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Laser-Induced Hydrogen Generation from Coal Powder in Water and its Time-Resolved Pump Probe Investigation.
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We have proposed to produce hydrogen from different ranks of coal using nanosecond pulsed laser irradiation at different laser energy densities, wavelengths and irradiation times. Our project presented a simple way of obtaining hydrogen gas in a single step. Different ranks of coal, namely anthracite, bituminous, lignite, and coke were used. We have successfully generated hydrogen from different ranks of coal, coke and graphite with and without the water. Samples were irradiated with 1064 and 532 nm laser pulses. Each of these coal and coke rocks were pulverized for 15 minutes by using a Ring and Puck coal pulverizer. The particle size distribution for each rank was investigated by Scanning Electron Microscopy (SEM) (JEOL 6510LV). The distribution shows that the particles have mean diameters between 1-5 µm, which is much smaller than the porous structure of coal [16]. Each of the gas generation experiments was performed under an air atmosphere unless otherwise stated. Additionally, pure carbon (graphite), with or without water, was also analyzed in an argon atmosphere. Component analysis of the SEM Electron Diffraction Spectrum (EDS) (JEOL 6510LV) was performed at the secondary electron imaging (SEI) mode at 15 kV. FTIR analysis was performed to understand the bond structure of the coal samples. The proximate analysis of the coke and coal samples were conducted by the Thermogravimetric analyzer (TGA701, Leco) using method D5142 with accordance to ASTM. Energy analysis of coal and coke powders were analyzed by the calorimeter. Then the water-coal mixture was irradiated with an unfocused beam (6 mm in diameter) of 5 ns laser pulses from a Q-Switched Nd: YAG laser (Continuum Surelite SL II-10) at 10 Hz frequency for 45 minutes, with magnetic stirring (Sci-Basics, MHS-800) 1500 rpm. The laser energy density was adjusted in the range of 90-700 mJ/cm2. The mixture was irradiated with both 1064 and 532 nm laser pulses; a second harmonic crystal (Continuum SL SHG T-2) was used in order to obtain the 532 nm laser pulses. SEM EDS analysis showed that anthracite coal has the highest weight percentage of carbon while lignite has the lowest weight percentage of carbon since it is the lowest rank of coal with the lowest fixed carbon content. The generated gases after irradiating samples with 1064 and 532 nm wavelength laser pulses in the energies between 90-700 mJ/cm^2 were analyzed by gas chromatography. Hydrogen and carbon monoxide were the main products.

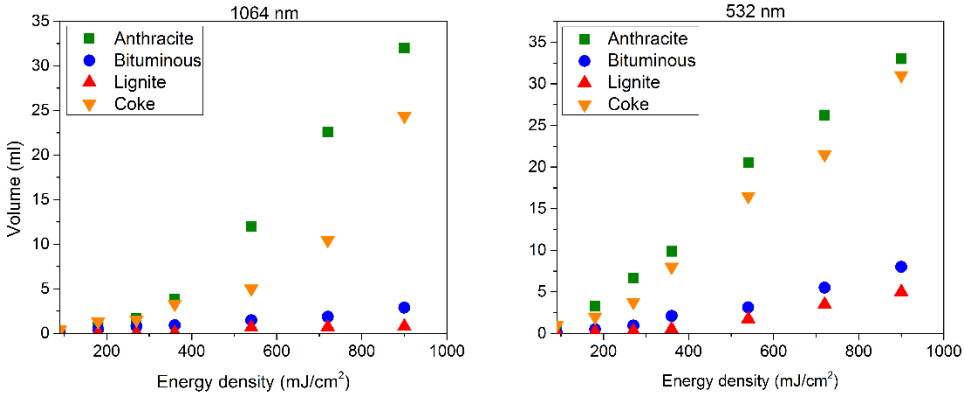

Figure: laser energy density dependence of gas generation from different ranks of coal using nanosecond laser pulses

Our results shows that gas generation increases exponentially with increasing laser power and the highest efficiency of hydrogen to carbon monoxide ration of 1.4 obtained from anthracite coal due to its high fixed carbon content and relatively high hydrocarbon amount. Possible reactions responsible for hydrogen generation were evaluated to understand the mechanism. To better understand the mechanisms of gas yield, various experiments under air and argon atmospheres in both the presence and absence of water were performed. Hydrogen was not generated after irradiating graphite powder without water due to lack of hydrocarbons in the structure. However, hydrogen was detected after irradiating graphite powder in water. Compared to conventional methods, hydrogen generation by laser irradiation was less efficient due to the lack of hydrogen purification system. Direct laser heating and pulse duration were also considered as an important parameter determining the gas generation mechanism. The temperature rise of water due to laser absorption was calculated. Our calculation shows that the temperature increase was around 27 °C. The water temperature was measured and a 25 °C increase was observed at the end of anthracite irradiation with 1064 nm for 45 minutes. We also studied the surface temperature evolution of the graphite sample in order to understand the laser irradiation process we solved the heat equation using standard finite method. Our results shows that heating of the

graphite sample occurs almost instantaneously, reaching the melting temperature of 4300 K or higher. However, it decreases to relatively low values almost within a couple of pulse durations.

ACS PRF grant has had a huge impact in my career and on my students. WKU excels at serving first-generation and low-income students. PI prioritize the involvement of underrepresented groups. I have history of involvement of undergraduate and graduate students in my research program. ACS PRF grant allowed to hire and work with many undergraduate students, some of whom are first generation college students in their family. All of the undergraduate students who worked on the projects were paid. All students learned to operate Class IV laser, SEM, TEM, and gas chromatography. Kentucky currently ranks 44th in the 2014 State New Economy Index (published by the Information Technology and Innovation Foundation), which is frequently used by the US Economic Development Administration (EDA) to gauge readiness for technology-driven economies. Also, Kentucky ranked 46th in terms of workforce educational attainment. These worryingly low ranks indicate that we must better prepare students for high-tech jobs in Kentucky. Considering the development of intellectual capital is a critical concern for Kentucky, training obtained by our student in this project will be very crucial in their future career. Most of my undergraduate students would like to continue their career in academia. Two of my graduate students worked in this project. One of them defended his thesis on hydrogen production and he has been admitted to North Carolina State University Physics PhD program while the other one was admitted to Purdue University Chemistry PhD program. We have had one publication in a highly reputable journal and my students presented their results at 8 different conferences. In addition, this project leads to collaboration with a faculty member at Oklahoma State University. He provided crucial simulation data to support our experimental results. This project gave us another idea about hydrogen generation. That led to a patent application.