Improved Microwave Re-entrant Cavity Design for Binary VLE Measurements Including Complete Phase Description

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The ability to accurately predict the thermodynamic behavior of fluid mixtures is crucial for a range of scientific and industrial applications. While available thermodynamic property models, such as multiparameter equations of state, are able to predict the phase behavior of fluid mixtures, the lack of accurate experimental data often leads to significant uncertainties in vapor-liquid equilibrium (VLE) calculations. VLE measurements based on microwave re-entrant cavity techniques have proven to deliver reliable and accurate results for phase equilibria and especially dew-point measurements of pure fluids and binary mixtures. Furthermore, a new method currently under study is based on microwave cavity technology and exhibits the potential for accurate and fast investigation of the complete phase properties of binary fluid mixtures by measuring liquid volume fractions (LVF). In this work, we describe an improved microwave resonator specifically designed for LVF measurements. The design process was aided by finite element analysis, addressing potential issues such as sample mixing inside the cavity and the distribution of the electric and magnetic fields necessary for high-quality frequency measurements. Homogenous mixing was addressed by developing a unique in situ mixture agitation device since preliminary sample mixing designs, such as circulation pumps, suffer from additional volume and higher uncertainties caused by dead volume. Our in-house mixing system utilizes a mechanical device that tilts the resonator around the axis through the resonator's center of gravity. With this setup, we present a novel approach for VLE measurements of binary mixtures, including complete phase description using a single instrument, without sampling; it is the first synthetic nonvisual technique that enables the determination of tie lines. The mathematical framework developed in this context was validated by comparison of the measured and predicted properties of a (0.35 C_3H_8 + 0.65 CO_2) mixture throughout the two-phase region along an isothermal pathway at T = 280 K.