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Carbon-mineral adsorbents with a diatomaceous earth/perlite matrix modified by carbon deposits

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ABSTRACT

Carbon-mineral adsorbents (CMA) were prepared using complex diatomaceous earth/perlite adsorbent spent in purification of apple juice and carbonized with addition of starch or glucose to enhance the content of carbon deposits and to develop the porosity of the CMA. The specific surface area of the carbon deposits was 500–640 m^2/g at the pore volume V_p = 0.28–0.35 cm^3/g depending on the type of an additive and the amounts of grafted carbon. Carbon deposits in CMA represent nanoparticles (nanodeposits) totally covering a surface of the mineral matrix. Thermal stability of these nanoparticles is lower than that of larger microparticles of activated carbon (AC) or carbon black. Contribution of aromatic structures with C atoms with the sp^2 hybridization is larger in CMA than AC but smaller than in graphitized carbon black.

1. Introduction

Interest to applications of such low-cost natural minerals as diatomite, perlite, clays, *etc.* in adsorption technologies increases during last decades [1–5]. Diatomite (diatomaceous earth consists primarily of the fossilized skeletons of diatoms, which were once marine planktons and algae) is durable, lightweight, porous material at specific surface area S_{BET} = 50–200 m^2/g [1] with a permeable structure, chemical resistance, and good adsorptive properties [6–10]. Different components at a surface of diatomite particles have both isolated and H bonded hydroxyls [2]. These groups are the main adsorption and reaction surface sites. As a result of unique physical and chemical properties, diatomaceous earth is used in industrial applications as filtration media for various beverages [3]. It is applied for filtration of sugar syrup, beer, whiskey, wine, fruit juice, water, mineral or vegetable oils and pharmaceuticals [10–13].

Perlite is an amorphous volcanic glass characterized by relatively high water content, typically formed by the hydration of obsidian [14]. Perlite is an excellent filter aid and used extensively as an alternative to diatomaceous earth. Commercial applications of perlite are due to its low density and low price. In the construction and manufacturing fields, it is used in lightweight plasters and mortars, insulation and ceiling tiles. Additionally, it can be used in complex adsorbents included diatomaceous earth and other components. A 50/50 mixture of perlite and diatomaceous earth was used as the initial material in the present work.

Pyrolysis (carbonization) processes can be used to utilize certain industrial and municipal waste organic or organic-mineral materials [15–25]. Carbon adsorbents can be prepared from waste fruit stones and other lignocellulosic materials [17,18], tires [19–21], domestic waste, packing paper [20,21], *etc.* [15]. The waste adsorbents, containing some organic substances deposited during their long-term work, are of particular interest both to utilize chemical and food industry wastes and to produce carbon–mineral adsorbents (CMA) [22–26]. The food industry can provide many waste materials suitable for production of CMA [16,27–29]. These CMA can be used for removal of heavy metal ions and other toxic compounds from water [16,29], for purification of underground water from the petroleum derivatives [30], *etc.*

A variety of mineral matrices is used to produce CMA [16,27–45]. The structural and adsorption characteristics of CMA were varied due changes in the matrix texture and chemical structure and the precursor type of carbon deposits. For instance, silica can be considered as an inert matrix that results in growth of carbon phase on first deposited carbon nuclei [31–33,43–45]. Growth of carbon deposits on zeolites, alumina, titania and other acid–base or redox catalysts occurs in other way than on silica. Thin films or small nanoparticles of carbons can be formed similar to those during catalyst poisoning in organic synthesis [46–49].

The problem of utilization of wastes can be considered in two aspects: removing of wastes harmful to the environment and utilization of surface deposited organics in the production of new

