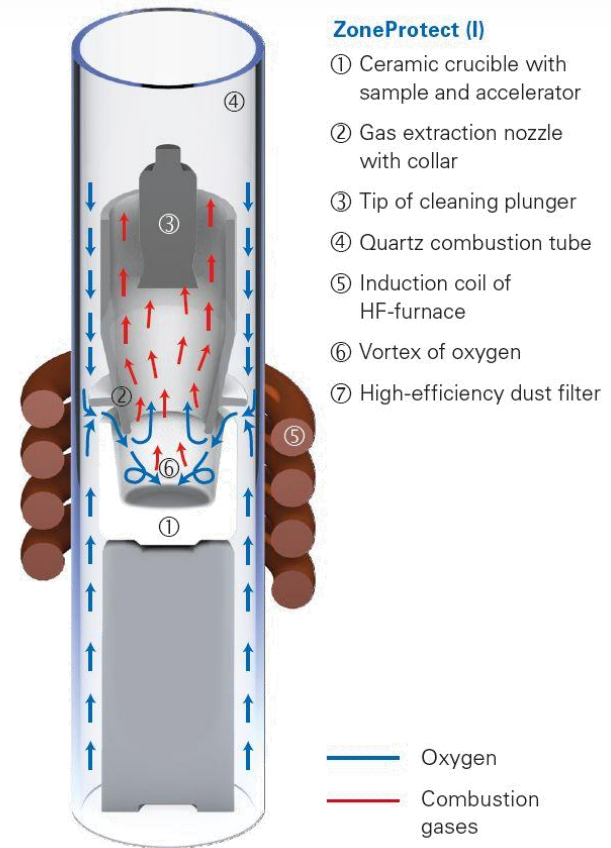
G4 ICARUS Series 2

Intelligent Design: ZoneProtect™



ZoneProtect™

- More efficient combustion on a wider variety of samples
- Superior gas flow design for better analytical quality
 - ⇒ Oxygen supply through annular flow gap & turbulences ensure **perfect oxygen supply** to the sample
- Combustion gases, dust & particles transported through the extraction nozzle upward
- Reduces splattering, maximizes component lifetime (combustion tube)
- Integrated auto cleaner



G4 ICARUS Series 2

Easy Maintenance: ZoneProtect™

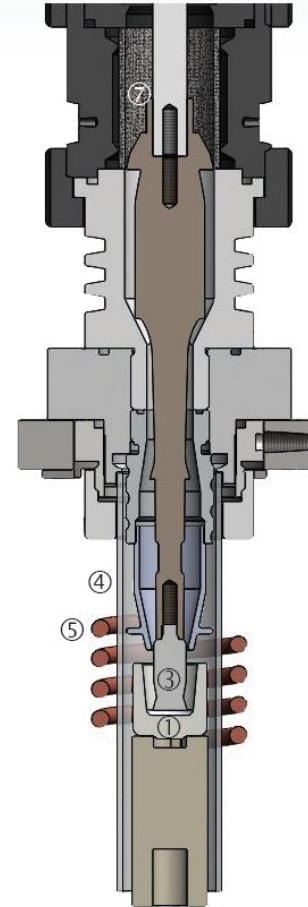


Integrated dust removal system:

- Vacuum & noise-free cleaning system
- Waste disposal into the used crucible
- Brush-free cleaning operated by solid plunger
- High efficiency, integrated dust filter (3µm pore size) for cleaner environment and improved analytical precision
- Tool-free & easy maintenance



