# Elemental Analysis with Laser-Induced Breakdown Spectroscopy

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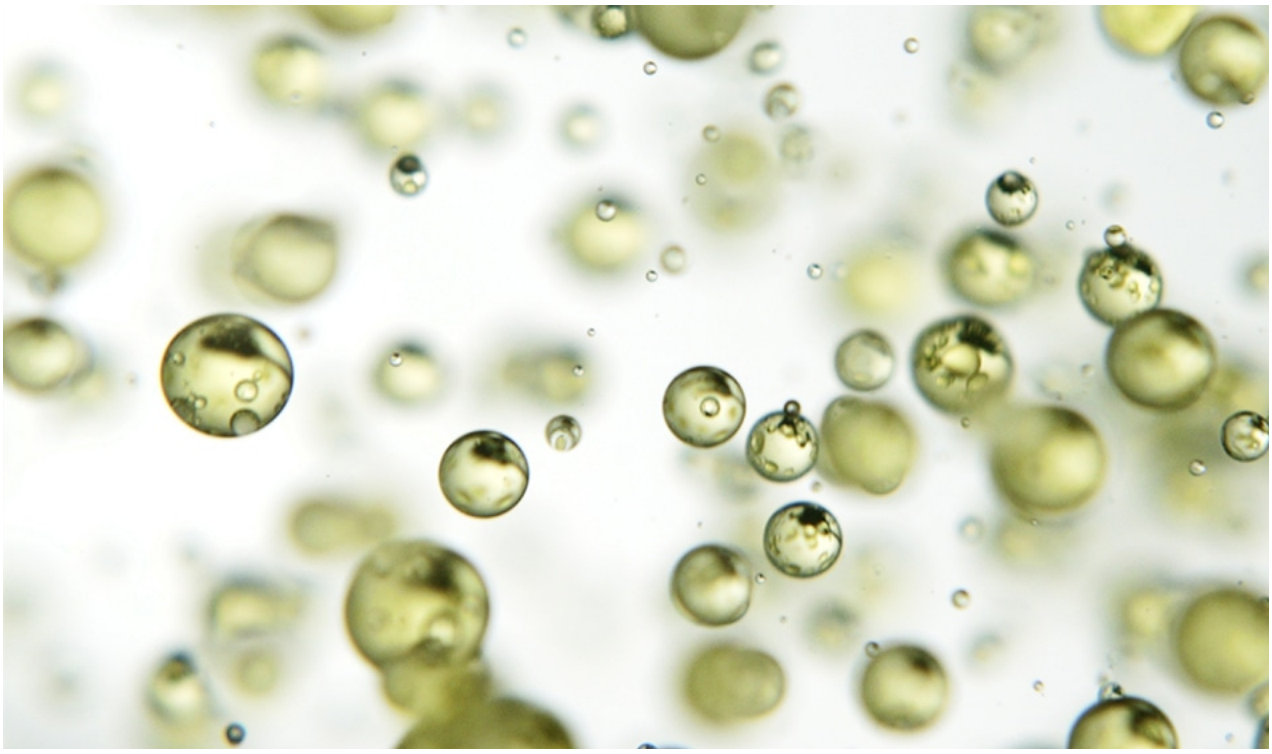
Feb 6 2019

**Elemental analysis is an analytical technique commonly used to determine the elemental composition of chemical compounds and their mixtures. This analysis answers what percentage of a sample is made up of chemical elements and what these elements are; providing both qualitative and quantitative analysis.**



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## Why LIBS for elemental analysis?

Laser-Induced Breakdown Spectroscopy (LIBS) is an optical emission spectroscopy technique used to measure elemental concentrations in a material; starting from the complex analysis of ultra-low elemental concentrations in alloys, ores, brines and powders, to basic material or scrap samples.

LIBS is one of the few analytical techniques with the ability to measure a large number of chemical elements simultaneously. This technique can provide multi-elemental analysis, determining the atomic composition of an unknown sample with only a single measurement.

In contrast to X-ray fluorescence (XRF) and other methods, LIBS offers light chemical elements characterization. The main advantages of the technique are as follows:

- No or minimal sample preparation
- Applicable for solid, liquid, gaseous samples and slurries
- Allows fast scanning of the sample surface and depth profiling
- Ultra-fast measurement time for a single spot analysis
- Sensitivity to light elements (e.g., H, C, N, O, Na, Li)
- Enables thin sample analysis with no substrate interference
- Is mostly a non-destructive technique

Laser-Induced Breakdown Spectroscopy is a competitive technology alongside other commonly used methods for elemental analysis, i.e., Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) and Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES).

## How does LIBS work?

LIBS utilizes a short laser pulse to create a hot plasma on the sample surface for fast and precise chemical analysis. More specifically, the laser ablation process takes place when a small volume of sample mass is removed under a laser beam focused on the surface of the material.

The ablated material consists of free electrons, neutral particles, and ionic species, and expands as a high-temperature plasma. Hot plasma, with a temperature above 10,000 K, possesses enough energy to induce excitation of electrons in the outer orbitals.

Next, the plasma cooling process occurs, and the electrons of the atoms and ions return to a stable state. Finally, the plasma emits light with separate spectral peaks, which are collected and combined with an ICCD detector for further spectral analysis.

Chemical composition can be easily evaluated by identifying the different peaks for the analyzed samples. Each element in the periodic table is linked with unique LIBS spectral peaks. Moreover, the spectral peak intensities enable to quantify the amount of trace and major elements in the tested sample.

The obtained LIBS spectra are characterized by using atomic databases and qualitatively assigned to the adequate elements. On the other hand, quantitative analysis is based on a calibration method, with reference materials comprising different analyte concentrations. Moreover, depending on the analyte-matrix, low ppm-range of element concentrations can be measured.

## Applications and elemental analysis development

The LIBS technique is suitable for a broad range of samples; from metals, semiconductors, glasses, insulators, plastics, and biological tissues, to coatings and electronic materials. Minerals, natural soils, contaminated soils, rocks, food products, atmospheric particles, and biological materials are often intensively examined using LIBS technology.

Some examples of LIBS technology applications include:

- Elemental analysis of hazardous materials, such as radioactive, high-temperature or toxic materials
- In-situ detection and analysis of radioactive impurities present on storage containers
- In-situ elemental analysis of steel materials in restricted access site environments, e.g., nuclear reactor pressure vessels
- Analytical study of cultural heritage metallic material
- Process control via on-line elemental analysis of liquid metals and alloys or liquid glasses
- In-situ materials analysis immersed in water
- Polymers identifications in waste electrical and electronic equipment (WEEE)

Elemental analysis with LIBS spectra can be divided into *multivariate analysis* (where several peaks of the same element or the entire LIBS spectrum is used) and *single analysis* (where only one peak is used). Multivariate analysis is usually performed using Partial Least Squares Regression (PLSR), which results in better precision and accuracy when compared to one-peak analysis.

Since LIBS is simultaneously sensitive to all elements, a single laser pulse can be used to record the broadband emission spectra, and thus a ‘chemical fingerprint’ of the material can be provided. That's why LIBS is currently being extensively investigated and developed for use outside the laboratory.

Recently, LIBS technology has been miniaturized into a handheld device form - HH LIBS that is capable of analyzing any element, depending on the spectrometer range selected for the device.

## References


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