Irradiation for the Novel Radiolytic Formation of Superalloy Nanoparticles

LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

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Problem

Utilization of Novel NP Formation without Sintering or Oxidation

Superalloys: Ni-based alloys that are hardened with refractory metals to higher temperatures while retaining superb mechanical strength e.g., γ-phases Ni/(Co, Cr, Mo, or W) or γ'-phases Ni_3(Al, Ti)

Synthesis of nanoparticles of alloy compositions allows for both nano- and bulk-scale applications of alloys.

Sintering of nanoparticles of an alloy allows for more defect-free bulk alloys, non-destruction of the refractory elements, and access to metastable phase spaces and morphologies.

Radiolysis is a room-temperature method to produce kinetically favorable, metastable alloy nanoparticles.

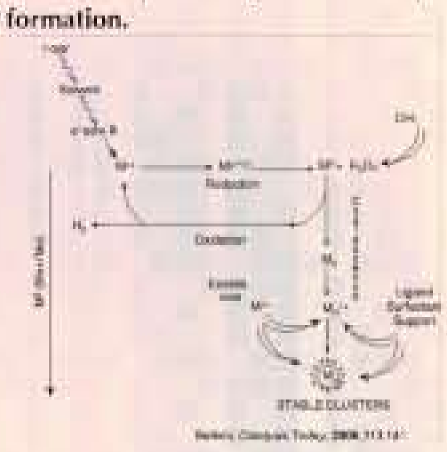
Ability to make homogenous NPs, independent of reaction size, means large quantities are possible.

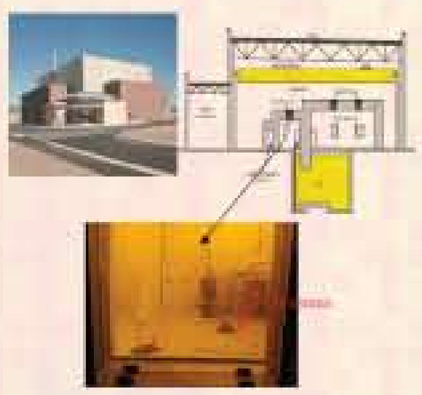
Approach

Room Temp Radiolysis at SNL's GIF Facility

Radiolysis is a method by which metal ions are reduced in water by ionizing radiation: The dose rate dictates the [e⁻] in the reaction solution thereby affecting the chemistry of the NP formation.

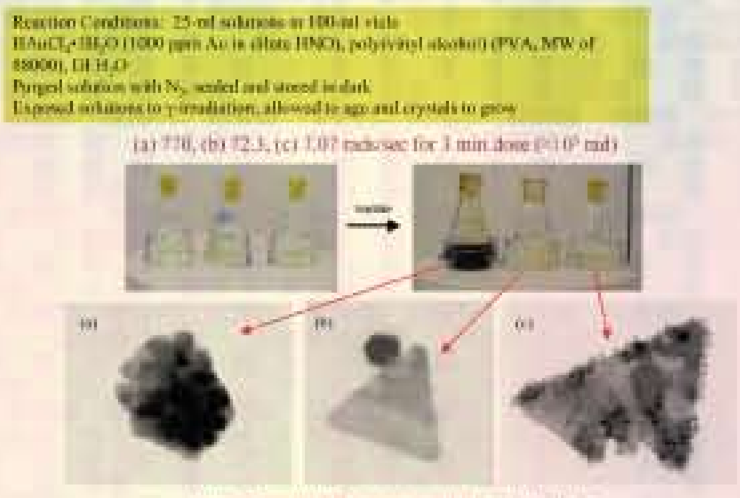
Sandia's Gamma Irradiation Facility (GIF) is a ^{60}Co source: 1.345 x 10^5 Ci, = 300 K rad/hr.



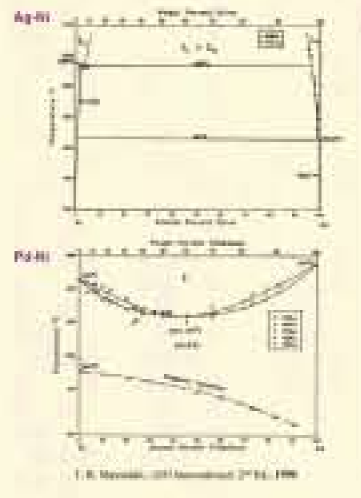


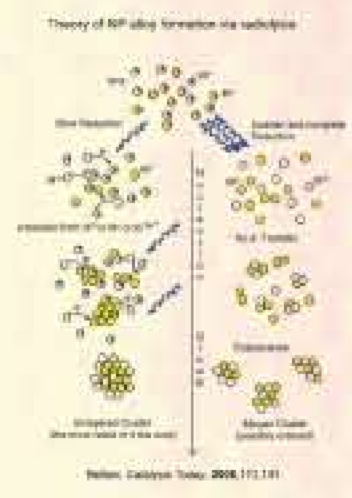
Results

Gold Nanoparticles, Morphology Determined by Dose Rate

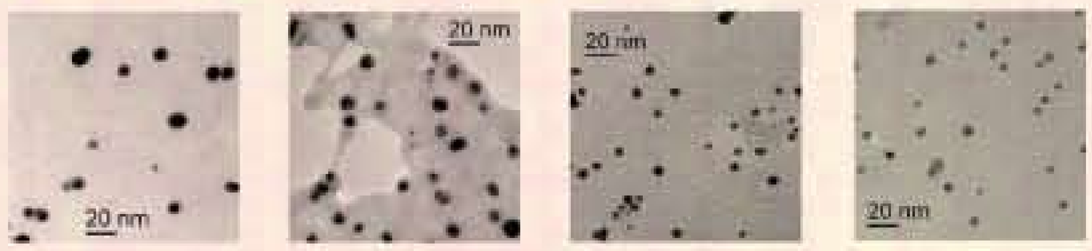


Kinetically Driven Access to New Phase Spaces: Thermodynamically inaccessible or limited Ni-based NPs