Efficient dust removal into the crucible



- Carbon and Sulfur Detection

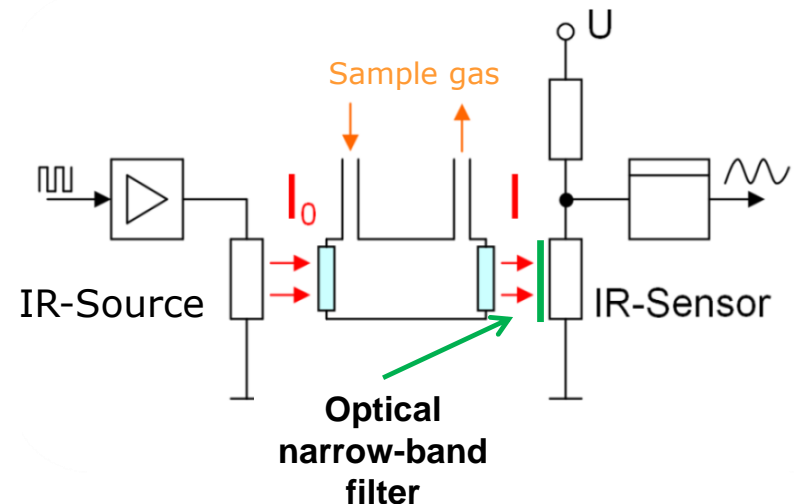
G4 ICARUS Series 2

NDIR Detection (CO₂)



NDIR = **non-dispersive infrared**:

- Molecules absorb infrared radiation under excitation to specific levels of higher rotational and vibrational energy
 - NDIR = non-dispersive IR wavelength is selected by narrow-band optical filters to the specific molecule, here to CO₂
 - Due to the absorption by the particular molecule, the transmission of the IR light is attenuated, which is registered by the sensor
 - IR sensors used (e.g. Pyroelectric) require chopping of the source
- ⇒ On-off mechanism
- ⇒ Not mechanical = no chopper



G4 ICARUS Series 2

HighSense™ SO₂ Detection by UV-LED

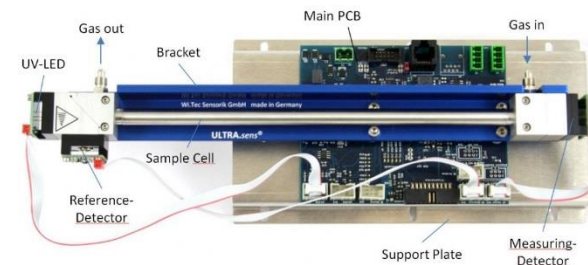


HighSense™

- **Electronic** transitions (UV-energy) within the molecules are used
- **UV-Transitions** have much higher quantum efficiency than IR absorption (**higher sensitivity, lower noise**)
- **No interferences** for utmost stability and selectivity
- Unmatched **lifetime** and modulation speed of LED

Compared NDIR:

- 10 times **better signal-to-noise**
- **Drift-free** baseline, long-term **stability**
- Staggering **selectivity** (ppm traces in 100%)

