Effect of CO$_2$ on the characteristics of soot derived from coal rapid pyrolysis

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Coal particles experience rapid pyrolysis in CO$_2$-rich atmospheres during oxy-fuel combustion, knowledge about soot formation in the CO$_2$-rich atmosphere is required to identify the possible chemical effect of high CO$_2$ levels on the soot characteristics. The present work aims to investigate the effects of a CO$_2$-rich atmosphere on the characteristics of coal-derived soot. The rapid pyrolysis of Shenfu bituminous coal was conducted in a Drop tube furnace (DTF) in N$_2$ and CO$_2$ atmospheres with a wall temperature of 1073-1473K and residence time below 700 ms. A series of techniques (elemental analysis, HRTEM, Raman, XRD, FT-IR and thermogravimetry techniques) were used to analyze the yields and microstructure characteristics of N$_2$-soot and CO$_2$-soot.

The soot formation was a rapid process and favoured T>1273 K. CO$_2$ enhanced the soot formation and proceeded the dehydrogenation. The sooting tendency increased in the CO$_2$ atmosphere compared to that in the N$_2$ atmosphere. The increased residence time and temperature caused the continually increased C/H and C/O atomic ratios. The higher C/H atomic ratios of CO$_2$-soot indicate the enhanced dehydrogenation in CO$_2$ atmosphere.

By analysing the Raman and XRD spectrum results, some remarkable differences of the carbon microstructures for CO$_2$-soot in comparison with N$_2$-soot were found: CO$_2$ improves the order of the internal carbon lattices, enhances the lateral extension of carbon nanostructures, decreases the interplanar spacing of the graphene layers and promotes the stack of polyaromatic layers. The variations of the SOLO, DUO, TRIO and QUARTO structures were also analysed, and the contribution of CO$_2$ was found to reduce the defects of the basic structure units (BSU).

The CO$_2$ atmosphere can promote the polymerization of tar and enhance the graphitization of soot. The CO$_2$-soot is more mature than the N$_2$-soot, and the gasification reactivity of CO$_2$-soot is relatively lower. The defects of soot are important indications of the initial gasification reactivity because there is an approximately linear correlation between $r_0$ and the area of the FT-IR peaks in the range of 925-700 cm$^{-1}$. 