Laser-induced breakdown spectroscopy in a biological tissue

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Abstract

The relative atomic composition of the laser-generated ablation plume in chicken myocardium is investigated by using luminescence spectroscopy. A Q-switched Nd:YAG laser emitting at 1064 nm with 9 ns pulse duration was used for the tissue ablation. The selected output energy was 210 mJ and the beam was focused to a 0.8 mm diameter spot size by using a 40 cm focal length lens. The luminescence emitted by the lasers-generated plasma due to the tissue ablation was collected by a 600 μm fused silica fiber. The collected light was coupled into a ¼ m spectrometer. An intensified CCD with 256x1024 pixels was connected at the monocromator detector port. The specified CCD gating capability was 5 ns and it was controlled by a DG535 model delay generator. The gate width was adjusted electronically to the desired time window. Four gates (100 μs, 10 μs, 5 μs and 100 ns) were tested and the ideal one, that presented more information about the samples under study, was the 5 μs window. The analysis of the spectral emission pointed out the presence of sodium, potassium, calcium, hydrogen and others. Each element was identified separately and compared to the common elements in tissues. In the extra-cellular matrix the presence of sodium prevails and in the intra-cellular space potassium predominates together with calcium and magnesium. The water diffusion through the membranes of living tissues carries ions of these elements. The perfect equilibrium between these distributions is necessary for the healthy maintenance of the organism. The measurement of the relative atomic composition by means of the laser ablation might lead to a diagnosis technique for the discrimination of different materials or tissues and even pathological conditions that promote chemical alterations to them.

Introduction

Spectroscopy's ability to identify and quantify materials has evolved to encompass analysis of atomic species. One technique that allows rapid detection of materials in the field is the laser-induced breakdown spectroscopy, which, with the relatively simple application of pulsed lasers, can measure trace elements in solids, liquids and gases. This technique condenses laser energy into a short pulse that produces a plume of ablated material from the sample in the form of a dense plasma. The plasma cools within microseconds, producing in turn, ionic, atomic and molecular emissions. Detection occurs during the ionic and atomic emission phases [1].

Because well defined spectral lines resulting from the chemical constitution of the material can be observed, the experimental observation of the ablation plume at various stages of its evolution by using time resolved spectroscopy can bring useful information for the analysis and, possibly, for the diagnosis of biological tissues, as well as for the understanding of the physical mechanisms involved in the ablation process [2- 4].

Experimental Setup

A Q-switched Nd:YAG laser (Quanta Ray) emitting at 1,064μm, with 9 nanoseconds pulse duration was used for the tissue ablation. The selected output energy was 210 mJ, and the beam was focused to a 0,8 mm spot size by using a 40 cm focal length lens and an estimated energy density of 42 J/cm^2. The laser beam irradiated a chicken myocardium tissue.

To avoid the excitation of the sample by the flash lamp, used to pump the Nd:YAG laser crystal, a Schott Glass Tech RG-715 filter (3 mm thickness) was inserted in the optical path. This filter absorbs wavelengths up to 715 nm.

The photoluminescence emitted by the tissue due to the ablation was collected by a 600 μm fused silica optical fiber. The collected light was coupled into a ¼ m spectrometer (Oriel Instruments MS257). An intensified CCD (Charge Coupled Device) with 256x1024 pixels was connected at the monocromator detector port. The specified CCD gating capability was 5ns and it was controlled by a Stanford Research delay generator (DG535 model).

The gate width could be measured and adjusted electronically to the desired time window. After adjusting electronically the acquisition time window, the laser was fired three times and the accumulated spectra was acquired. The sample was moved to a fresh point for a new acquisition. For each time window, several measurements were taken under this procedure. The data could than be evaluated for the repeatability and averaged for a better signal to noise ratio.

Results and Discussions

The measured spectra obtained for the 100 μs time window presented no defined structures of narrow emission peaks not allowing the study of the ablation plume as can be seen in figure 1. The need of working with smaller time windows was evidenced so it would be possible to make a detailed analysis of the spectral emissions.

Three other gates (10 μs, 5 μs and 100 ns) were tested. Using the 100 ns gate, spectra presenting well defined spectral lines were captured. These lines are: 499,5 nm, 517,6 nm, 568,1 nm and 594,3 nm, as shown in figure 2.

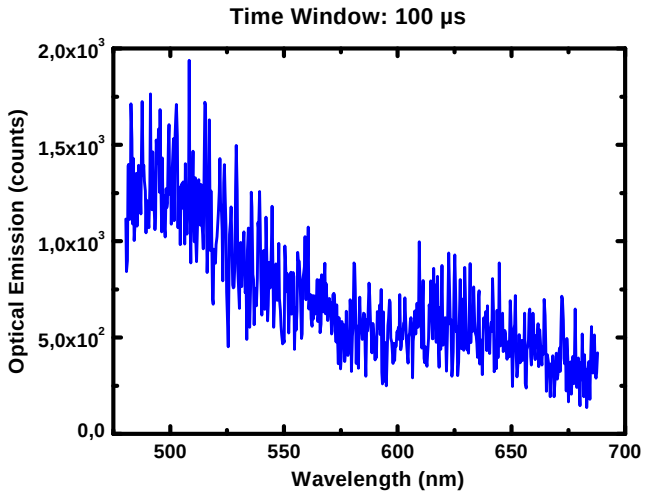

Figure 1: Captured spectrum for the 100 μs time window.

