Determination of Composition of Ethanol-CO_2 Mixtures at High Pressures Using Frequency Response of Microcantilevers

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Determination of composition of ethanol-CO_2 mixtures at high pressures is important in many applications involving supercritical fluids such as drying of alcogels or release of microelectromechanical devices. In this study, we found that the composition of a high-pressure ethanol-CO_2 mixture can be related to the frequency response of microcantilevers immersed in the mixture fluid. The measurements were carried out with a custom built experimental setup consisting of a high-pressure vessel with temperature and pressure control, a coil for magnetic actuation of the immersed cantilevers, and a quadrant photodetector for optical readout of the cantilever displacement. The resonant frequency and quality factor (Q-factor) of ferromagnetic nickel microcantilevers immersed in ethanol-CO_2 mixtures were measured in a temperature range of 308.15 – 338.15 K and pressures range of 8 MPa to 16 MPa. The measurements were carried out for different mixture compositions ranging from 0.5 to 10 mol % ethanol in CO_2. The resonant frequencies and Q-factors were found to decrease in a smooth manner with the increasing fraction of ethanol in the mixture. At a constant temperature, the sensitivity of resonant frequency to changes in fluid composition was found to increase with decreasing pressure. These changes in parameters of the cantilever frequency response could be attributed to the changes in density and viscosity of the mixture with composition which could be quantitatively predicted by the hydrodynamic model of Sader. The experimental results show that ethanol-CO_2 mixture composition can be determined with good accuracy at high pressures using mainly the measured resonant frequency of microcantilevers. The considerable changes in the resonance frequency as a function of different compositions suggest that this approach can potentially be used in the supercritical drying process for aerogel production to measure ethanol concentration at the exit of the extractor as a function of time and enable the determination of the end of the drying process.

Acknowledgment**:** - This project has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 685648.