Spectroscopy Performance Note

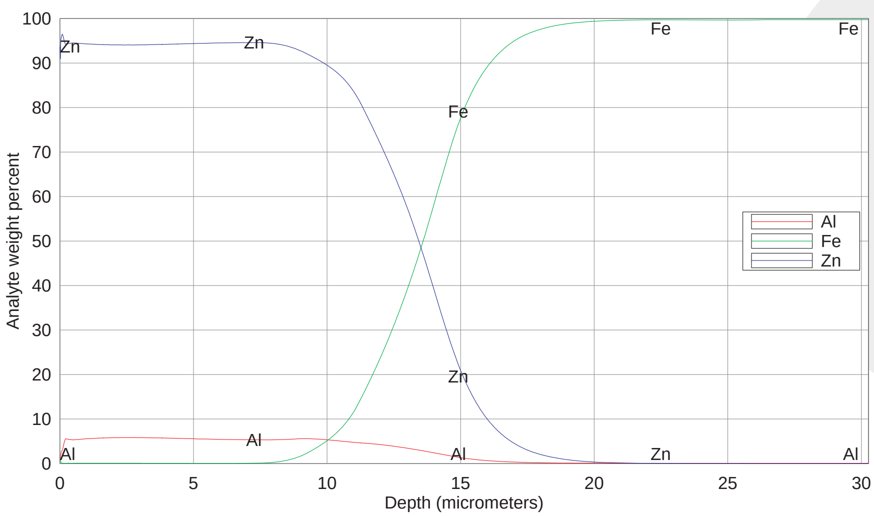
QDP Analysis of Galvanized Steel

- **Galvanizing Thickness and Coating Weight**
- **Composition on the Coating and Substrate**
- **Surface Treatments**

The application of zinc and zinc-alloy coatings to steel provides both galvanic and barrier corrosion protection. Galvanized coatings can be applied by either continuous hot-dip coating or electroplating. Hot-dip coatings include galvanized (zinc), galvannealed, Al-Zn with 55% aluminum and Zn-Al with 5% aluminum. Electroplated coatings include zinc and Zn-Ni. The choice of coating depends on the application. Thin coatings provide sufficient corrosion resistance where the corrosion rate is low, such as interior panels and painted parts. Thick coatings are needed where corrosion rate is high and long service life is required, such as marine or underground applications. The analysis conforms to and is in accordance with ISO 16962.

Hot-Dip Galvanized Coatings

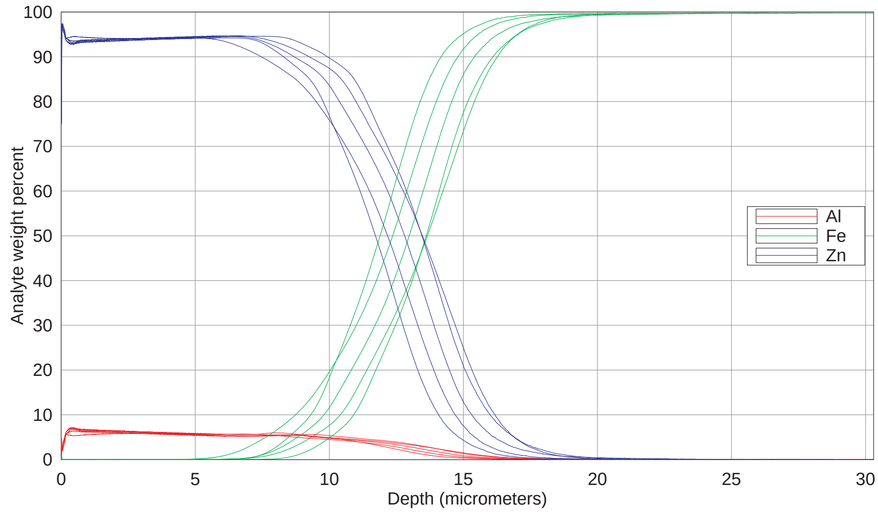
Zinc and Zinc-5% Aluminum:Galvanized is the most common hot-dip coated product. Zinc provides both galvanic and barrier protection of the underlying steel. A small amount of aluminum, typically 0.2 to 0.3%, is present in galvanized coating. The addition of 5% aluminum improves the corrosion resistance and ductility of the coating layer. Typical coating weights for galvanized coatings range from 90 to 1200 g/m². The plot and table below show a Zn-5% Al galvanized coating.



