Changes to the dielectric and mechanical properties of coal by ECBM-relevant fluids: Preliminary results and proposed experiments.

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Introduction

Injection of waste CO_2 fluid may be used to displace and produce adsorbed methane from coal seams whilst removing CO_2 from the Biosphere. Monitoring the progress of such displacement may require remote sensing by geophysical methods. In particular, by the use of electromagnetic (EM) methods such as Ground Penetrating Radar (GPR) and magneto-telluric soundings or direct resistivity measurements. Propagation of EM-waves and interpretation of GPR soundings are dependent upon dielectric properties of the coal/fluid system. Therefore, data on electrical conductivity and dielectric properties during the (ad/de)-sorption processes are required. The enhanced solvent properties of supercritical CO_2 are also expected to affect the organic content of coal and possibly alter its mechanical strength and transport properties. These two aspects form the basis of research by the HPT group at Utrecht University in collaboration with NITG-TNO, Netherlands. Preliminary experiments on the dielectric properties of powdered coal have been carried out under ambient conditions as a precursor to further experiments under ECBM production conditions. The role of humidity is found to be especially important due to the high dielectric constant of water (~80, c.f. ~1 for most other materials and gases). Apparatus is under development to extend these experiments to supercritical conditions and also to monitor compaction creep deformation with the presence of the same ECBM-relevant fluids.

Method

A cell has been constructed to measure the capacitance and resistance of powdered coal discs held between permeable stainless steel disc-electrodes and guard-ring to facilitate a flow-through of gas. The measurements are made with an impedance spectrometer (Solartron 1260A + 1296 dielectric interface) with a frequency range of 1mHz to 10MHz. Impedances of 10^1 to 10^{14} ohm may be determined. Capacitance changes of the order of 10^{-14}F may be resolved. The coal from the RECOPOL test site was powdered to 300μm and air-dried at 50°C before measurement at near ambient P/T conditions in the cell. A capacitance based humidity sensor, within the cell, was used to monitor the water content of the various gases (Ar, CH_4, CO_2 and air +/- water vapour) passed through the coal cell during testing.

Results

The effect of humidity is immediately apparent when moist air is used as the pore-filling gas. Figure 1, shows the increase in the real component of impedance (cell resistance, at the minima of double arcs) as the relative humidity is lowered from 52%, via 45% to 28%. At very high humidity, (~99%), the double arcs are replaced by a single arc with an impedance 2-3 orders lower (~10^4 ohm). The comparative effects of saturation by the ECBM-relevant gases, CH_4 and CO_2, are best seen when the system is dried to ≤ 8% RH. Figure 2 gives the typical impedance values at 1kHz for these gases and for Argon as an inert gas and there is a weak basis for separation of the data according to adsorbed gas species.

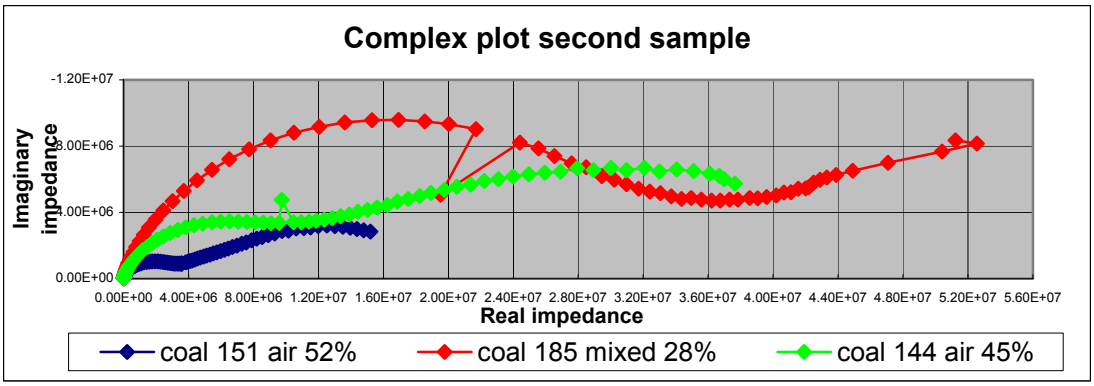

Figure 1: Nyquist impedance plots showing increasing impedance for coal in air with 52%, 45% and 28% RH respectively. Note the double arcs; minima indicate bulk cell resistance. The second arcs at lower frequency indicate an additional conduction process.

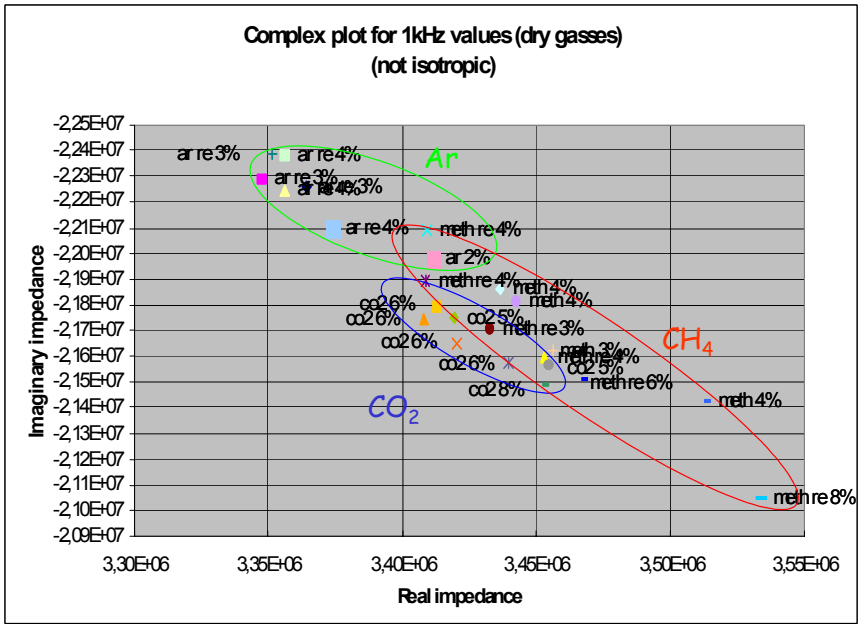

Figure 2: Compilation of 1kHz impedance data for dry coal (<8% RH) with CH_4, CO_2, and Ar. The data suggest a weak grouping (ellipses) according to adsorbed gas species.

Conclusions

Effects of humidity dominate the electrical impedance of powdered coal, at ambient P/T conditions. Some very minor differences in dielectric properties due to gas adsorption are discernable when the effects of water are minimized. Since much higher levels of adsorption occur at high pressure, then amplified differences can be expected. Work is underway to construct a cell for ECBM-relevant conditions to investigate this further. Since the effects of water are so dominant, and its presence lowers the impedance dramatically, low frequency site-monitoring techniques (resistivity and/or magneto-telluric methods) appear more favourable than high frequency GPR. *In situ*, Time Domain Reflectometry probes could also be used. The future experiments will be carried out in conjunction with investigations into the compaction creep of the coal material under similar conditions. The solvent properties of supercritical CO_2 are expected to weaken the coal via dissolution and/or stress corrosion related effects.

Acknowledgements

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