Development of compositional-gradient metallic alloys for combinatorial investigation of microstructures

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Abstract: The transformation of austenite into ferrite in steels is of considerable interest in controlling the final properties of steels, in particular Advanced High-Strength Steels (AHSS) such as Dual Phase (DP) steel. Despite tremendous efforts in understanding the mechanisms controlling ferrite formation, the role of substitutional elements during ferrite growth and their interaction with the migrating α/γ interface remain unclear. Several models have been developed to describe ferrite growth kinetics in ternary and higher systems. The solute drag based models have been successfully used to predict kinetics for multiple substitutional solutes, compositions and temperatures in ternary systems. However, the extension of this model to higher order systems highlighted a complex behavior of the interaction between the different interstitial and substitutional elements at the interface. Validation of the developed models requires an experimental study of the effect of both composition and temperature on growth kinetics. The aim of this contribution is to present a complete combinatorial high-throughput methodology to accelerate the investigation of the dependency of ferrite growth kinetics on substitutional composition in alloy steels. It is noteworthy, however, that this new methodology could be used to study any other phase transformation in any other metallic alloy. The essence of the methodology is to fabricate materials with macroscopic composition gradients, and to perform time- and space-resolved in situ high-energy X-ray diffraction experiments to gather the austenite-to-ferrite phase transformation kinetics in many points of the compositional space. Diffusion couples containing millimeter-scale solute gradients and an almost constant carbon content were generated using the present methodology and used to study ferrite growth kinetics at inter-critical temperatures using in-situ high-energy X-ray diffraction experiments. During 4 days of experiments, more than 1500 kinetics were gathered for different compositions and at different temperatures. This dataset of unprecedented size was used validate a modified version of the three-jump solute drag model for both ternary and quaternary systems. The model calculations matched experimental

transformation kinetics at all investigated temperatures and over almost all the investigated composition ranges of Si, Cr, Mn, Ni, and Mo, contrary to results from para-equilibrium (PE) and local equilibrium negligible partitioning (LENP) models. Additionally, it was demonstrated that the calibration of thermodynamic parameters in ternary systems held true in quaternary systems, paving the way towards modeling of the transformation in higher-order systems.