Name	Depth, µm	Total coat wt, g/m²	Zn%	Al%
Hot Dip-1	13.52	89.10	94.41	5.57

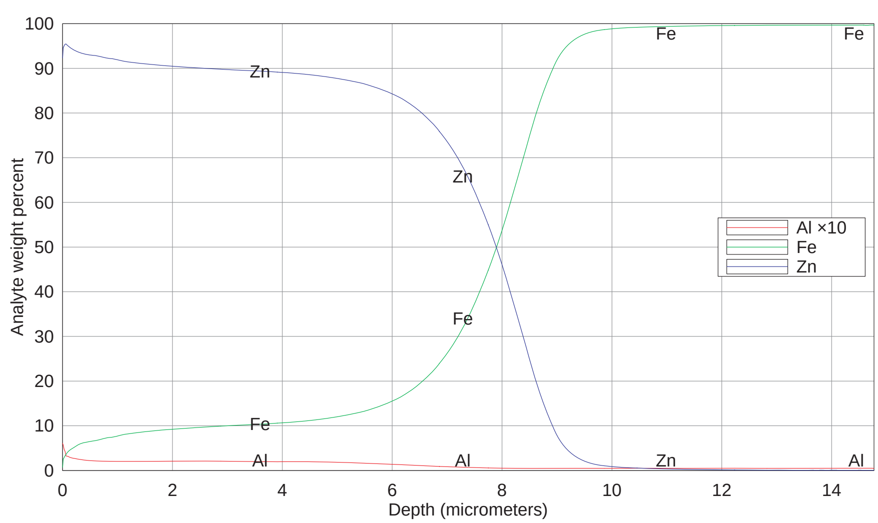
GDS-Series

The next plot and table show an overlay of replicate analyses on a Zn-5% Al galvanized coating. The variability within the coating is demonstrated both in the plot and by the statistics shown in the table.



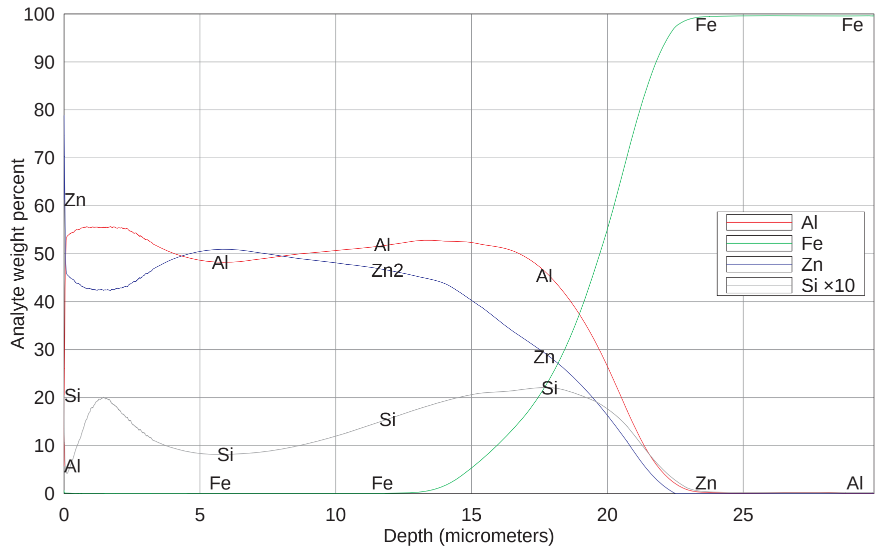
Name	Depth, µm	Total coat wt, g/m²	Zn%	Al%
Hot Dip-1	13.52	89.10	94.41	5.57
Hot Dip-2	13.59	88.93	94.43	5.56
Hot Dip-3	12.88	84.14	94.23	5.75
Hot Dip-4	11.84	77.30	93.88	6.10
Hot Dip-5	12.26	79.32	94.04	5.94
Mean	12.82	83.76	94.20	5.78
Rsd	5.99	6.45	0.25	4.07

