THE INFLUENCE OF STACKING FAULT ENERGIES AND SOLUTE SEGREGATION ON HIGH TEMPERATURE CREEP STRENGTH IN L1$_2$-CONTAINING CO-BASED SUPERALLOYS

Michael S. Titus, University of California Santa Barbara
and Max-Planck-Institut für Eisenforschung
m.titus@mpie.de
Alessandro Mottura, University of Birmingham
Robert K. Rhein, University of California Santa Barbara
Min-Hua Chen, University of California Santa Barbara
Anton Van der Ven, University of California Santa Barbara
Tresa M. Pollock, University of California Santa Barbara

Co-based superalloys strengthened by the γ'-(L1$_2$) phase exhibit comparable and, in some cases, superior high temperature creep resistance to 1st-generation Ni-based superalloys. Despite the comparable creep resistance between Co- and Ni-based superalloys, the high temperature creep deformation modes are markedly different: the γ' phase in Ni-based superalloys is typically sheared via coupled a/2<110> matrix dislocations, whereas the γ' phase in Co-based superalloys is sheared via Shockley superpartial a/3<112> dislocations, which leave superlattice intrinsic stacking faults (SISF) behind in their wake. Previous investigations have shown that the creep strength of Co-based alloys increases with increasing SISF energy. In this contribution, the SISF energies for Co$_3$(Al,W,X) and Co$_3$(Al,Mo,X) compounds (X = Cr, Ta, Ti, Nb, and V) are calculated using density functional theory and special quasi-random structures (SQS) in order to assess the potency for quaternary alloying additions to increase the SISF energy, and thus the high temperature creep strength. In all alloy systems except Co-Al-W-Ti, quaternary compositions exhibited higher SISF energies compared to binary or ternary compositions. This implies that higher-order alloying additions that partition to the γ' phase will always aid to increase the SISF energy and the high temperature creep strength as well. Recent work incorporating vibrational entropy in order to determine temperature-dependent SISF energies will be presented. Additionally, recent observations via high resolution microscopy and atom probe tomography of solute segregation at the SISFs will be presented. The relationship between solute segregation, SISF energy, and high temperature creep strength will be exemplified.
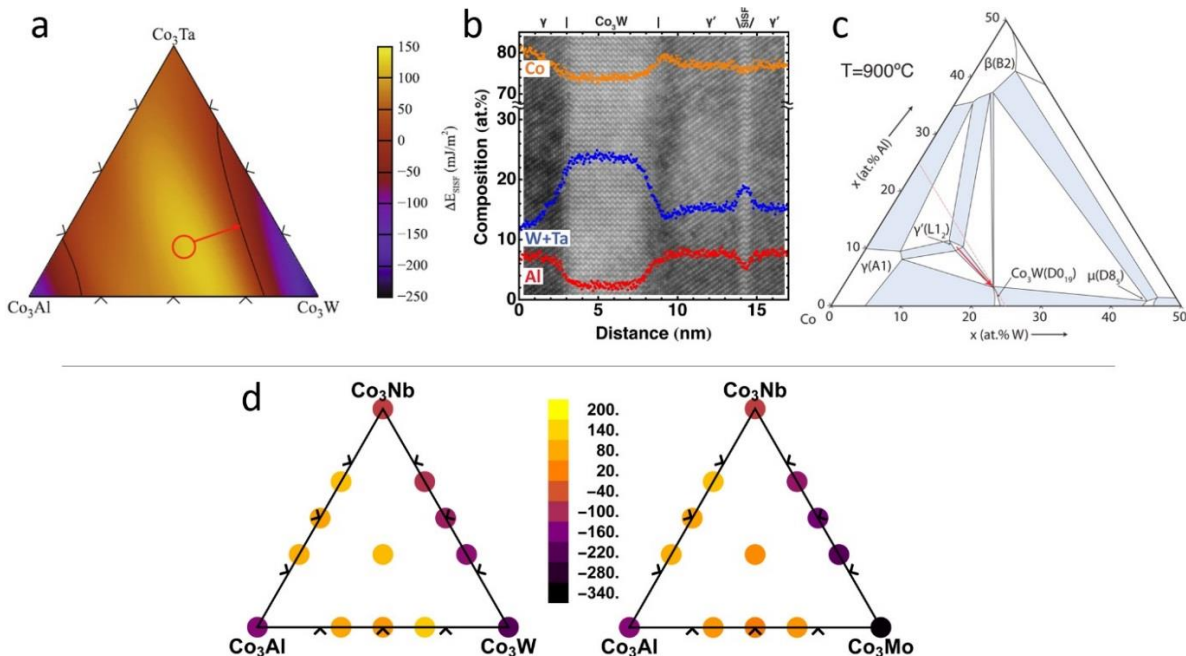

Figure 1 – (a) Calculated SISF energy of the Co$_3$Al-Co$_3$W-Co$_3$Ta pseudo-ternary showing the gradient in decreasing SISF energy from the γ' composition (circled) (b) high resolution microscopy of segregation across an SISF, (c) phase diagram with labeled solute segregation compositional change, (d) calculated SISF energy of the Co$_3$Al-Co$_3$W-Co$_3$Nb and Co$_3$Al-Co$_3$Mo-Co$_3$Nb systems.