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Laser desorption/ionization of carbon clusters

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Abstract

Results of mass spectrometric investigations of soot by using the laser desorption/ionization (LDI) method and time of flight (TOF) mass spectrometry are presented. Several liquid fuels (benzene, tetrahydrofuran, toluene, acetonitrile, acetone, isopropanol, ethanol) were used to produce soot samples. Each soot gives specific mass spectrum of carbon clusters C_n as well as their size. The best clustering process was observed for benzene soot with the cluster size $n \leqslant 31$. The benzene soot was applied in the detection of insulin by using the matrix-assisted laser desorption/ionization (MALDI) method.

Keywords: Carbon clusters; Laser desorption; Soot; Insulin; TOF spectrometer

1. Introduction

Since the discovery of buckminsterfullerene there has been much interest directed toward fullerenes and carbon clusters researches [1]. A large number of experimental and theoretical works have been devoted to understand the carbon clusters formation during many processes. Carbon materials such as hydrocarbons, graphite, glassy carbon, diamond, and fullerenes were used for these investigations. The earliest studies used flames, hydrocarbons flames usually, as sources of formation of carbon structures [2–4].

A flame is a very sophisticated system due to its chemical and physical processes. During these processes many different carbon species are formed: polydromatic hydrocarbons, fullerenes, nanotubes and soot particles. Soot (black carbon) is a randomly formed particulate carbon that contains a variety of organic components to make up a complex system. In the recent years carbon nanoparticles as well as soot formation has been studied in different flame types [5–8]. Many methods, especially mass spectrometric, were applied for these studies of flame ions and different types of analysers were used [9–13]. The study of carbon clusters by laser desorption/ionization (LDI) method is particularly interesting because their importance in many scientific fields, and their role in combustion, soot formation and matrix-assisted laser desorption/ionization (MALDI) processes [14–17].

In this work we present mass-spectrometric investigations of soot by using the LDI and MALDI methods and the time of flight (TOF) mass spectrometry. Several liquid fuels were used to produce soot samples.

2. Experimental and results

All chemicals (benzene, tetrahydrofuran, toluene, acetonitrile, acetone, isopropanol, ethanol, insulin) chosen for the investigations presented here were purchased from the Sigma Aldrich and used without further purification.

The preparation of soot samples was carried out in a simple burner constructed in house (Fig. 1). The round stainless-steel sample holder directly collected soot produced from the flame. After few minutes of combustion process a visible and apparently homogeneous soot layer of ~0.2 mm thickness appeared. Next, this sample holder was placed in the vacuum chamber of TOF spectrometer (Fig. 2). Ions were formed as a result of directing pulsed laser beam onto a sample holder.

An idea of the mass-spectrometric experiments is given in Fig. 2 and has been described in details previously

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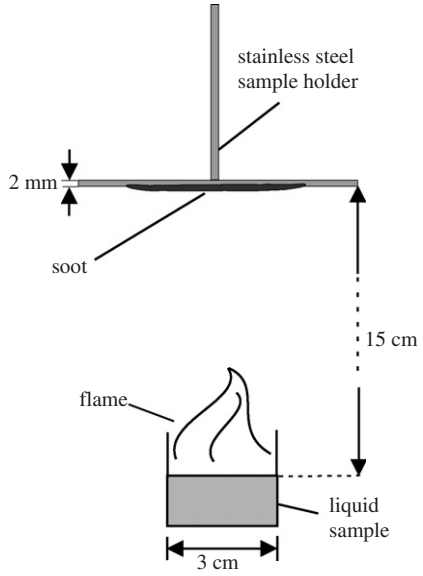

Fig. 1. The preparation of the soot sample.

[16,17]. All presented here mass spectra were collected as an average of 64 laser shots. The results of LDI investigations are presented in Figs. 3–5. The intensities of ion currents are in arbitrary units but the marked scale in these figures is the same, for better comparison of results.

Fig. 3 presents positive (a) and negative (b) ion mass spectra obtained for the benzene soot and several ion-accelerating voltages. For both cases we observed fragmentation of carbon cluster ions, higher for negative ones. Therefore, observation of cluster ions for accelerating voltage lower than 4 and 9 kV for C_n^+ and C_n^-, respectively, can be very difficult. The higher stability (longer time of live) of positive carbon cluster ions evidence also their higher size ($n \leqslant 31$) in comparison to negative ones ($n \leqslant 12$). We should note that benzene soot was the best, of the other investigated here soot probes, i.e., from the intensity of ion current point of view. Mass spectra of soot obtained from toluene, tetrahydrofuran and acetonitrile are presented in Figs. 4 and 5, respectively.

