Application of atmospheric microwave nitrogen plasma torch for carbon treatment

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Abstract
We present the first tests of carbon benefication done by heating the carbon samples by a microwave (MW) plasma generated by Litmas Red MW torch (2.45 GHz, 3 kW) in nitrogen at atmospheric pressure. The diagnostics of carbon samples was performed by SEM equipped with WDX element analyzer and FTIR spectroscopy. The plasma heat treatment causes a mass loss, a composition change and a structure change of the carbon waste.

Introduction
Atmospheric pressure MW plasmas present considerable interest for a wide range of applications, such as air pollution control, surface treatment, or carbon nanotube growth [1].
We use Litmas Red MW torch (2.45 GHz, 3 kW), which is able to generate plasma in a state close to Local Thermodynamic Equilibrium (LTE) in temperature range of 1000-5000 K at atmospheric pressure in various gases. In our previous works [2] we investigated the basic characteristics of atmospheric MW nitrogen plasma torch. Here we present the first tests of its application for thermal treatment of carbon waste. The treated carbon is a product of pyrolysis of used tyres. Its benefication is needed to get rid of the volatile components causing its bad smell, and to make it reusable for other processes, e.g. it could be used as a colouring agent for plastic materials; adsorbent.

Experimental setup
Atmospheric pressure MW plasma is generated by a Litmas Red plasma torch (2.45 GHz, 3 kW) in N_2. Experimental setup and the basic torch characteristics are described in more detail in [2]. The original carbon sample was placed on a stainless steel plate in the plasma flame about 1 cm above the nozzle (Fig. 1).

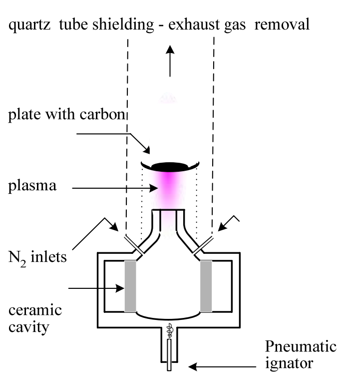

Figure 1. Treatment of carbon samples.

Approximate temperature of the plate, measured by a pyrometer, was 1500 K. The system was closed and exhausted because of possibly dangerous gases being emitted from polluted carbon samples. The carbon samples were heated for 5 or 10 minutes in nitrogen plasma of 13 l/min flow rate and 1.4 kW generator power. After plasma being switched off, the sample was cooled at a low N_2 flow 2 l/min to avoid oxidation. The diagnostics of carbon samples was performed directly by a scanning electron microscope (SEM) Tescan TS5136MM equipped with wavelength dispersive X-ray (WDX) INCA Wave analyzer, and on KBr pellets analyzed by Fourier-transform infrared (FTIR) spectrometer Perkin Elmer Spectrum BX. KBr powder to the sample ratio was 1:100.

Results and discussion

After plasma heating of the carbon samples, we first observed that the sample did not smell anymore and its mass decreased (by 27% for 5 min and 48% for 10 min heating). We assume that some volatile substances, most likely aliphatic and aromatic hydrocarbons and their –OH and ether derivates were released from the carbon, which was confirmed by FTIR spectra (Fig. 2). An apparent reduction of CH_2, C-O-C, -OH, and aromatic C-H functional groups was observed. On the other hand, new compounds were created. We assume them to be metal oxides of trace elements found by WDX analysis. Detailed interpretation of the measured FTIR spectra requires further investigation.

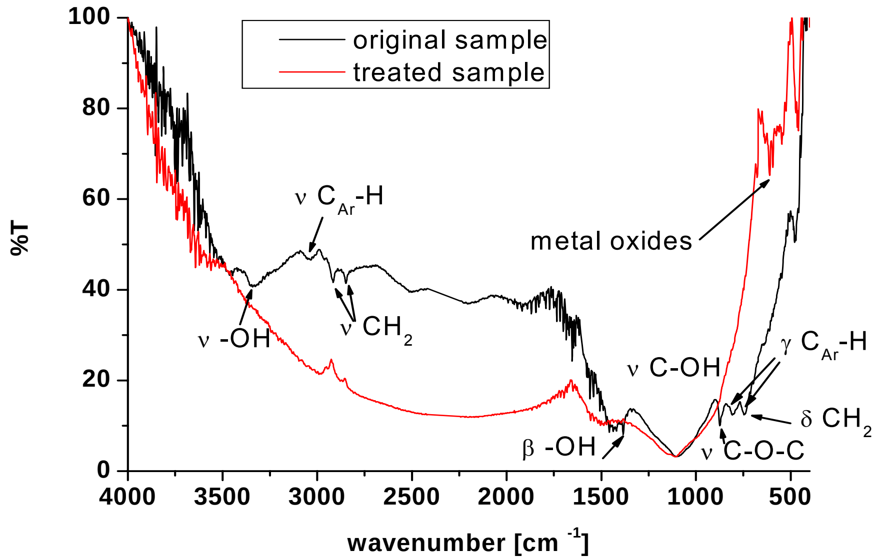

Figure 2. FTIR spectra of carbon samples.

