Owing to differences in compatibility between Re and Os, the decay of $^{187}$Re to $^{187}$Os is an exceptional tracer of melting in the Earth’s upper mantle. There is a wide consensus that the mantle displays Os isotopic heterogeneity at the grain scale, which is exemplified by large variations of $^{187}$Os/$^{188}$Os in oceanic basalts. The decoupling of the Re-Os isotopic system during partial melting of the mantle, is thought to be associated with alloy/sulfide equilibrium at high temperature. Alloys remain at the source and develop non-radiogenic Os isotopic ratios, as they have very low Re/Os. On the other hand, sulfides have high Re/Os and develop more radiogenic $^{187}$Os/$^{188}$Os over time. However, not much is understood on the timing and conditions at which the de-coupling of the Re-Os isotope system takes place. Alloy model ages calculated using Os isotopes can be as old as 4.1Ga. The relative long-lived nature of these alloys implies that these phases are extraordinarily resilient to isotopic re-equilibration despite being hosted by mantle lithologies. Sulfides on the other hand, are broadly younger than alloys and are vulnerable to low-T metasomatic re-equilibration.

In order to provide constraints on the high-T stability of Os-rich alloys, we have carried out piston-cylinder experiments where variable proportions of Re, Os and Ir were equilibrated with FeS at temperatures ranging between ~1800 and ~2000K and constant pressure (15 kbar). Experiments were carried out in closed graphite capsules, with oxygen fugacity buffered near the C-CO redox buffer. Results show that Re, Os and Ir form an almost complete solid solution in the alloy at temperatures exceeding 1900K. At T lower than 1900K, a miscibility gap develops in the Re-Os-Ir-Fe-S and run products consist of a Re-rich sulfide melt, an OsIrFe alloy and a discrete Re alloy phase. We also show, that depending on the initial proportions of Re, Os and Ir in the charge, alloy-sulfide pairs will develop different $^{187}$Os/$^{188}$Os over time.

Our results preclude equilibration of Os-rich alloys in the mantle at temperatures exceeding 1900K, as alloys would be richer in Re, which is not the case for natural alloy compositions. Furthermore, we show that alloys have to be isolated from mantle sulfides for up to several billion years, with implications to our understanding of mantle convection.