Galvannealed Coating: Galvannealed coatings are characterized by diffusion of 8 to 11% iron into the zinc coating. The zinc is applied by a continuous hot-dip process which is diffusion-alloyed by the application of additional heating after the galvanized layer is formed. Galvannealed coatings are painted for most applications. The coating weight ranges from 90 to 180 g/m². The following plot and table show a typical galvannealed coating.



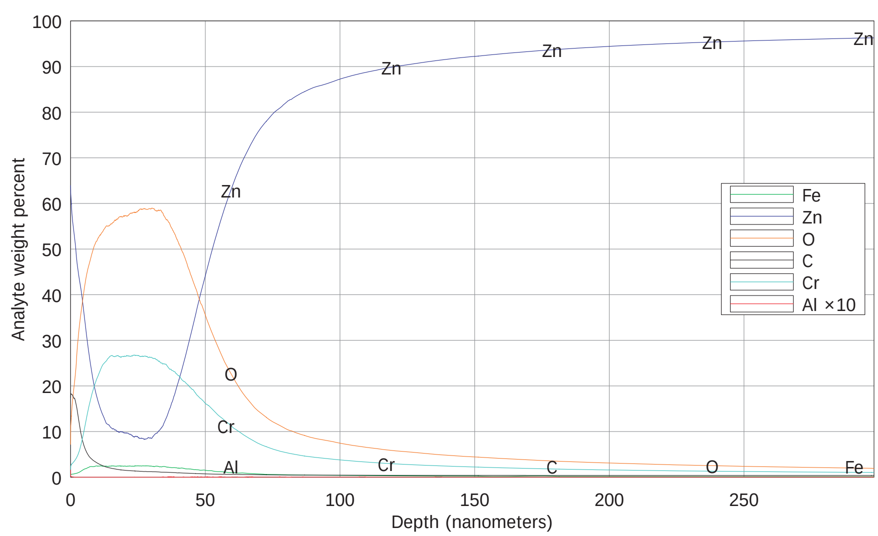
Name	Depth, µm	Coating wt, g/m²	Zn%	Fe%	Al%
Galvanneal-1	8.01	56.98	89.83	9.97	0.19

55% Aluminum-Zinc Coating: The 55% Al-Zn alloy is used in applications where improved corrosion resistance is required. In addition to aluminum and zinc, silicon is present at approximately 1.5% to control the alloy layer growth and improve adhesion during forming. The following plot and table show a Zn-Al coating.



Notes	Depth, µm	Coating wt, g/m²	Zn%	Al%	Si%
204 #1	18.57	75.47	44.92	53.33	1.75

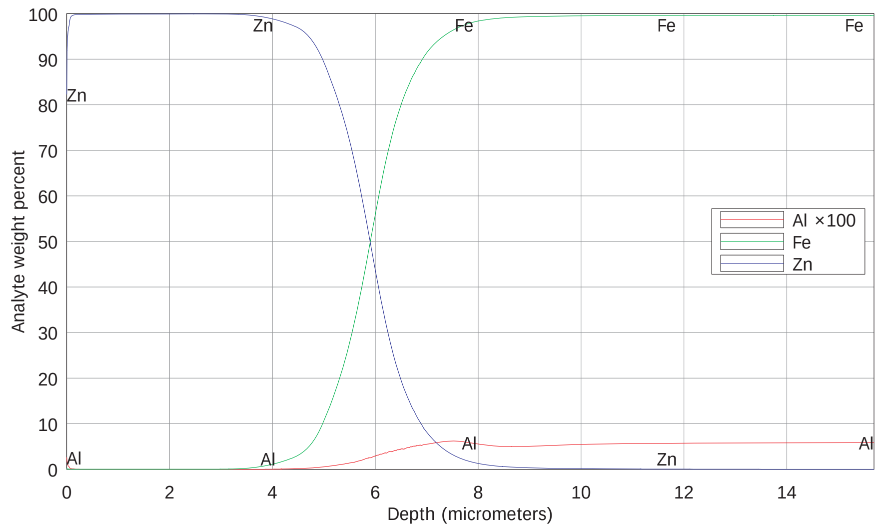
Surface Treatment: Some galvanized products have a surface treatment applied. Below is an example of a chromate coating applied to a galvanized steel. The plot shows the first 300 nm of analysis. The accompanying table gives values for both the surface coating and the full galvanized coating.



