Nanostructuring of anthracite by high-temperature steam activation

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Introduction

Activated carbons are used in many technical processes, such as the purification of water and pharmaceutical products, the removal of volatile organic components, colorants and aroma from effluents [1, 2]. They are also used as carriers for catalysts [3]. Anthracites are very suitable precursors for activated carbon preparation, since they are high-rank coals (high C to H atomic ratio even without carbonization) and show a high volume of very fine micropores [4, 5]. However, the above-mentioned processes often require precisely nano-sized pores for the adsorption or conversion of large-sized molecules (colorants, biomass, etc.). Conventional carbon activation methodologies are divided in too physical using steam or CO_2, and chemical using KOH, $ZnCl_2$, and H_3PO_4, which are the most reported oxidizing agents [6]. Disadvantages of chemical activation: reagents came with a price, the activation process is more corrosive than physical activation, reagents can be hazardous to the environment, and also a time-consuming washing step is needed to remove chemical residues [6, 7]. At the same time, physical activation to obtain nanoporous materials from anthracites is poorly studied [8, 9].

In this work, the influence of the activation duration by high-temperature steam treatment (900 °C) of anthracite (**A**) on its structury, thermal stability, and other technological properties was studied.

Experimental methods

Isotherms of low-temperature (T = 77 K) nitrogen ad(de)sorption were measured on a Quantachrome® NOVA-1200e automatic sorbtometer after in situ evacuation at 473 K for 6 h. The NovaWin 11.04 software was used to calculate the parameters of a porous structure (*Figure 1-2, Table 1*).

The thermal stability of anthracite samples were characterized by heating in air (10 K/min) on a Linseis PT1400 derivatograph (*Figure 3*).

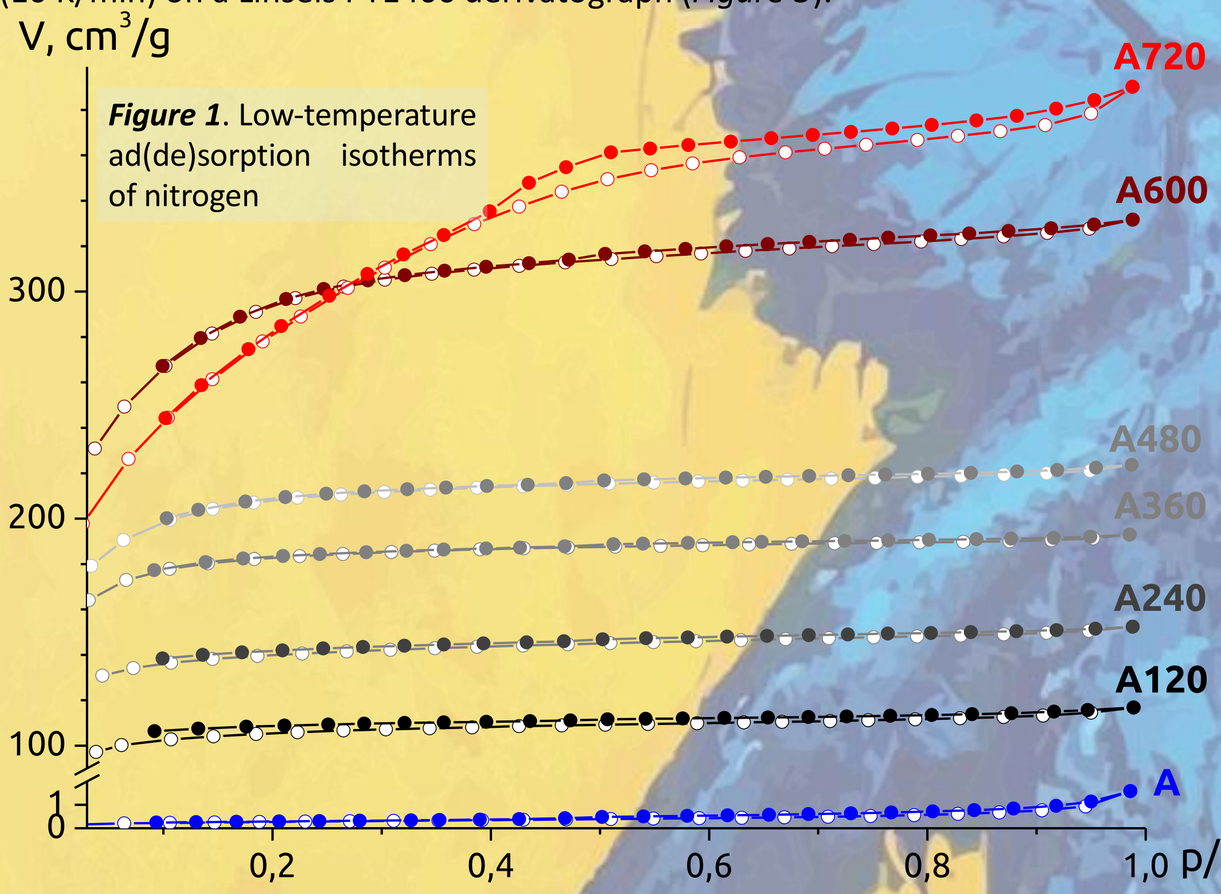
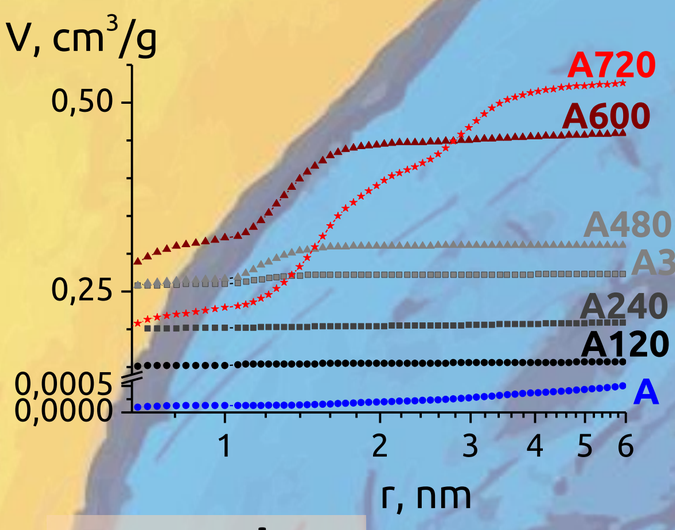


