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Exsolution textures in diamond anvil cell partitioning experiments: An atom probe tomography investigation

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Laser-heated diamond anvil cell (DAC) experiments are increasingly being used to extend our knowledge of superliquidus metal-silicate partitioning behaviour to the extreme conditions of core formation. Such experiments indicate that the partition coefficients of many elements have a clear pressure and/or temperature dependency, and the results are used to guide our understanding of accretionary processes and planetary differentiation. These experiments produce a metal ball surrounded by a thick rim of silicate glass. In detail, these two phases have more complex textures: the silicate may contain nm-scale suspended metal and larger entrained blobs, and the metal contains oxide spheres of 10s-100s nm diameter. The nm-scale features are usually assumed to have exsolved during quenching, and conventional analyses use an analytical spot size large enough to integrate them and their matrix. However, this assumption must be tested in order to confirm the validity of the experimental interpretation. In addition, the oxide spheres in the metal invalidate the microprobe phi-rho-z correction, resulting in low totals and uncertain light element concentrations. To resolve both issues, we conducted an atom probe tomography (ATP) investigation of a typical experimental quenched metal. This technique can resolve individual atoms, and is used to explore compositional and spatial relationships of nm-scale features. We determined that the exsolved balls are pure SiO_2, and that the matrix is C-bearing iron. A narrow (< 5 nm) trace element and C-enriched rim exists at the interface. The presence of significant carbon in these nominally C-free experiments results from carbon contamination from the diamonds or laboratory sources, and may be common in DAC experiments. Additionally, the two phases were remarkably homogeneous, with no preserved diffusion gradients. This could indicate that these features were stable during the experiment rather than exsolving on rapid quench. However, in order to confirm or dismiss such an interpretation, we need better constraints on quench rates at very high temperatures (up to 5000 K) in DAC experiments: we have therefore created new thermal and diffusion models to probe quench rates and diffusion lengthscales in the DAC, to guide the interpretation of the APT data.