



Surface modification of carbon fabric for isopropanol removal from gas stream



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ABSTRACT

The surface chemistry of carbon fabric (CF) was modified by both chemical and physical activation. The increasing oxygen concentration was estimated by using elemental analysis, and quantified by temperature programmed decomposition (TPD) in helium atmosphere. Modified carbon fabrics were used as adsorbents during the removal of a model volatile organic compounds (VOCs) isopropanol from gas streams. Typical results indicated that CF modified by air plasma has the best adsorption capacity, probably due to the formation of highest amount of acidic functional groups during the treatment.

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1. Introduction

Volatile organic compounds (VOCs) are known to have adverse health effects on living organisms. The source of VOC emissions may be man-made activities like petroleum refineries, automobile, chemical/paint and electronic industries in the form of solvents for cleaning, etc. and motor vehicles etc. VOCs are known to pollute both outdoor and indoor air [1–3]. Moreover, once emitted into the atmosphere, VOCs may stay in the atmosphere for a long duration and their presence in the atmosphere may also cause photochemical smog, secondary aerosol and depletion of ozone [2].

Isopropanol (IPA) is a commonly used solvent used in electronic industry for cleaning. The recommend exposure limit to IPA is 400 ppm (US Occupational Safety and Health Administration) and it is known that higher concentration can cause health problems like irritation of eyes, drowsiness, and dizziness; hence, its abatement is warranted [3,4]. IPA from industrial effluent can be recovered by absorption into water by using wet scrubbers followed by distillation [4]. Various emission control technologies like catalytic oxidation, bio-filtration, and plasma mineralization have limited applicability and some of them may not be efficient for dilute mixtures [5–7]. As a consequence, the best practiced solution for indoor VOC removal is adsorption [8–10].

However, the physical properties of adsorbate play a major role in the adsorption process carbon based materials like activated

carbon; CNT, CNF, etc. are well documented for the removal of heavy metals, dyes, organics, etc. from water [10–15]. Activated carbon, CNT and CNF have also been proved to possess potential application in air pollution control. Compared to the activated carbon powder, CNT and CNF, use of carbon fabric (CF) is easier [16]. Activated carbon cloths have great importance because they offer comparative advantages over the powdered or granular forms. CF is well-known adsorbent, providing potential uses for technological innovations in several fields. Besides, CFs are light materials that can be staged in different stable shapes and furnish a contiguous carbon form suited for several applications. Due to this, CF has larger SSA and a porous structure. For environmental applications in comparison with other forms of carbon, CF including huge adsorption volume, pore diffusion, and heat-resistance. It also demonstrates great ability in the sorption of bacteria. CF not only adsorbs for high concentration pollutants but also it will work for low concentrations [16,17]. In this context, for a better use of CF, suitable activation that increases surface functional groups is very much warranted [11]. During the present study, it is proposed is to modify CF for separating IPA from indoor air.

Plasma based activation is an interesting alternatives to conventional physico-chemical activation for carbon based materials [11,18–20]. Plasmas are largely employed for the modification of surface properties of materials [18,21–23]. During the plasma treatment different active species may form, if the feeding gas is zero air or oxygen UV radiation, shock waves, ions (H^+ , H_3O^+ , O^+ , H^- , O^- , OH^- , O_2^-), molecular species (H_2 , O_3 , H_2O_2), most importantly reactive radicals (such as O, H, OH) and electrons

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[24–26] may interact with the surface of materials. Plasma activation is usually a combination of an etching and a grafting process that is intended to modify or improve surface properties, enhancement of electric field or electron energy in plasmas play an important role [27–31]. The objectives of this study surface activation of CF followed characterization of CF and estimation of adsorption capacity during the removal of 500 ppm of IPA from air stream.

2. Materials and methods

2.1. Chemical activation

For this study PAN-based CF supplied by the Ram composite materials, Hyderabad-India was used. The CF sample was taken into a 250 ml beaker and addition of 50:50 (v/v%) of 69% HNO_3 then the samples were kept on a magnetic stirrer with hot plate to maintain at 70 °C. Afterwards, CF was cleaned with deionized water, dried at 373 K for 4 h in an oven and named as a N-CF.

