Laser-Induced Breakdown Spectroscopy (LIBS)

Application Note

LIBS is used to determine the elemental composition of various solids, liquids and gases. A high-powered laser pulse is focused on a sample to create a plasma or ‚laser spark'. Emissions from the atoms and ions in the plasma are collected by a lens or fibre optics and analysed by a spectrograph and gated detector. The atomic spectral lines can then be used to determine elemental composition or elemental concentrations in the sample. The main benefit of LIBS is that little or no sample preparation is required to obtain useful results and the technique is readily portable to the field.

Methodology

Laser-induced breakdown spectroscopy can be produced typically using excimer or Pulsed Nd:Yag lasers. The 5 to 20ns laser pulse produces a plasma plume that evolves with time from the point of impact of the incident laser pulse (Figure 1). The plasma plume emission is collected and analysed by the detection system, typically at some distance from the sample to reduce the significance of self-absorption or surface effects.

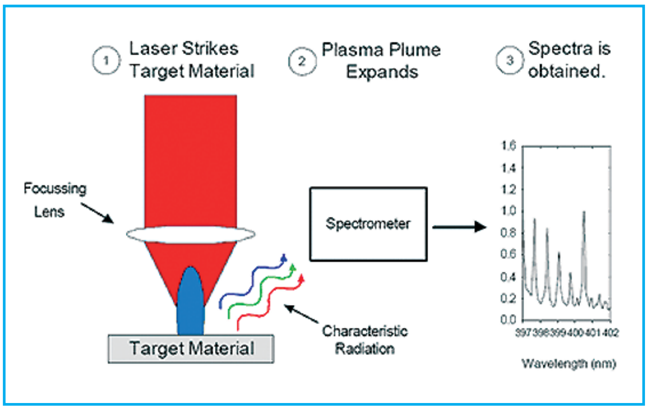

Figure 1

The plasma created breaks down all the sample's chemical bonds and ionises many of the constituent elements. The spectral emission occurs as a result of the subsequent relaxation of the constituent excited species. The exact timing of the spectral emission lines vary with the type of sample, the distance from the centre of the plasma, and the wavelength of the incident laser light. Typically, the evolution of the plasma and the changes in its content occur on a microsecond timescale so the gating requirement of LIBS is not very demanding, enabling a slow gate ICCD to be used. A typical experimental configuration is shown here.

The LIBS Advantage

LIBS is a very versatile technique enabling analysis of solids, liquids or gases, with little or no sample preparation. It is non-invasive due to very small sampling regions (~0.1mg to 1mg of material). Very hard materials can be investigated and simultaneous multi-elemental analysis is possible. All-in-all, it provides simple and rapid analysis carried out in a single step. However, further research is required into the quality of LIBS analysis as inherent characteristics of the technique can limit its usefulness. Future LIBS investigations should involve improving measurement accuracy and precision and also minimising interference effects.

Total LIBS solution from Andor

The Andor range of iStar cameras is ideally suited for LIBS, with features like 2ns gating, wide spectral range, minimum insertion delay and compact detector head. When coupled with a Mechelle spectrometer this would provide an ideal LIBS solution. Based on the Echelle grating principle this no moving parts spectrograph is unique. Combined with an Andor iStar, this patented design achieves the highest bandwidth coverage while simultaneously achieving the highest spectral resolution, without any compromises.

Andor cameras being used for LIBS

Laser Induced Breakdown Spectroscopy (LIBS) - LIBS is used to identify the elemental composition of materials, including chemical substances in the environment. When a laser, or spark, is focused onto a surface a small amount of the material is vaporised which forms a short lived plasma. As the plasma emits light it is collected by a spectrograph and an ICCD where the main laser plume is gated out.

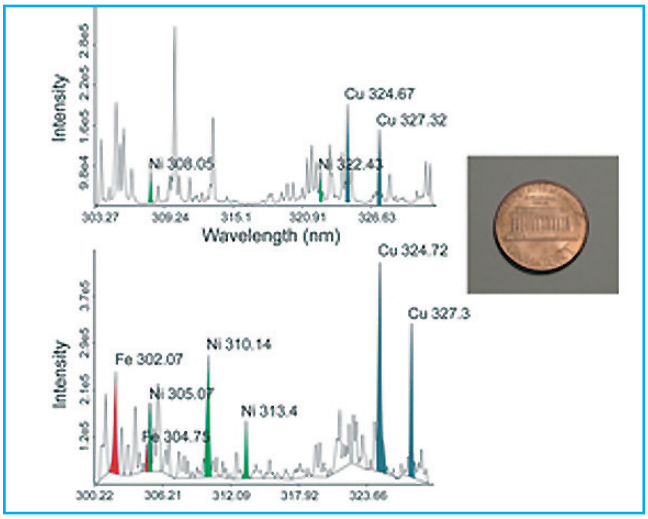

Figure 2

Figure 2 shows a LIBS spectra of a one cent US coin. The coin contains the elements iron (Fe), nickel (Ni) and copper (Cu). The top spectrum is a LIBS analysis of the electroplated surface of the coin, where Fe lines are not clearly identifiable. After 2000 shots of the laser, the surface layers of the coin have become ablated and the Fe lines can then be seen.

Various analytical techniques have been used extensively to reliably determine the elemental composition of materials or objects, often down to the level of trace elements. Laser-Induced Breakdown Spectroscopy (LIBS) is one of those techniques and, being practically non-destructive, is ideal for the analysis of artworks and archaeological artefacts. Researchers at the Foundation for Research and Technology - Hellas (FO.R.T.H.) in Crete, Greece, have developed a LIBS instrument in conjunction with the Institute of Aegean Prehistory (Philadelphia, USA).

Figure 3
„La Bella" - 18th century oil painting on canvas: copy of Palma Vecchio's Original

LIBS is a fast analysis technique and does not involve sampling and sample preparation, while damage to the object is minimal, estimated at around 20-200ng for a typical crater 1-2μm deep and 100μm in diameter, virtually invisible to the naked eye. This technology has been used to identify the restoration history, characterize paint pigments and date artworks. It has also been used in the field of archaeological metallurgy. Figure 3 is an analysis of an 18th century artwork. LIBS was performed on original and retouched areas of the painting. Lead (Pb) was found on the original paint, implying the use of lead white pigment. Titanium (Ti) was found in the retouched areas which points to the use of titanium white, a modern pigment. The results suggest that restoration was performed in the 20th century as titanium white became commercially available only after 1920.

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