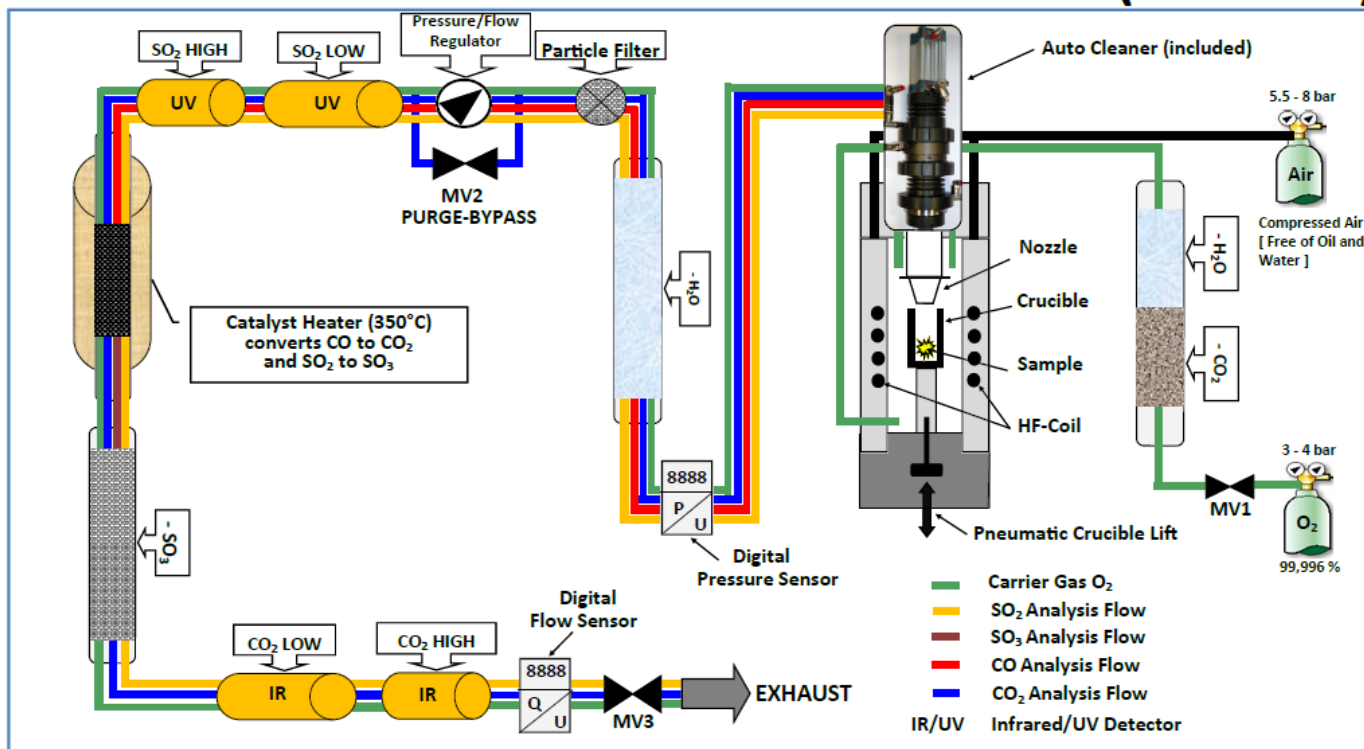


G4 ICARUS Series 2

Gas Flow Diagram



GAS FLOW DIAGRAM - G4 ICARUS HF CS (SERIES 2)



Bruker AXS GmbH
 Östl. Rheinbrückenstr. 49
 76187 Karlsruhe
 Germany

Phone +49 (721) 50997-0
 Fax +49 (721) 50997-5654
 info.baxs@bruker.com.de
 www.bruker.com



Rev_D6_2019_CHZ/KS

- Maintenance

G4 ICARUS Series 2

Tool-free & easy maintenance



Loosening of the screws and removal of the protective cover



Detaching of tubings (Push-ins)



Removal of the autocleaner

G4 ICARUS Series 2

Tool-free & easy maintenance



Removal of the filter



Removal of ZoneProtect™



Cleaning of the components

- Instrument specifications

G4 ICARUS Series 2

Instrument specifications



Analytical ranges

- Carbon: 0.0002 – 6 % (2 Ranges = Low/High)
- Sulfur: 0.0001 – 1 % (1 Range = Low)
- Sulfur: 0.0001 – 10 % (2 Ranges = Low/High) **Optional**

@ 1 g sample weight, extend ranges by reducing the sample weight

Analysis time

- Typically 40-60 s

Carrier gas & pneumatics

- Oxygen
- Purity: min. 99.95%
- Pressure: min. 3.5 bar
- Compressed air: min. 5 bar, free from oil, water and particles