2.2. Air plasma activation

2.2.1. Plasma reactor

Air plasma treatment of CF was done in a nonthermal plasma dielectric barrier discharge (NTP-DBD) reactor. A schematic representation of the experimental setup is given in Fig. 1a. The AC voltage is applied by a high-voltage 0–40 kV AC source transformer (Jayanthi transformers) with a fixed frequency of 50 kHz. The reactor is a transparent quartz cylinder with an inner diameter of 20 mm coated with silver paste acting as grounded electrode. The high voltage electrode is made up with stainless steel, with 13 mm thickness. The length of the discharge is 20 cm and the discharge gap is fixed at 3.5 mm. Both the current and the voltage wave forms were obtained by using an oscilloscope (Tektronix TDS 2014B, 100 MHz, 1.0 GS/s) and a high voltage probe (Agilent

34136A HV 1/1000). A voltage – charge ($V-Q$) Lissajous figure at 18 kV (corresponding power 2.03 W) is shown in Fig. 1b. The gas flow was controlled by a mass flow controller (AALBORG, GFC-17) system it was kept constant at 300 ml/min. 1 g of CF was treated with plasma up to 3 h to create a surface functional groups.

2.3. Characterization

BET surface area was calculated by N_2 adsorption isotherms at 77 K on Quantachrome Nova 2200e physisorption apparatus. Prior to N_2 adsorption, samples were degassed at 573 K for 5 h. Temperature programmed decomposition (TPD) was carried out in a fully automated Quantachrome gas sorption analyzer equipped with a thermal conductivity detector. Oxygen functional formed during the decomposition were quantified in helium atmosphere (50 mL min^{-1} , ramp 10 K min^{-1}) in the temperature range 300–1173 K [11,12]. Before the TPD runs, the reactor was purged with He for 30 min. In a typical TPD run, 0.1 g of the catalyst was placed in a quartz plug-flow reactor and the decomposition products were analyzed by a mass spectrometer (RGA PRISMA PLUS 200 AMU) calibrated with gas mixtures of known compositions. The intensity of the following peaks with m/e 2, 4, 15, 18, 28, 30, 32, and 44 was monitored simultaneously. Elemental analyzer (Euro Vector EA) was used to determination of the composition of C, H, N, S and O in the samples.

2.4. Adsorption experiments

Adsorption capacity of the CF, P-CF and N-CFs was examined for the removal of isopropanol (IPA) from gas streams. For batch sorption studies 1 g of CF samples were placed in a quartz column with an inner diameter of 19 mm, was filled with a CF which were totally packed. Zero air from the laboratory air flowed through

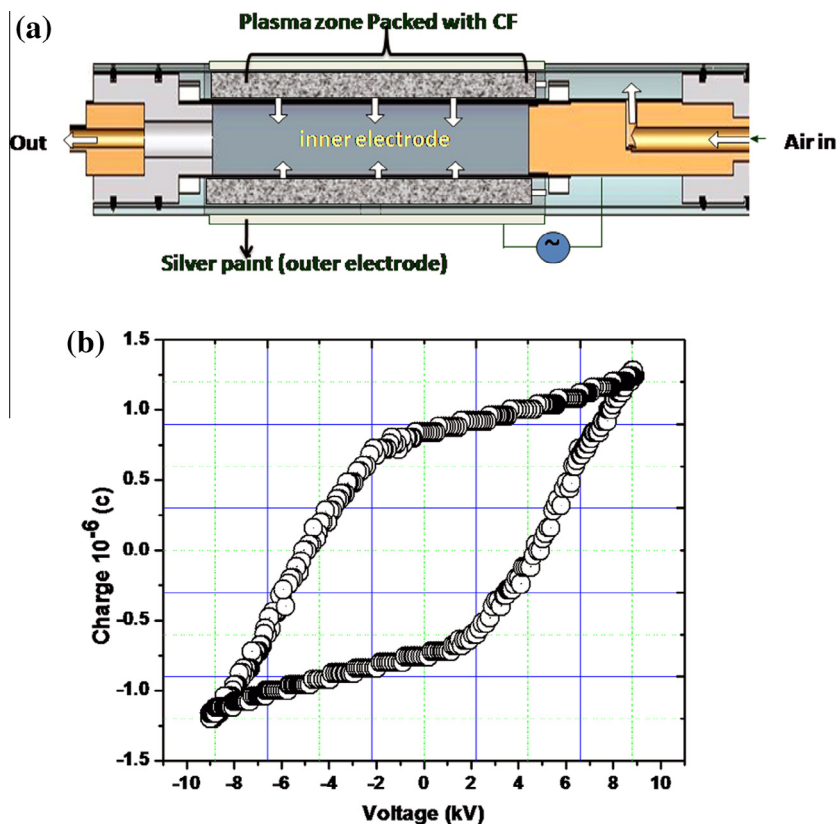


Fig. 1. (a) Nonthermal plasma setup for CF modification, (b) $V-Q$ Lissajous figure at 50 Hz and 18 kV applied voltage.

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