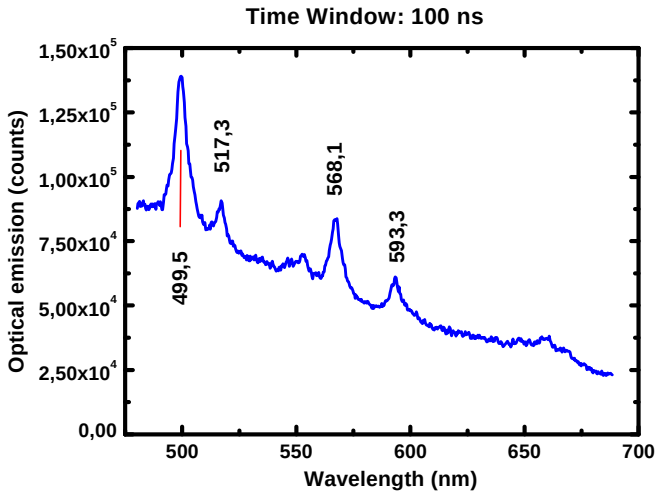

Figure 2: Captured spectrum for the 100 ns time window.

The spectra obtained for the 10 μs gate presents similar characteristics to those obtained for the 5 μs time window. However, a better definition of the spectral lines was observed for the acquisitions made using the smaller gate. In both cases well defined and narrow peaks can be observed (see figures 3 and 4). The best signal to noise rate was obtained for the 5 μs time window and more peaks could be identified for the spectra captured under this gate. These lines were identified as traces of magnesium, sodium and calcium.

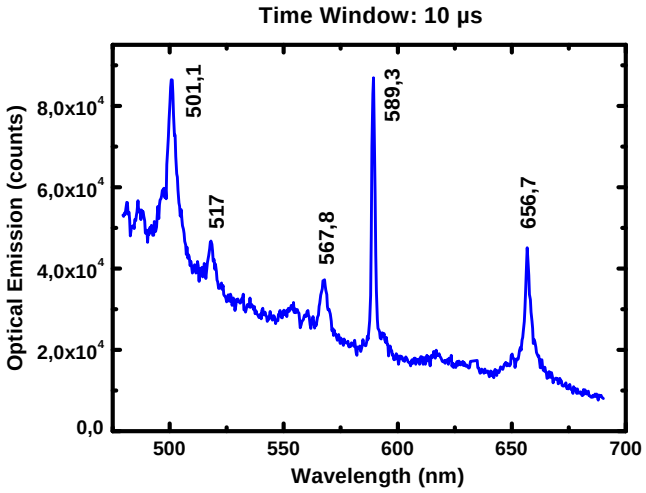

Figure 3: Captured spectrum for the 10 µs time window.

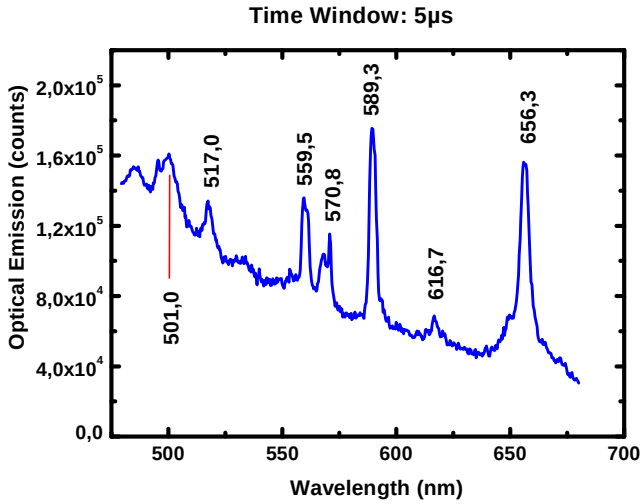

Figure 4: Captured spectrum for the 5 µs time window.

Conclusions

Laser-induced breakdown spectroscopy was performed on chicken myocardium tissue. The CCD gate width was adjusted electronically to four chosen time windows: 100 ns, 100 µs, 10 µs and 5 µs. Accumulated emission spectra were collected during the ablation process of the tissue.

The smaller the gate chosen the better the results obtained. While no defined peaks could be observed for the 100 µs time window, a great number of emission lines could be analyzed for the 5 µs gate. These identified emission lines are related to the following elements: sodium, hydrogen, calcium and magnesium.

Acknowledgements

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