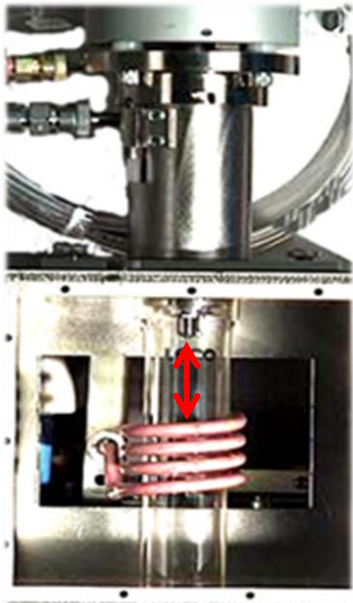
- # Benefit of Bruker

G4 ICARUS Series 2

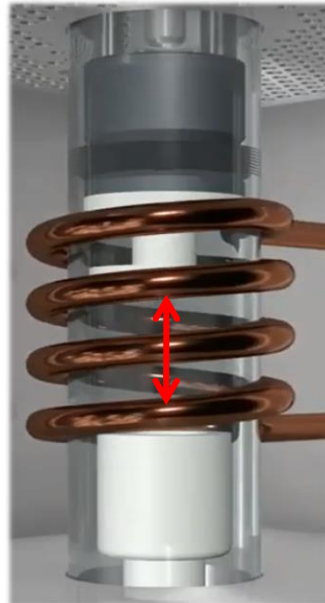
Comparison to competing manufacturers



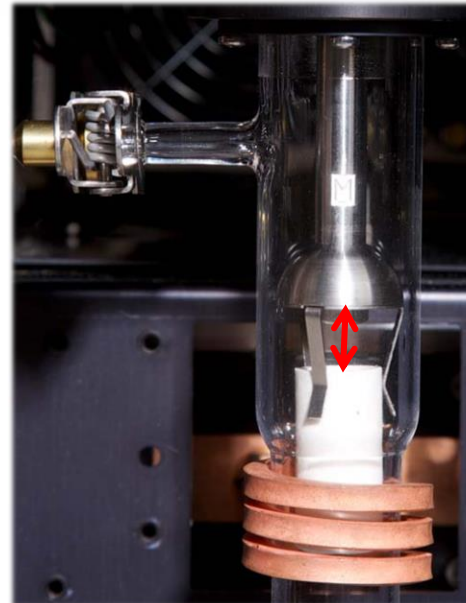
Manufacturer A



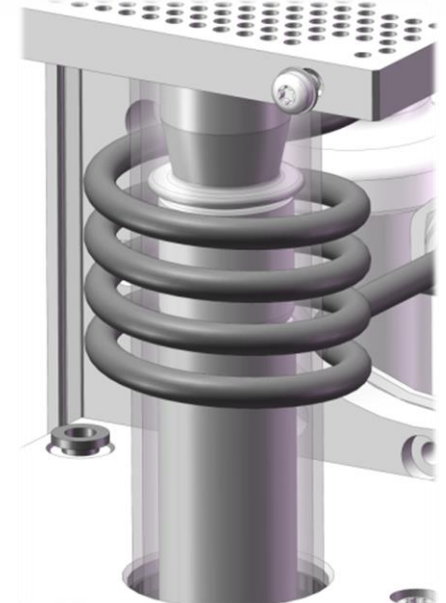
Manufacturer B



Manufacturer C



Bruker



What is the first thing you notice when comparing the other systems to the Bruker system?