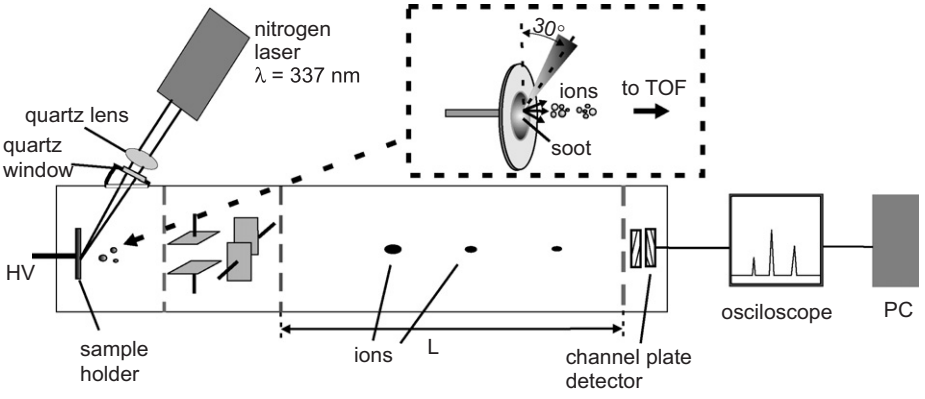

Fig. 2. The schematic diagram of linear time of flight mass spectrometer.

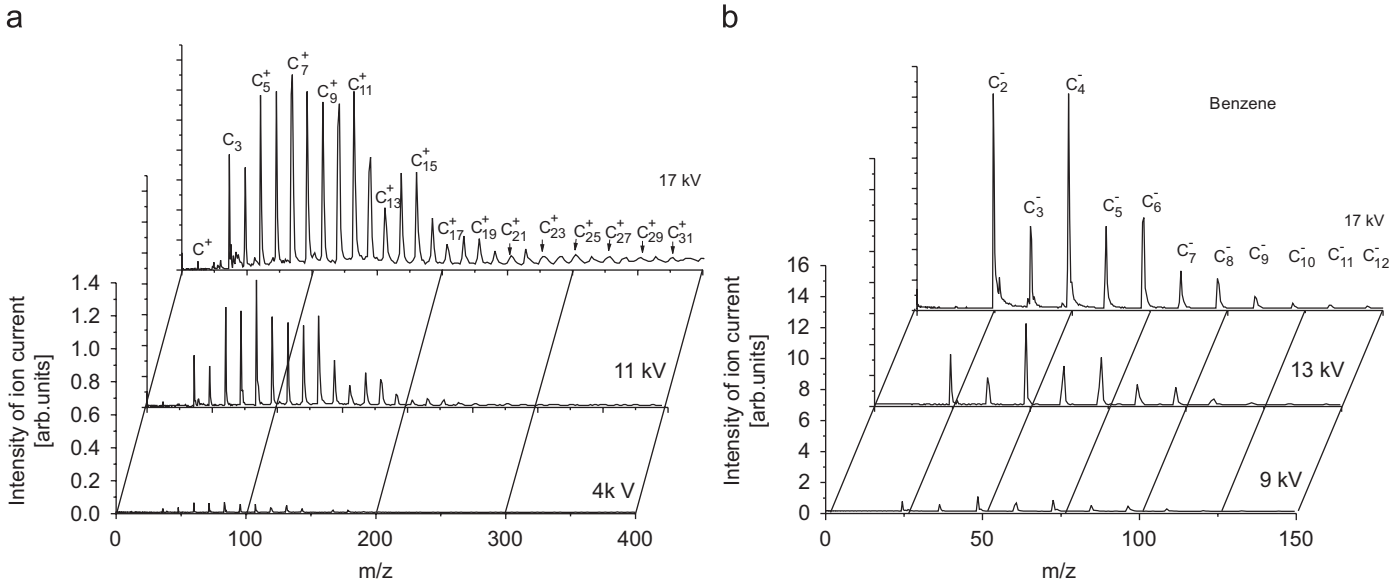

Fig. 3. LDI positive (a) and negative (b) ion mass spectra of the benzene soot for several accelerating voltages.