WDX analysis of all samples demonstrated C as a dominant element. Trace amounts of S, Ca and Zn were found in the original carbon sample and decreased after the heating, but new elements, such as Fe, Al, Si, K, Mg were found. We assume that some of these metals were released from the stainless steel plate during the heating (Fe, Si). Cu is from the supporting tape used during SEM analysis (Fig. 3).

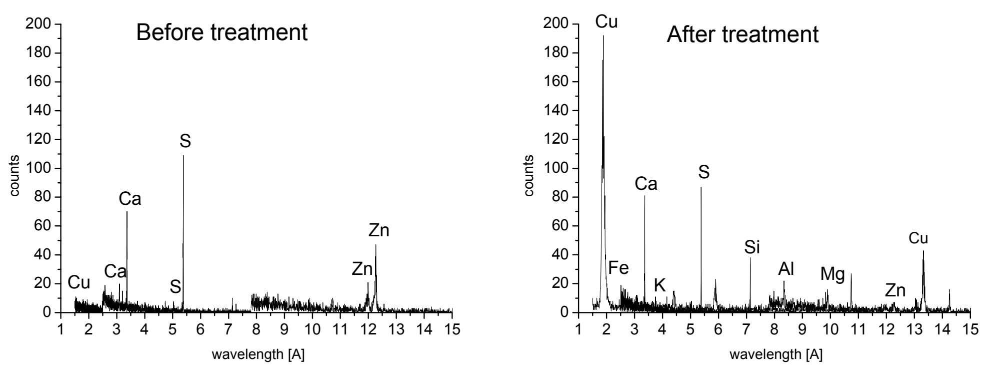

Figure 3. WDX analysis of carbon samples.

Despite the conductivity of the carbon samples being weak, it was good enough for SEM analysis at low magnifications. Microscopic pictures showed that the carbon has an amorphous structure with pores (Fig. 4a). Pictures of the treated samples revealed the steps-like shaped cleaving area (Fig. 4c), which compared to the smooth shape in the original sample (Fig. 4b) shows that material became more compact. Other SEM pictures of the treated carbon are shown in Fig. 4d-e.

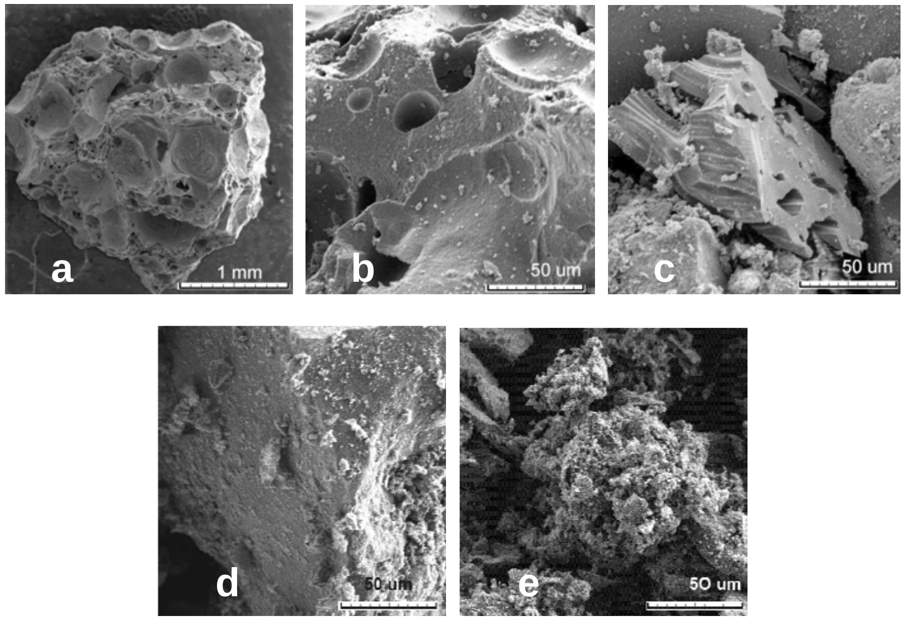

Figure 4. SEM pictures of carbon samples.

Summary and perspectives

Atmospheric pressure nitrogen microwave plasma was used as a heat source for used tyre carbon benefication. The plasma heat treatment causes a mass loss, a composition change and a structure change of the carbon. We are currently adapting the microwave torch system so that the carbon powder could be inserted directly into the plasma chamber, which will provide a higher temperature compared to when the sample is heated on the supporting metal plate. The new setup will turn the plasma chamber upside down to enable the collection of the treated carbon powder. Because of the presence of pores we also plan further investigations of the treated carbon, such as measuring its adsorption capacity. This could be interesting for its potential use as an active carbon.

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