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Desorption corona beam ionisation (DCBI) mass spectrometry for in-situ analysis of adsorbed phenol in cigarette acetate fiber filter

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ABSTRACT

The study of spatial distribution characteristics of the adsorbed compounds for absorbent materials has significant importance in understanding the behaviors of aerosols while they migrating in the absorbent materials. Herein, for the first time, desorption corona beam ionization–mass spectrometry (DCBI–MS) has proposed for direct in-situ analysis of adsorbed aerosol for absorbent materials. DCBI is a novel atmospheric pressure chemical ionization (APCI)-related technique developed by our group in recent years. It can facilitate accurately localizing sampling by forming a visible thin corona beam and avoid the risk of sample contamination and matrix interference compared with other similar techniques. The advantages of DCBI–MS allow rapid screening of the spatial distribution characteristics of the adsorbed compounds for absorbent materials. The distribution characteristic of phenol in cigarette filter tip filled with cellulose acetate fiber was studied as a model case for demonstrating the feasibility of the developed method. As a comparison, conventional HPLC was also used for the study of the distribution characteristic of phenol. The results revealed DCBI–MS had highly improved assay simplicity in spatial distribution characteristic analysis of phenol for the acetate fiber tip, therefore, exhibiting a great potential for convenient, rapid and cost-efficient analysis of the spatial distribution characteristic investigation of adsorbed compounds for adsorbent materials.

1. Introduction

Aerosol adsorption and retention has widely applications in many fundamental industries including chemical, food, medicine and so on [1–3]. Especially, it is becoming a unique technology in solving environmental pollution recent years, and has attracted great interest in the development of various absorbent materials [4,5]. Beyond developing novel absorbent materials, the study of the distribution characteristics of the adsorbed compounds for the absorbent materials is also an important task in such research area [6,7].

Analysis of the adsorbed aerosol for an absorbent material has been carried out by diverse analytical techniques, such as UV absorption spectroscopy [8], infrared spectroscopy [9], and gas or high performance liquid chromatography–mass spectrometry (GC or HPLC–MS) [10,11]. However, no matter using what kind of the techniques, most of them are requiring multiple-step pre-treatment and time-consuming separation. Moreover, it is hard for almost all the methods to get the spatial distribution information about the adsorbed compound for the adsorbent material [10–13]. Nevertheless, the spatial distribution characteristics of the adsorbed compounds may provide more useful information for understanding the behaviors of aerosols while they migrating in the absorbent materials. In the context, the development of convenient techniques with desirable operational attributes for rapid spatial distribution analysis of the adsorbed compounds should be a topic of intensive interest for the study of adsorbent materials.

In the last decade, ambient ionization–mass spectrometry (API–MS) techniques, including desorption electrospray ionization (DESI) [14], electrospray laser desorption/ionization (ELDI) [15], direct analysis in real time (DART) [16], dielectric discharge barrier ionization (DBDI) [17], atmosphere solid analysis probe (ASAP) [18], plasma assisted laser desorption ionization mass spectrometry (PALDI) [19] and so forth, have attracted considerable

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attention in different fields of biomedicine, food security, anti-terrorism, environmental emergencies and forensic analysis due to their unique sample desorption/ionization and injection mechanisms [20–25]. The greatest advantage of them is little or no need for sample pre-treatment even in complex matrix. For example, Jana Hajslova and coworkers used DART ionization coupled to high resolution mass spectrometry to analyze multiple mycotoxins in wheat and maize [26]. Katerina Riddellova and coworkers reported an approach, coupling DART to a medium high-resolution/accurate mass time-of-flight mass spectrometer (TOFMS), for rapid examination of the fish muscle extracts [27]. A novel desorption corona beam ionization (DCBI) technique for direct analysis of samples from surface in mass spectrometry under ambient condition was reported [28,29]. Compared with the current ionization and sampling methods, such DCBI–MS can form a visible thin corona beam for sampling by using a hollow needle/ring electrode, which greatly facilitates localizing sampling areas and performing imaging/profiling experiments. To be an atmospheric pressure chemical ionization (APCI)-related technique, it is also no need for spray solutions, thus overcoming some common drawbacks of electrospray ionization (ESI)-related ones, such as sample contamination and matrix interference. DCBI is also capable of performing progressive temperature scans from room temperature to 450 °C during sample desorbing to achieve a rough separation of the individual components in complex matrices [28]. Successful applications of DCBI–MS have been made for a broad range of compounds, such as pesticides, illegal additives, drugs and explosive materials [30,31].