Figure 1. Low-temperature ad(de)sorption isotherms of nitrogen



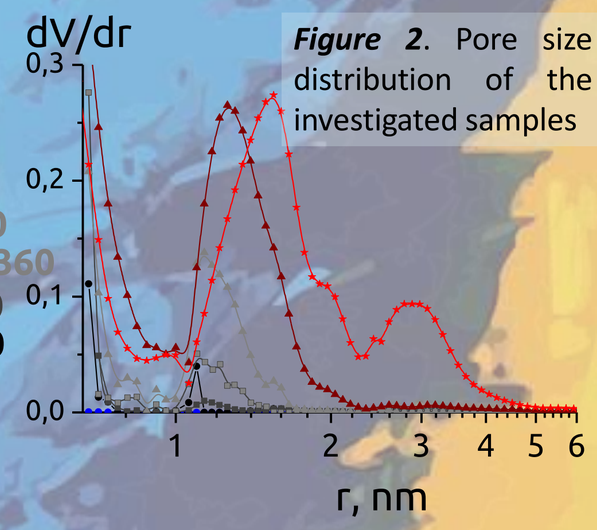


Figure 2. Pore size distribution of the investigated samples

Results

In the process of activation, a gradual decrease in the bulk density of the samples was observed, while the resistance to abrasion began to decrease only after 600 minutes of activation. Contrarily the treatment leads to a gradual increase in the average pore radius and the BET specific surface area in anthracite. This is accompanied by an increase in the proportion of micropores up too 480 minutes of activation, after which it decreases. The DFT pore size distribution shows the development of mesoporosity in anthracite during the activation process.

The thermogravimetric (TG) and differential thermogravimetric analysis (DTA) curves showed that rapid mass loss begins at about 723 K and ends near 973 K for all samples. The mass loss is accompanied by an exothermic effect of combustion on the curves of high-temperature differential scanning calorimetry (HDSC). This indicates that the heat resistance of the anthracite samples after high-temperature steam treatment remains near the level of the original anthracite.

