Orientation relationship of the fcc-to-bcc transformation in DIN 1.4970 austenitic stainless steels due to dissolution corrosion in liquid Pb-Bi eutectic

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The deployment of Generation-IV lead-cooled fast reactors (Gen-IV LFRs) requires the compatibility between the candidate structural/fuel cladding steels and the inherently corrosive lead-based alloy coolants. Therefore, understanding the liquid metal corrosion behaviour of candidate structural/cladding materials in contact with heavy liquid metal coolants is crucial for the design and safe operation of Gen-IV lead-fast reactors (LFRs). The Multipurpose hYbrid Research Reactor for high-tech Applications (MYRRHA) system, currently under development at SCK•CEN, uses the lead-bismuth eutectic (LBE) alloy as both primary coolant and spallation target. The MYRRHA candidate steels are: the 316L structural steel and the DIN 1.4970 fuel cladding steel; both steels are austenitic (fcc) stainless steels.

At sufficiently high temperatures (T >450 °C) and low LBE oxygen concentrations ($C_O < 10^{-8}$ mass%), these steels are susceptible to dissolution corrosion, a particularly undesirable corrosion mechanism that can jeopardize the structural integrity of the reactor components. Dissolution corrosion is manifested by the progressive transfer of steel alloying elements to the LBE coolant; dissolution starts by the selective leaching of the highly soluble steel alloying elements (Ni, Mn, Cr), which in turn leads to the ferritization (fcc-to-bcc phase transformation) of the dissolution-affected zone due to the removal of the austenite stabilizers (Ni, Mn).

In literature, the austenite to ferrite (γ→α) phase transformations have mainly been studied when depending on the steel alloying and thermal processing of the steels. These transformations can occur in a displacive manner by a coordinated movement of atoms or through a diffusion-driven reconstructive transformation mechanism. Specific orientation relationships (ORs) have been repeatedly found between the two phases. In steels, for the vast majority of cases, the Kurdjumov-Sachs (K-S) and/or Nishiyama-Wassermann (N-W) ORs have been reported.

In this work, the focus is on the less studied austenite-to-ferrite phase transformation, which occurs when austenitic stainless steels are exposed to heavy liquid metals (HLMs), such as lead and lead-bismuth eutectic (LBE), under specific exposure conditions (i.e., high temperatures, low-oxygen HLMs). A large statistical population of γ/α phase boundaries was analyzed by electron backscatter diffraction (EBSD) on LBE-exposed austenitic stainless steels, in order to determine the dominant OR between several selected ORs (i.e., Bain, K-S, N-W and Pitsch). The Pitsch model was found to be the dominant orientation relationship, which is unique for γ→α bulk transformations in steels. The unusual nature of the transformation, which involves loss of alloying elements and the presence of an interfacial liquid metal layer, is discussed to explain this finding.