Considering the advantages of the DCBI–MS in direct in-situ analysis, herein we developed this technique for rapid screening of the spatial distribution characteristics of the adsorbed compounds for absorbent materials. To demonstrate the feasibility of the developed method, cigarette filter tip filled with cellulose acetate fiber [32] which was treated using a certain amount of tobacco smoke was studied as a model case. As far as we know, the retention distribution of the compounds in cigarette filter released during smoking is an issue that has never been reported. Among the thousands of compounds existing in tobacco smoke, we focused on the spatial distribution characteristic of phenol [33]. Besides DCBI–MS, conventional HPLC was also used as a comparison.

2. Experimental section

2.1. Materials and reagents

Ethyl alcohol and ethanoic acid were purchased from Fuyu Fine Chemical Co., Ltd. (Tianjin, China). Acetonitrile (Fisher, Hampton, NH, USA) was of HPLC grade. Standard (> 97%) of phenol was purchased from the National Institutes for the Control of Pharmaceutical and Biological Products (NICPBP, Beijing, China). Acetate fiber filter tips adsorbed certain amount of tobacco smoke were provided by China Tobacco Hunan Industrial Co., Ltd. All solutions were prepared and diluted using ultra-pure water produced by a Millipore Milli Q system.

2.2. Sample preparation

2.2.1. Sample preparation for DCBI–MS analysis

For in-situ analysis of the trapped phenol in acetate fiber tips using DCBI–MS, the tobacco smoke-treated acetate fiber tips (21 mm in length and 7.6 mm in diameter) were carefully cut into seven equal parts along an axial direction as illustrated in Fig. 1a by using a sharp blade. The resulted seven pieces were 3 mm in thickness and 7.6 mm in diameter, which were directly used for the investigation of the axial, radial and 2-dimensional (2D) distribution characteristic of phenol using DCBI–MS without any treatment.

2.2.2. Sample preparation for HPLC analysis

For comparison, the distribution characteristic of phenol for acetate fiber tip was also analyzed using HPLC. The tip was cut into seven pieces along an axial direction and the obtained pieces of the tip were used for investigating the axial distribution characteristic of phenol. For radial distribution investigation, limited by the shape and size, the acetate fiber tip was cut for two times along the radial direction as illustrated in Fig. 1b using a precision laser cutting machine (ILS-IIINM, Taiwan). Such a cutting mode

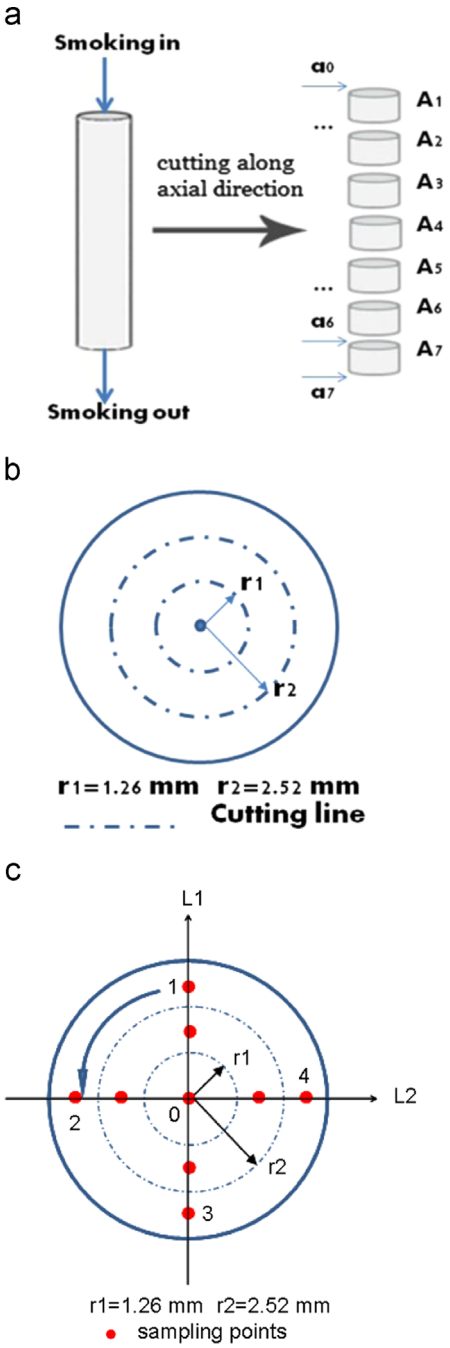

Fig. 1. Illustration of the cutting modes of the acetate fiber tip for the investigation of phenol distribution characteristics: (a) along axial direction; (b) along radial direction; (c) DCBI–MS sampling points on the surface of the acetate fiber tip piece.