Notes	Cr coat wt, mg/m²	Zn coat wt, g/m²	Zn Depth, µm
Chromate on Zn-1	111	4.35	4.64

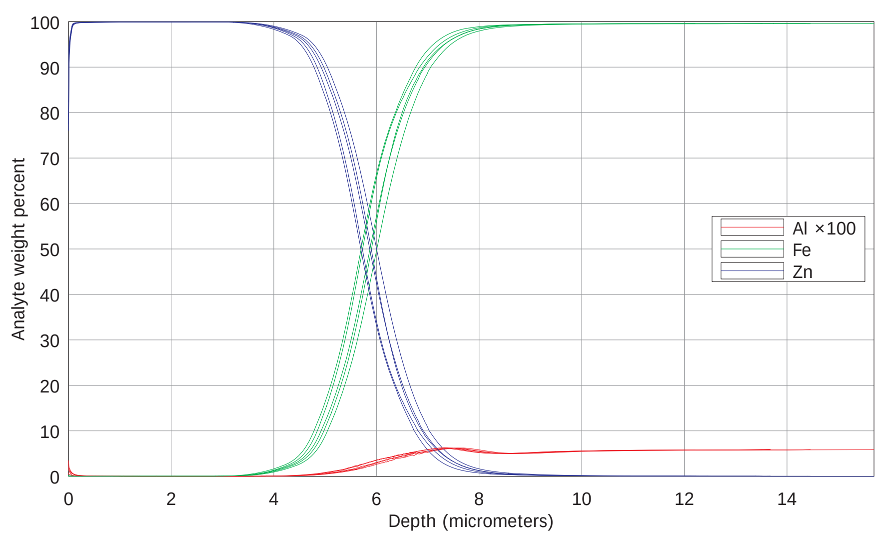
Electroplated Zinc Coatings

Electrogalvanized Zinc: Electroplated zinc is applied by passing the steel strip at a high speed through a series of plating cells, building the coating thickness a little at a time. An advantage of electrogalvanized coatings is their excellent surface finish. Typical coating weights for electrogalvanized coatings range from 50 to 80 g/m². A typical electrogalvanized coating is shown in the following plot and table.



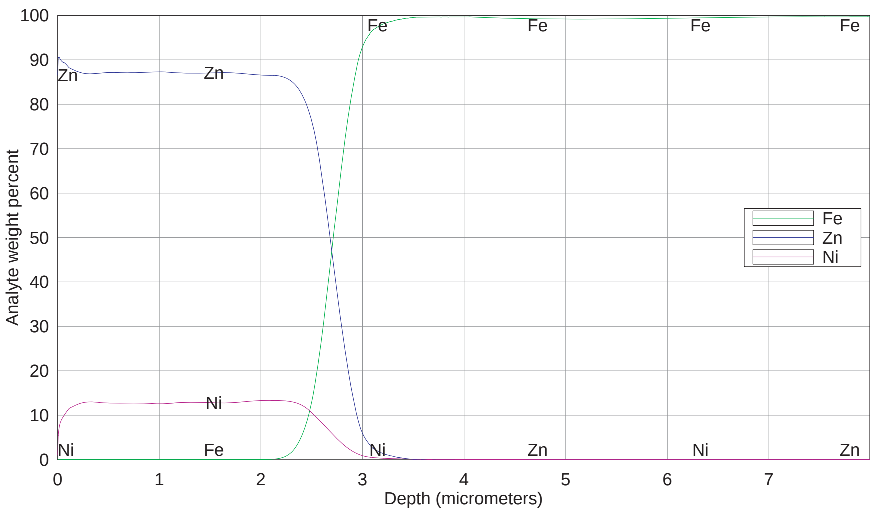
Notes	Zn Depth, µm	Zn Coat wt, g/m²
EG-1	5.95	42.4

An overlay of replicate analyses of electrogalvanized steel is shown below. The uniformity of the layer is clearly seen.



