## **Characterising Binary Mixture Phase-Behaviour with Microwave Re-entrant Cavities**

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The ability to accurately predict the behaviour of fluid mixtures is crucial for a range of industrial and scientific applications. Ongoing development of more accurate and comprehensive equations of state is reliant on the availability of reference-quality data for binary mixtures, in particular those from which the properties of more complex mixtures can be predicted. However, characterising the fluid phase-behaviour of binary mixtures is a slow process, typically involving many discrete measurements of individual thermophysical properties. In this work, we present a novel approach to fully describe the phase compositions and densities of heterogeneous binary mixtures within a microwave re-entrant cavity resonator. Microwave re-entrant cavities present a number advantages over contemporary methods including compact size, robust construction, absence of moving parts, and the ability for rapid *in-situ* measurement without sampling. The measurement technique builds upon the unique ability of microwave re-entrant cavities to probe liquid volume fractions in a way that is both independent of the fluid and with manifold sensitivity to the liquid and vapour phases. Finite element modelling has been used to quantify the response of the microwave cavity to homogenous and heterogeneous samples, which has been experimentally confirmed with excellent agreement through measurements of the pure fluids CO<sub>2</sub> and C<sub>3</sub>H<sub>8</sub>. A new framework will be described for deriving the composition, density, dielectric constant, and volume fractions of the liquid and vapour phases for binary mixtures are soft to derive a small, robust instrument capable of rapid measurements.