In-situ electron irradiation within a TEM: a way to study the stability and evolution of cavities in pure aluminium

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Al-based alloys are foreseen for the cladding of the future material testing reactor Jules Horowitz. Under irradiation, a large amount of point defects (interstitials and vacancies) are created. They are mobile and may cluster to form extended defects such as dislocation loops in 2D or cavities in 3D. This work is focused on cavities, which may induce swelling and embrittlement. Because of its low Z number, it is possible to create defects in this metal with the typical low-electron energy available within a Transmission Electron Microscope (TEM), as recently obtained at the atomic scale in a Mg metal\textsuperscript{1}.

Facetted cavities are indeed observed within in-situ experiments performed with 200 and 300 keV electrons and stabilities of cavity surfaces can be determined. In fact, the surface free energy ratio of low-index planes \{100\} to \{111\} in pure Al (99.999\%) are estimated by means of the Wulff construction and measurement of the relative proportion of the corresponding facets. This ratio is then compared to recently published \textit{ab initio} values.

On the other hand, to determine the kinetics of cavity evolution under irradiation in pure aluminium, other experiments are performed in a zone axis [100]. In situ observations show that cavities appear after the formation of interstitial loops. Surprisingly, cavities adopt a cross shape along \langle100\rangle directions during growth (figure) before taking a cubic shape. A model based on a pentavacancy cluster\textsuperscript{2} is proposed to explain those results. To improve statistics, electron irradiation under lower electron intensity and lower electron energy within the TEM are on-going so that more data per unit time will be collected. The effect of irradiation flux on the cavity formation will be studied.

\textsuperscript{1} Xu W \textit{et al.}, \textit{In-situ atomic-scale observation of irradiation-induced void formation}, Nat. Commun. 4, 2288, 2013