Notes	Zn Depth, µm	Zn Coat wt, g/m²
EG-1	5.95	42.4
EG-2	6.06	43.2
EG-3	5.93	42.3
EG-4	5.81	41.4
EG-5	5.76	41.1
Mean	5.90	42.1
Rsd	2.02	2.00

Electroplated Zinc-Nickel: The electroplated zinc-nickel alloy is formed by co-depositing the Zn and Ni to create the alloy coating. The typical alloy contains 10 to 16% Ni with a balance Zn. The plot and table below show a typical electroplated Zn-Ni coating.

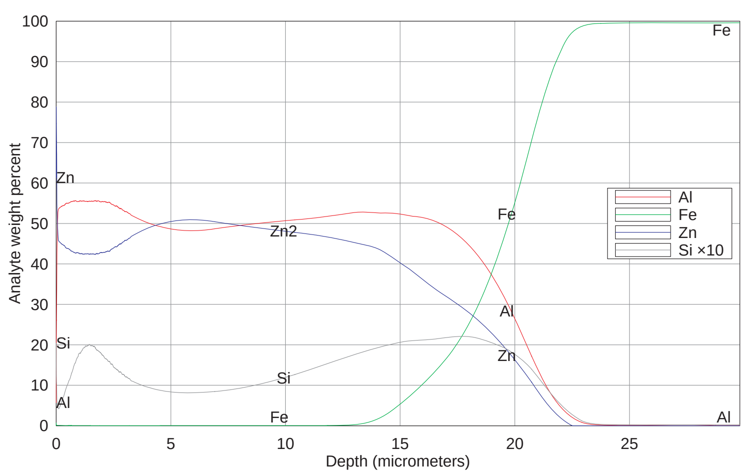


Name	Zn Depth, µm	Coating Wt, g/m²	Zn%	Ni%
Zn-Ni 1	2.72	19.93	87.36	12.61

Report Generator

The report generator included in the Quantitative Depth Profile (QDP) software helps the operator easily produce a polished report. The generated report shown includes a range of the features available. Text boxes are used at the top and as table labels. A bitmap is included that shows the LECO® QDP logo. The sample tables near the bottom of the page give calculated information on both the coating and the substrate. The plot is reported in concentration in weight percent versus depth in micrometers (µm), the multipliers for each element and line color are operator selected. The analyte table to the right of the plot shows the variation with depth for the Zn, Al, and Si from the coating and into the substrate. The report form is stored in the software and can be reused for newly acquired data.

Analytical Information



Coating Composition vs. Depth

Depth (µm)	Zn (%)	Al (%)	Si (%)
1	42.4	55.6	1.89
2	42.3	55.8	1.77
3	45.4	53.3	1.24
4	49.1	49.9	0.94
5	50.5	48.6	0.83
6	51.0	48.2	0.80
7	50.3	48.8	0.83
8	49.4	49.6	0.93
9	48.9	50.1	1.03
10	47.9	50.8	1.20
11	47.3	51.2	1.37
12	46.6	51.8	1.56
13	45.1	52.9	1.76
14	44.0	52.5	1.92
15	40.2	52.4	2.08
16	36.0	51.4	2.10
17	31.7	49.3	2.18
18	27.7	44.3	2.22
19	22.7	36.9	2.05
20	16.2	26.2	1.72
21	8.4	13.8	1.20
22	1.9	4.6	0.52
23	0.0	0.6	0.09
24	0.0	0.1	0.03
25	0.0	0.1	0.02
26	0.0	0.1	0.02
27	0.0	0.0	0.02
28	0.0	0.0	0.02
29	0.0	0.0	0.02
30	0.0	0.0	0.02

