

X-RAY FLUORESCENCE

Quality Control of Aluminum Alloys with EDXRF

Lab Report 125

Introduction

Aluminum is one of the most extensively used metals across industries due to its exceptional properties—low density, high corrosion resistance, and excellent electrical conductivity. These characteristics make aluminum ideal for applications in transportation, packaging, and high-voltage power transmission.

To enhance mechanical performance and processing capabilities, aluminum is commonly alloyed with elements such as silicon and magnesium. Alloying improves heat-treatability and reduces melting temperatures, enabling the production of high-strength materials. Monitoring the elemental composi-

tion of aluminum alloys is critical, especially in high-performance applications. Iron impurities, for example, tend to form brittle intermetallic phases during cooling, which negatively impact the ductility and machinability.

This lab report explores how X-ray fluorescence (XRF) can be used to quantify alloying elements and detect trace impurities in aluminum products.

Fast and reliable quality control with the S2 PUMA

The S2 PUMA is the high-performing benchtop energy-dispersive X-ray fluorescence (EDXRF) spectrometer for a wide range of applications. It is ideally suited for quality control of aluminium samples due to its XY Autochanger for unattended analysis of large batches of process samples. Its optimized beam path geometry with the HighSense silicon drift detector (SDD) ensures high sample throughput in combination with excellent precision and accuracy. Even continuous 24/7 process control can be achieved by the Automation option, which allows for the professional integration in automated laboratory environments.

The instrument is perfectly equipped for industrial environments due to its ergonomic TouchControl™ interface for the independent routine operation without any PC peripherals. The dedicated instrument protection system SampleCare™ (Figure 1), the powerful user account control of the spectrometer's software SPECTRA.ELEMENTS, and sturdy design guarantee a high instrument uptime.

Table 1
Details on calibration data

Compound	Concentration Range [wt%]	Calibration Standard Deviation 3σ [wt%]
Mg	0.19 - 8.32	0.0916
Si	0.62 - 12.89	0.1422
Ti	0.040 - 0.360	0.0042
Cr	0.030 - 0.170	0.0067
Mn	0.020 - 0.400	0.0038
Fe	0.380 - 1.090	0.0217
Ni	0.060 - 0.660	0.0141
Cu	0.070 - 2.56	0.0361
Zn	0.030 - 0.880	0.0060
Sn	0.040 - 0.190	0.0009
Pb	0.010 - 0.120	0.0022

Calibration Data

For this report 10 aluminium reference samples have been used to set-up a calibration on the S2 PUMA. The samples have been obtained with a coquille and have been cast as cylinders with diameters of 40 mm, and then cut into disks of 4 - 13 mm height. The surfaced to be analyzed was mill-cut and polished.

Analyses have been performed under vacuum for optimal light element detection and lower operating costs (no helium required!). Peak and background positions have been defined by fixed position, integration, and peak height or lower envelope, respectively. Table 1 lists the concentration ranges of the elements covered by the reference samples used for calibration. The measurement conditions are summarized in Table 2.

The exemplary calibration curve of Si (Figure 2) shows the excellent analytical abilities of the S2 PUMA with a strong linear association ($R^2=0.99941$) and 3σ standard deviation of 0.1422 wt% for a concentration range of 0.62 wt% to 12.89 wt%. Aluminium was calculated by difference to 100 wt%.

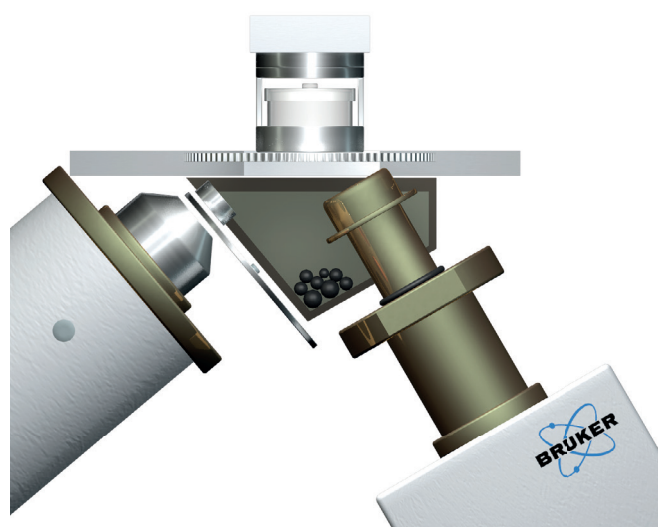
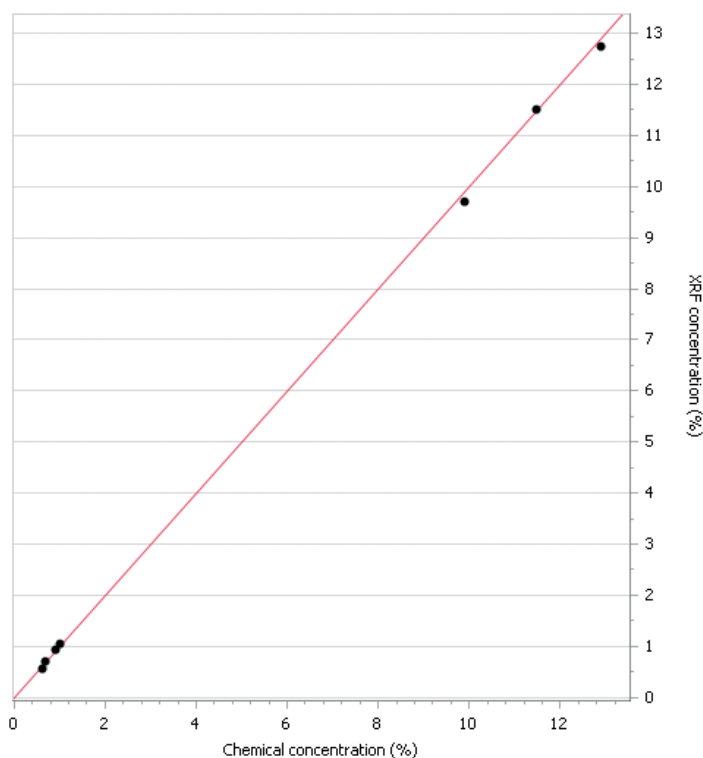