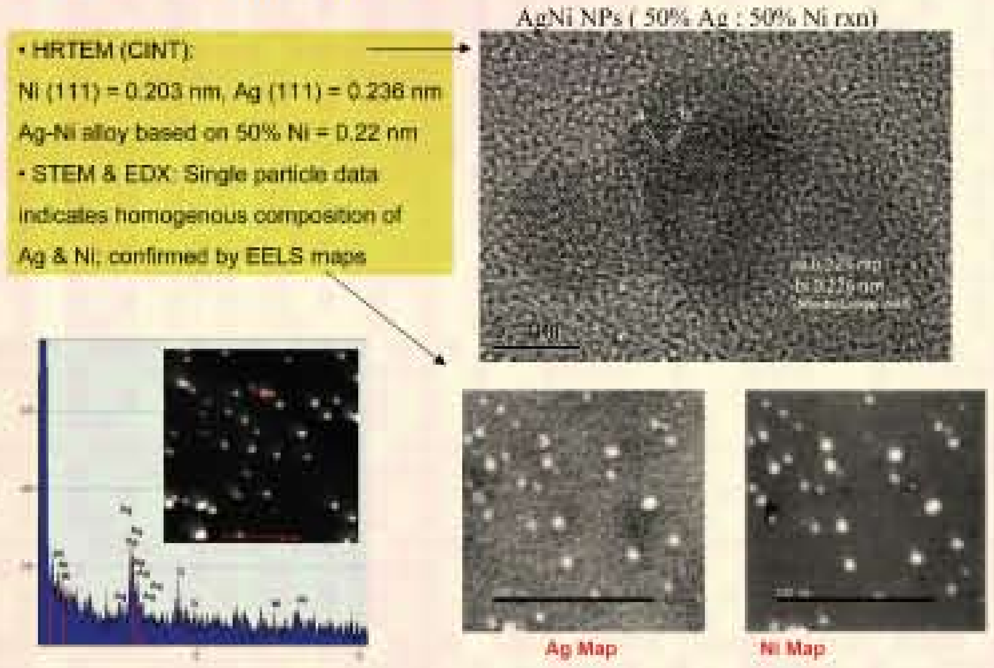


Reaction Composition Effect on NP sizes: TEM

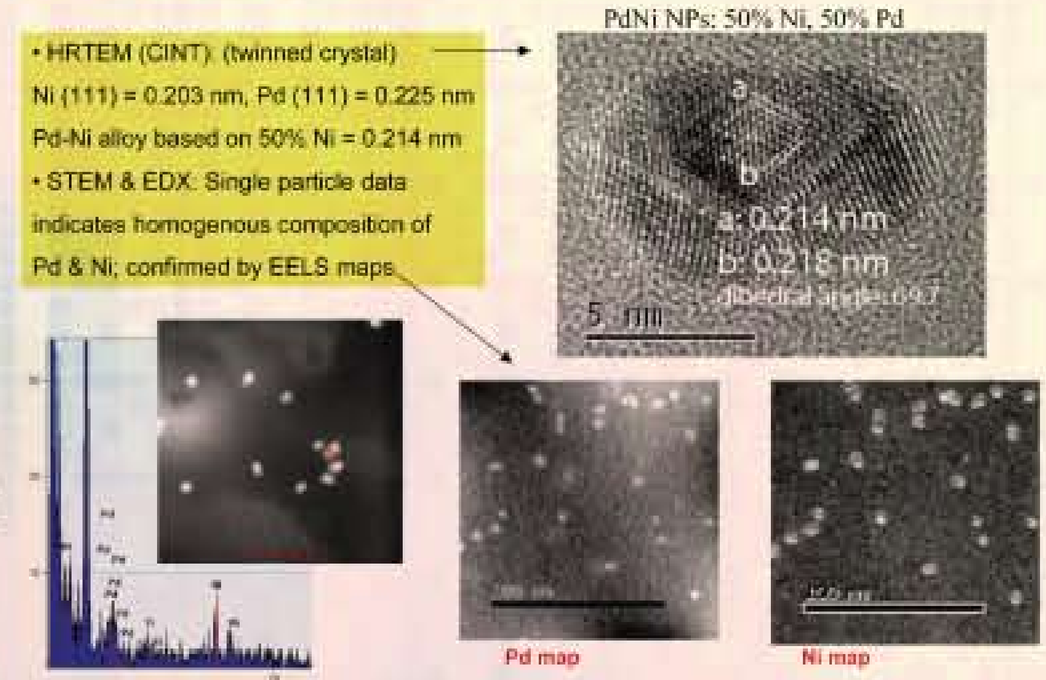


Pure Ag NPs | 10% Ni, 90% Ag NPs | 30% Ni, 70% Ag NPs | 50% Ni, 50% Ag NPs

AgNi Superalloy Nanoparticles



PdNi Superalloy Nanoparticles



Significance

- Long-term Science for SNL Business SMUs (NTM, ERN) plus DOE National Security Mission and Strategic Goals.
- Defense, Energy, Science applications require SuperAlloys: lightweight, corrosion-resistant, sintered refractory materials (weapons casings & connects, aircraft, satellites, power plants, gas turbine engines & burners)
- Leverage future funding by DOE/NE (nuclear fuel alloys), DOE/H_2 (H_2 dissociative membranes), DOD/DARPA/DTRA

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NNSA National Nuclear Security Administration

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