Lance system vs. Bruker ZoneProtect™

G4 Icarus Series 2

...different furnace design, different outcome

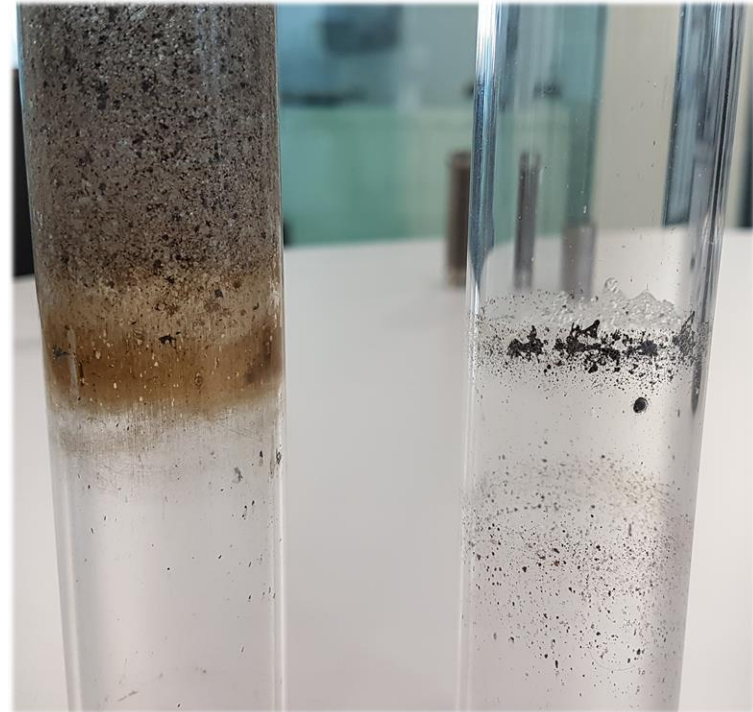


Metal samples, W+Fe accelerator



Competitor

Bruker



Competitor

Bruker

G4 ICARUS Series 2

Different dust filters



Competitor

Bruker

Support for Your Team Applications and Service



Mark West: Service Supervisor
Time with Bruker: 22 years



Okan Celik: Applications Scientist
Time with Bruker: 8 years



Kristin Odegaard: Sr Sales Engineer
Time with Bruker: 8 years

Mike Baal: Sr Sales Engineer
Time with Bruker: 8 years

Support for Your Team Lab Reports







Lab Report CS/ONH 20
G4 ICARUS Series 2

- Fast and Reliable Carbon and Sulfur Determination in Cement





Lab Report CS/ONH 22
G4 ICARUS Series 2

- Fast and reliable Carbon and Sulfur Determination in Cast Iron





Lab Report CS/ONH 21
G4 ICARUS Series 2

- Fast and Reliable Carbon and Sulfur Determination in Limestone, Dolomite and Lime





Lab Report CS/ONH 23
G4 ICARUS Series 2

- Fast and reliable Carbon and Sulfur Determination in Ore Concentrates, Metal-Bearing Ores and related materials



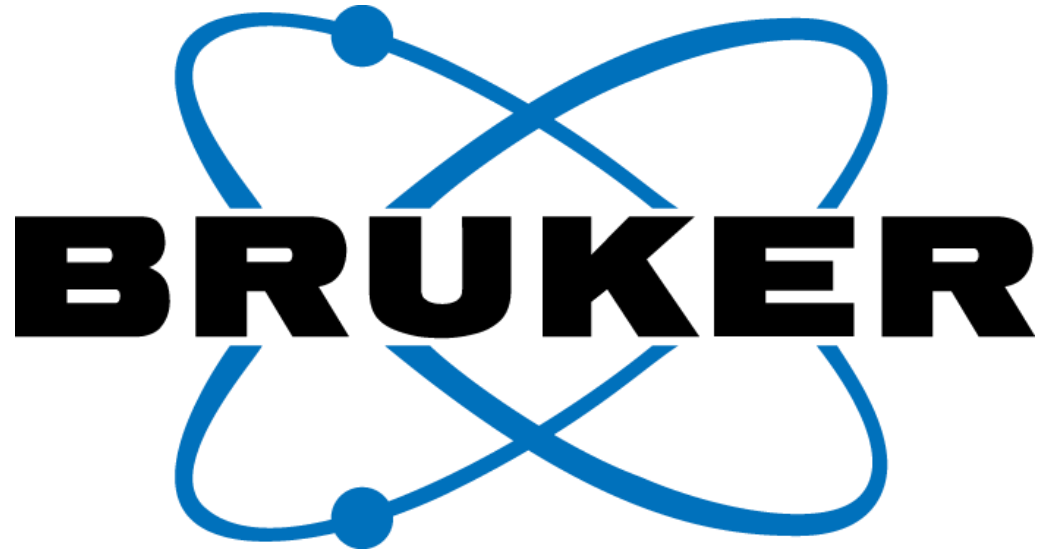


**Elemental Analysis & Metrology
for Powder Metallurgy**

- Analytical Solutions for Modern Production Processes

Q & A Session





Innovation with Integrity