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New sensor approach for separating CO_2 – sources in subsurface monitoring

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Carbon dioxide (CO_2) is the most abundant gas in volcanic and post-volcanic regions. The CO_2 - discharges occur as plumes, fumaroles and mofettes but also as diffuse soil emanations. Studies in volcanic or post-volcanic regions clearly demonstrated the risk of significant CO_2 fluxes from deep formations into the atmosphere with local concentrations up to nearly pure CO_2.

For greenhouse-gas mitigation it is planed to store billions of tons of CO_2 in deep geological formations (Carbon Capture & Storage - CCS) during the next decades. The CCS - CO_2 from such geological repositories can move along of permeable geological structures forming local or even diffuse leakages at the surface.

For safety reasons, monitoring of such geological CO_2 is required. Variable meteorological patterns and the landscape morphology highly affect the atmospheric CO_2 concentration close to the land surface. Thus, in terms of risk forecasting monitoring of CO_2 is more reliable below the soil surface where the concentration is much less influenced by the atmospheric conditions. Ideally, measurements in soil should be able to distinguish between the natural background concentration and the additional CO_2 coming from the geological source. This additional concentration might be comparable to the concentration of the background CO_2, which is produced by root respiration, microbial respiration and oxidation of organic matter and varies in dependence of temperature, moisture, soil type, cultivation, vegetation cover and herewith also with temporal changes in the land use. Thus, the separation of theses different sources is challenging.

Actually, the isotopic investigation of the soil CO_2 or a detailed geochemical analysis of the gas phase are applied for differentiation of both sources, however the effort is considerable. We introduce a new approach which is expected to be more efficient and economically more attractive. It is based on selective permeation of gases through a set of two membranes. The tubular or point-like sensors can be installed in the soil. The pressure evolution inside the individual sensor is related to the concentrations of the different ambient gas species permeating the membrane. Our experiments and theoretical considerations show that the time course of the differential pressure between the two sensors is independent of the concentration but depends on the mixing ratio between geological CO_2 and background CO_2. For a typical background of $pCO_2 < 5\%$ in soils we demonstrate a sufficient linearity of this dependency. In this case, such mixing-line sensor can precisely operate in the field without excessive calibration.