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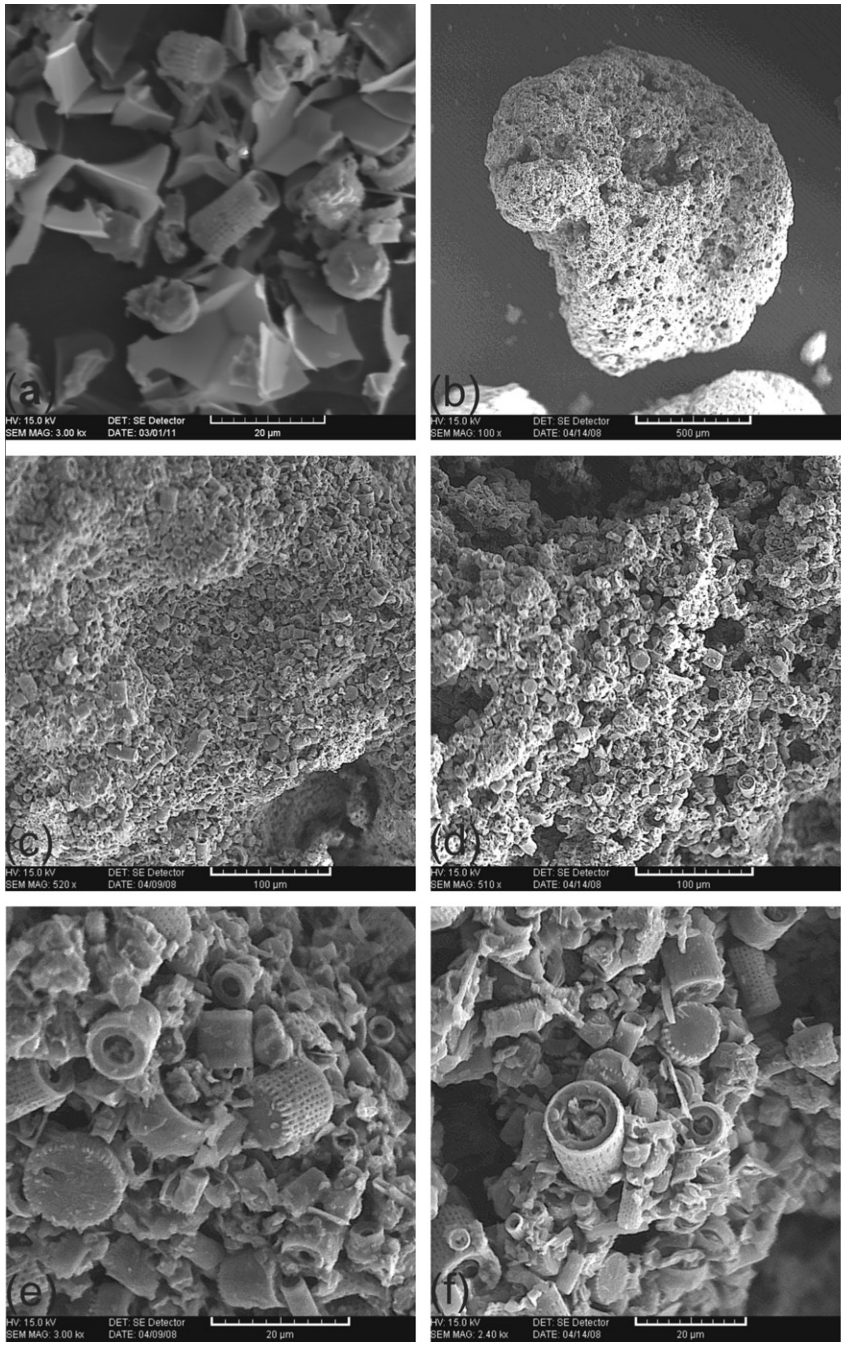

Fig. 1. SEM images of (a) MW0, (c and e) MG6 and (b, d and f) MS6 samples of different magnification (scale bars are (b) 500, (c and d) 100 and (a, e and f) 20 μm).

materials [45]. Therefore, the aim of this paper was to show the potential of CMA prepared from diatomaceous earth/perlite adsorbent spent in purification of apple juice with addition of starch or glucose to enhance the content of carbon deposits and to develop the texture appropriate for effective use of CMA in adsorption and filtration techniques.

The textural and adsorption characteristics are the main characteristics of any adsorbent [50,51]. Therefore, the main attention was paid here to these characteristics of a set of prepared hybrid materials. These materials have a complex spatial texture and chemical composition. Therefore, a complex model of pores as a mixture of slit-shaped and cylindrical pores and voids between spherical particles (SCV model) with self-consistent regularization (SCR) procedure [52] was used. The SCV/SCR procedure allows to estimate contributions of different pore types with different materials (carbons, silica, titania, *etc.*) to the total porosity and the specific surface area. Additional information on morphological, structural, and adsorption characteristics was obtained using SEM, Raman spectroscopy, thermal analysis, and methylene blue adsorption.

2. Experimental

2.1. Materials

Powdery diatomaceous earth/perlite adsorbent spent in purification of apple juice (fruit and vegetable processing plant