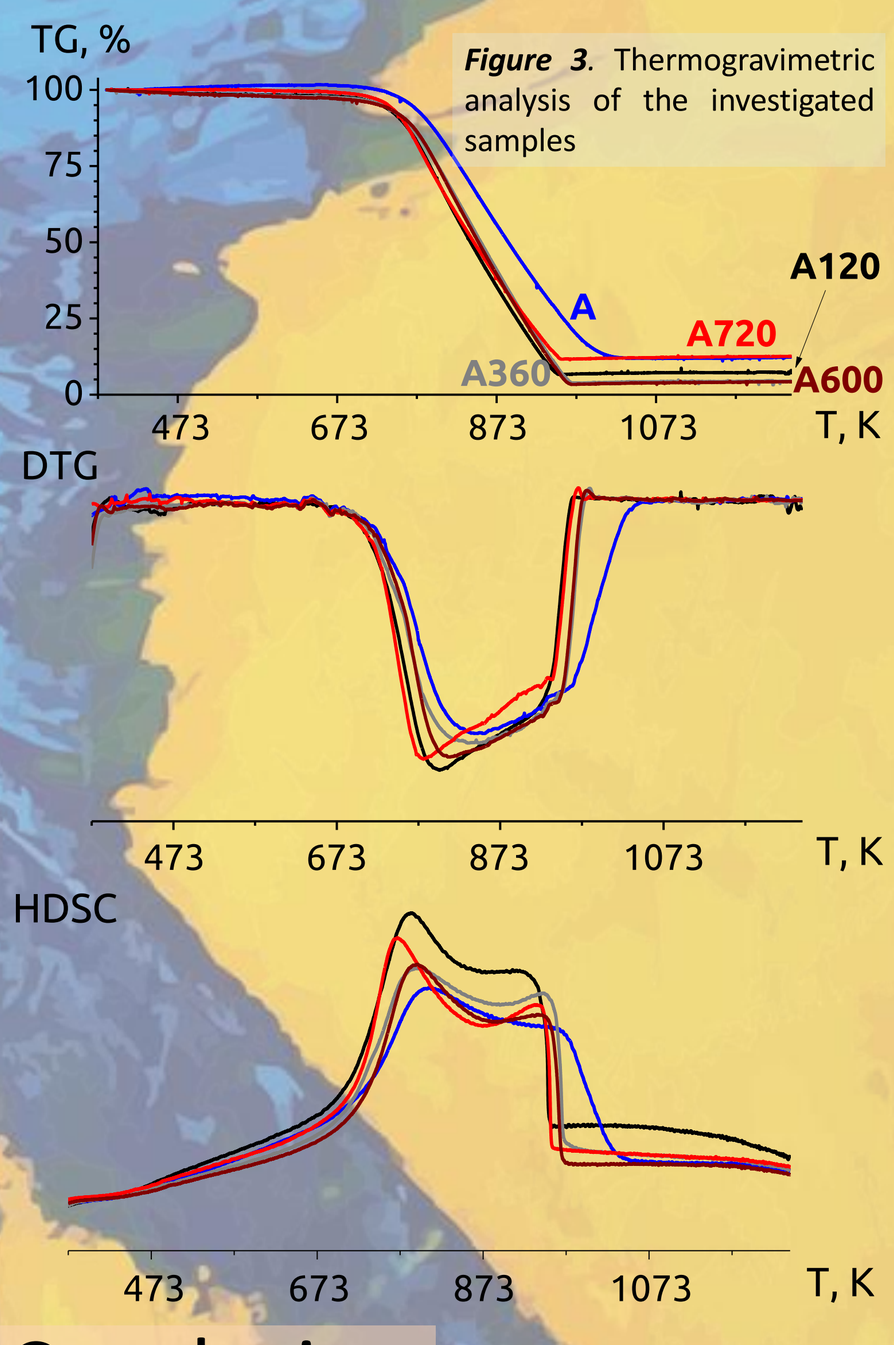


Figure 3. Thermogravimetric analysis of the investigated samples

Table 1. Technological properties and parameters of a porous structure of the samples studied

Sample*	Bulk density, g/cm³	Abrasion resistance, %	S^{BET}, m²/g	S^{t}, m²/g	S^{t}_{micro}, m²/g	V^{t}_{micro}, cm³/g	V_{Σ}, cm³/g	V_{micro}/V_{Σ}, %	R, nm	Adsorption capacity for benzene, cm³/g
A	-	-	1,0	0,8	0,1	0,0	0,002	0	5,0	-
A120	0,9	90	413	9,0	404	0,16	0,18	90	0,9	0,2
A240	0,8	90	522	10	512	0,22	0,24	93	0,9	0,2
A360	0,8	90	692	10	683	0,28	0,30	95	0,9	0,3
A480	0,7	90	786	11	775	0,33	0,35	95	0,9	0,3
A600	0,6	90	987	32	956	0,47	0,51	91	1,0	0,4
A720	0,4	80	998	83	915	0,49	0,60	81	1,2	0,5

*A number indicates the duration time of activation in min

Conclusion

In this way, the possibility of structuring anthracite by high-temperature steam treatment, which does not require chemical agents and is environmentally friendly, has been shown. Micro-mesoporous carbon material with a significant proportion of nanopores obtained by this method retains the high thermal stability.

Acknowledgments

Glory to Ukraine!

Glory to the Heroes of Ukraine!

References

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