Coating Weights

Zn, g/m²	Al, g/m²	Si, g/m²	Total, g/m²
33.9	40.2	1.3	75.5

Avg Coating Composition

Zn%	Al%	Si%
44.9	53.3	1.75

Coating Depth

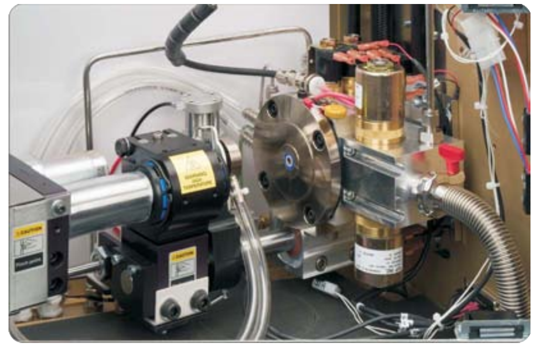
Depth, µm
18.6

Substrate Composition

Fe%	C%	Mn%
99.6	0.035	0.20

Understanding the Glow Discharge Source

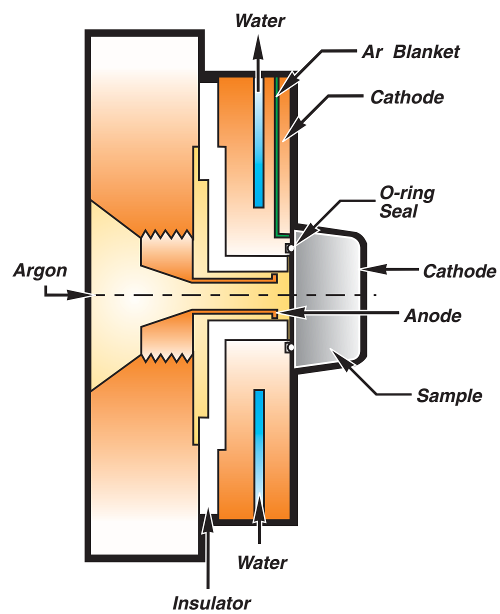
The Sputtering Process



- The Glow Discharge Spectrometer (GDS) lamp provides a low pressure argon environment (typically 5-10 Torr) over the sample surface.
- A high negative potential (typically -800 to -1200V) is applied to the sample. The sample thus becomes the cathode.
- Spontaneously produced Argon ions (Ar^+) are accelerated across the anode/cathode gap by this potential.
- The collision of Ar^+ ions with argon gas molecules causes plasma formation and further production of Ar^+ ions. This plasma is called a glow discharge.
- Some of these high velocity Ar^+ ions reach the sample surface where they sputter (or mill out) materials uniformly from the sample substrate.
- Some of this sputtered material diffuses into the glow discharge plasma where it is dissociated into atomic particles and finally excited.
- The light emitted from these excited state species as they collapse back to a lower energy level is characteristic of the elements composing the sample.
- The wavelengths and intensity of the light emission are used to identify and quantify the composition of the sample.

GDS Advantages

- Layer-by-layer removal of material allows for qualitative and quantitative depth profile analysis
- Separation of sampling (sputtering) and excitation resulting in:
  - Freedom from metallurgical history
  - Fewer matrix effects
- Grimm-type Lamp design provides lowered self-absorption and material re-deposition
- Linear calibration curves with wide dynamic range
- Fewer lines required to analyze full concentration range
- Linear calibrations require fewer standards for calibration
- Fewer spectral interferences due to:
  - Narrow emission lines
  - Excitation of almost exclusively atom lines
- Very little sample-to-sample carry-over allows quick matrix changes
  - Automatic cleaning between samples
  - No sputtering of anode or other lamp components
- Low reference material consumption
  - More burns before required resurfacing
  - Shallower burn spots requiring less material removal during resurfacing
- Low gas and other consumable consumption
- Very easy to operate
- Quiet, clean, and low maintenance
- Small footprint—fits through standard lab door



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