

Growth kinetics of plutonium hydride corrosion sites

Camille Coe and John Knowles

AWE Nuclear Security Technologies, Aldermaston, United Kingdom; camille.coe@awe.co.uk
UK Ministry of Defence © Crown owned copyright 2026/AWE

Plutonium hydride formed below 100 °C is a finely divided, face-centred cubic material that can spontaneously ignite when exposed to air at room temperature [1]. During long-term storage of plutonium metal in sealed containers, hydrogen can accumulate due to radiolysis of packaging materials and reactions between the metal and moisture released from those materials. As a result, the formation of plutonium hydride becomes a credible possibility during extended storage [2]. This raises concerns about the long-term integrity of vessels containing plutonium, as corrosion and associated products may compromise containment [2]. To ensure safe and reliable storage over long periods, it is important to be able to predict storage behaviour [3], which in turn requires an understanding of the variability in hydride growth kinetics.

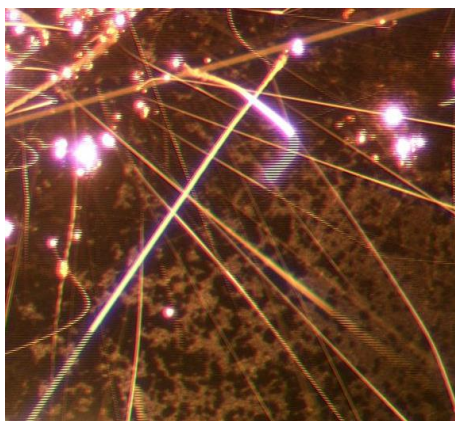


Figure 1 – Photograph capturing the ignition of some plutonium hydride on the surface of a partially corroded sample of a plutonium alloy.

The kinetics of plutonium hydride formation have been reported numerous times, yet the results across studies can be inconsistent [4]. A key challenge in obtaining reliable measurements for this highly exothermic reaction is controlling temperature. The reaction between plutonium and hydrogen proceeds rapidly, and even a small sample of less than 10 g can experience a temperature rise exceeding 50 °C if the heat is not effectively dissipated. Although methods such as using a heat sink [5] can reduce this temperature rise, uncertainty in the actual reacting surface area can still lead to misleading results when using conventional gravimetric or barometric techniques. In contrast, hot-stage microscopy provides a more robust approach [6], offering not only improved temperature control but also the ability to directly observe the nucleation and growth behaviour of individual corrosion sites.

Previous research reported sub-ambient reaction kinetics as part of an ongoing work to understand storage corrosion [7]. In this study, the growth rate of corrosion sites has been measured between 0.01 and 7 bar. The rate of reaction varies with a square root pressure dependence as seen with sub ambient kinetics. However, considering the individual rates measured from different corrosion features allows variability to be considered. Where previous reports have indicated a singular kinetic value for any given condition [4] this study highlights the variability in the growth kinetics of each corrosion site.

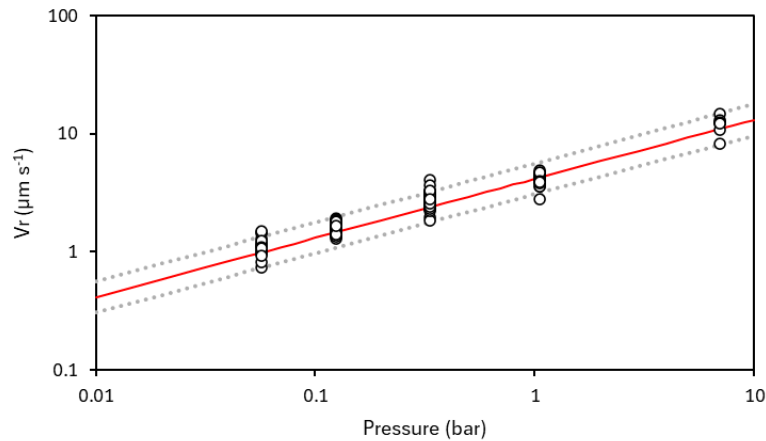


Figure 2 – The pressure dependence of the radial growth velocity (V_r) of plutonium hydride corrosion sites, a best fit is shown (red) alongside the upper and lower 95 % prediction limits (dotted).

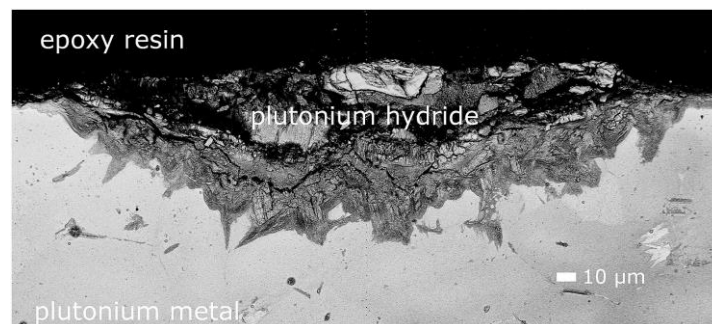


Figure 3 - Cross section of a typical plutonium hydride reaction site imaged using backscattered electrons, noting the discontinuous interface, reproduced from [8].

This study demonstrates that plutonium hydride formation during long-term storage is influenced not only by environmental conditions such as temperature and hydrogen pressure, but also by the intrinsic variability of individual corrosion sites. While the overall reaction rate follows the expected square-root pressure dependence, direct observation using hot-stage microscopy reveals substantial differences in growth behaviour from site to site. These variations arise from microstructural features and discontinuities at the metal-hydride interface, underscoring the limitations of reporting a single kinetic value for complex, heterogeneous systems. Recognising and accounting for this variability is essential for improving predictive models of plutonium storage behaviour and ensuring the continued safety and integrity of sealed containment over long periods.

References

- [1] J.M. Haschke, A.E. Hodges, R.L. Lucas, J. Less-Common Met., 133 (1987) 155
- [2] J.L. Stakebake, J. Nucl. Mater., 38 (1971) 241
- [3] J.M. Haschke, J.L. Stakebake, L.R. Morss, N.M. Edelstein, J. Fuger (Eds.), Chem. Actin. Transuranium Elem., Springer, Dordrecht (2006), pp. 3199-3272
- [4] Plutonium Handbook: Nuclear Science and Materials Science (2nd Edition), American Nuclear Society, 2019
- [5] J. Ogden, C. Alexander, C.A. Colmenares, LLNL Report UCRL-84307, 1980.
- [6] C.K. Saw, J.M. Haschke, P.G. Allen, W. Mclean II, L.N. Dinh, J. Nucl. Mater. 429 (2012) 128
- [7] G.W. McGillivray, J.P. Knowles, I.M. Findlay, M.J. Dawes J. Nucl. Mater. 385 (2009) 212
- [8] M. Brierley, J.P. Knowles, A. Sherry, M. Preuss, J. Nucl. Mater. 469 (2016) 145