Figure 1
SampleCare™ protects all vital system components, providing high uptime and easy maintenance.

Table 2
Measurement conditions

Voltage [kV]	Analyzed Elements	Filter	Measurement Time [s]
20	Mg, Si	none	100
40	Ti, Cr, Mn, Fe, Ni, Cu, Zn, Pb	Al (500 μ m)	100
50	Sn	Cu (250 μ m)	100



Analytical Precision

To demonstrate the analytical stability of the S2 PUMA, the measurement of one sample was repeated 10 times whereby the sample was unloaded from the sample chamber after every analysis. The results of the repeatability test are summarized in Table 3, revealing high precision even for trace elements.

Measurement Accuracy

The results of a measurement of an aluminium are compared to the certified values in Table 4.

Figure 2
Calibration curve for Si in SPECTRA.ELEMENTS

Table 3
Excellent results of the precision test on the S2 PUMA

	Mg [wt.-%]	Al* [wt.-%]	Si [wt.-%]	Ti [wt.-%]	Cr [wt.-%]	Mn [wt.-%]	Fe [wt.-%]	Ni [wt.-%]	Cu [wt.-%]	Zn [wt.-%]	Sn [wt.-%]	Pb [wt.-%]
Rep-1	0.24	85.48	11.54	0.045	0.032	0.400	0.603	0.079	0.933	0.584	0.014	0.050
Rep-2	0.24	85.54	11.50	0.040	0.029	0.398	0.603	0.079	0.932	0.582	0.014	0.050
Rep-3	0.24	85.47	11.54	0.049	0.038	0.400	0.604	0.078	0.933	0.582	0.015	0.050
Rep-4	0.24	85.51	11.52	0.037	0.031	0.397	0.606	0.078	0.935	0.583	0.014	0.051
Rep-5	0.23	85.50	11.53	0.040	0.033	0.398	0.608	0.079	0.936	0.583	0.013	0.050
Rep-6	0.24	85.50	11.51	0.041	0.033	0.398	0.608	0.079	0.936	0.584	0.013	0.050
Rep-7	0.24	85.54	11.49	0.044	0.028	0.396	0.602	0.079	0.935	0.584	0.016	0.051
Rep-8	0.24	85.54	11.49	0.038	0.032	0.399	0.604	0.078	0.931	0.582	0.013	0.050
Rep-9	0.25	85.50	11.52	0.042	0.028	0.397	0.606	0.080	0.933	0.585	0.014	0.051
Rep-10	0.24	85.51	11.51	0.037	0.029	0.397	0.606	0.079	0.933	0.583	0.015	0.051
Avg.	0.24	85.51	11.52	0.041	0.031	0.398	0.605	0.079	0.934	0.583	0.014	0.050
Abs. Std. Dev.	0.00	0.02	0.02	0.004	0.003	0.001	0.002	0.001	0.002	0.001	0.001	0.001
Rel. Std. Dev.	1.96	0.03	0.16	9.28	9.77	0.34	0.35	0.80	0.18	0.18	7.05	1.02

*Aluminum was calculated by difference to 100 wt%.

Table 4
Accuracy test of the certified reference material measured against the calibration

	Mg [wt.-%]	Al* [wt.-%]	Si [wt.-%]	Ti [wt.-%]	Cr [wt.-%]	Mn [wt.-%]	Fe [wt.-%]	Ni [wt.-%]	Cu [wt.-%]	Zn [wt.-%]	Sn [wt.-%]	Pb [wt.-%]
Reference	0.37	85.95	9.90	0.220	0.170	0.020	1.090	0.660	0.720	0.670	0.120	0.110
Measured	0.37	85.99	9.81	0.227	0.191	0.062	1.105	0.644	0.704	0.676	0.121	0.100
Abs. Dev.	0.00	0.04	0.09	0.007	0.021	0.042	0.015	0.016	0.016	0.006	0.001	0.010

*Aluminum was calculated by difference to 100 wt%.

Conclusion

This report demonstrates the excellent analytical performance of the S2 PUMA for rapid quality control of aluminum products. Accuracy, precision, and low cost of operation are ensured by the powerful X-ray tube, the HighSense beam path and vacuum mode operation. Industry-leading features such as the XY Autochanger sample handling with optional integration into automated environments and TouchControl make continuous process control as well as product quality assurance easy and quick.



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