Engineering NanoStructure To Achieve Targeted Properties In Steels

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ABSTRACT

In this presentation, essential aspects of solidification will be presented showing how solid solid state transformations can be used to refine the microstructural scale in 'steels' to achieve phase / grain sizes in the nanoscale regime. By changing the kinetics of solidification, high undercoolings can be achieved allowing either, complete avoidance of nucleation resulting in a metallic glass which can be subsequently devitrified into nanoscale phases, or the achievement of an extremely rapid nucleation rates in order to form nanocrystalline scale phases / grains directly during solidification. As will be detailed, the key to forming nanoscale structures in industrial materials is not the external cooling rate but the material response to the cooling rate and the total undercooling which is achieved, with large undercoolings leading to rapid nucleation during solidification. The achievement of nanoscale microstructures should not be considered the end goal but instead represents an enabling ability to develop vastly improved properties which are not possible on conventional length scales. To document this, three specific case examples will be presented detailing the basic requirements, challenges, and successful approaches that have been used to engineer the nanostructure of steels to achieve (1) high energy density / high intrinsic coercivity, (2) high strength / hardness, and (3) high tensile elongation / low temperature superplasticity. Within these case examples, specific aspects of microstructure engineering will be given to allow improvements in targeted sets of properties.