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Project Title: Microstructure control and property optimization of high-strength weldable steels strengthened by nanoparticles for construction applications

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Project Outline:

High-performance steels with high strength and good weldability are highly desirable for modern buildings and civil engineering structures, such as large-space structures, super high-rise buildings and long-span bridges. Recently, nanoscale co-precipitation-strengthened (NCPS) steels, as a new class of high-strength steels, have attracted considerable attention and become the cornerstone for the development of high-performance steels for construction applications. In the NCPS steels, nanoparticles can provide a substantial increase in strength, and thus the carbon content of these steels can be kept very low, which improves both weldability and toughness. Moreover, the metallic nanoparticles can be easily re-precipitated out upon post-weld annealing, providing a promising way to achieve good welding properties. However, the precipitate nanostructure is very complex and evolves significantly upon heat-treatments and welding processing; so far, the atomic scale understanding of the precipitation mechanism and microstructure-property relationship in the NCPS steels is still lacking. In view of this situation, this research intends to investigate the microstructure control and property optimization of high-strength weldable steels strengthened by various types of nanoparticles, including BCC Cu-rich nanocluster, B2-ordered NiAl intermetallic particles, and DO_{24}-ordered Ni_3Ti intermetallic particles. The nano-/micro-structures and mechanical/welding properties will be examined by 3D atom probe tomography, electron microscopy, X-ray diffraction, and mechanical tests, aiming at obtaining a fundamental understanding of the relationship between the nano-/micro-structures and mechanical/welding properties of the NCPS steels. Scientifically, this research is interested in the nanoscale co-precipitation mechanism and thermal stability of nanoscale co-precipitates (1-5 nm in size) in the NCPS steels. The nanoscale co-precipitation pathway and mechanism are very complex but interesting, because synergistic alloying effects and the co-precipitate interaction may have a

significant impact on the nucleation, growth, and coarsening of the nanoscale co-precipitates. It is of fundamental importance to understand the precipitation thermodynamics and kinetics of the nanoscale co-precipitates in NCPS steels. Technically, this research can lead to the development of advanced high-performance steels with high strength, good ductility/toughness, good weldability, and low cost, all of which make them attractive materials for the effective design and construction of modern buildings and civil engineering structures to promote sustainable infrastructure development in Hong Kong. In addition, the technical knowledge on the microstructural control and property optimization will provide useful guidelines for the application of these high-performance steels in the construction industries in Hong Kong and overseas.

Objectives:

- To establish scientific principles for microstructure control and property optimization of nanoparticle-strengthened steels with high strength and good weldability for construction applications.
- To quantitatively characterize the nano-/micro-structures and mechanical/welding properties of nanoparticle-strengthened steels through multi-scale experimental tools.
- To fundamentally understand the relationship between the precipitate nano-/micro-structures and mechanical properties of the nanoparticle-strengthened high-strength steels.

Expected deliverables:

- Atomic, nano- and micro-scale information of the precipitate microstructures, including the precipitate size, number density, crystal structure, composition, and spatial distribution, in the NCPS steels at different conditions.
- Bulk mechanical properties, such as hardness, yield strength, ultimate tensile strength, and ductility, of the NPCS steels at different conditions.
- The fundamental relationship between the precipitate nano-/micro-structure and mechanical properties of the NCPS steels for construction applications.