Irradiation for the Novel Radiolytic Formation of Superalloy Nanoparticles

SAND2008-5191P

Tina M. Nenoff, Zhenyuan (Mark) Zhang, Jianyu Huang,
Paula Provencio, Kevin Leung, Donald T. Berry
Sandia National Laboratories
Albuquerque, NM 87185
www.sandia.gov/nenoff

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the US DOE's NNSA under contract DE-AC04-94AL85000.

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 meta-stable 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

T. M. Nenoff, tmnenof@sandia.gov

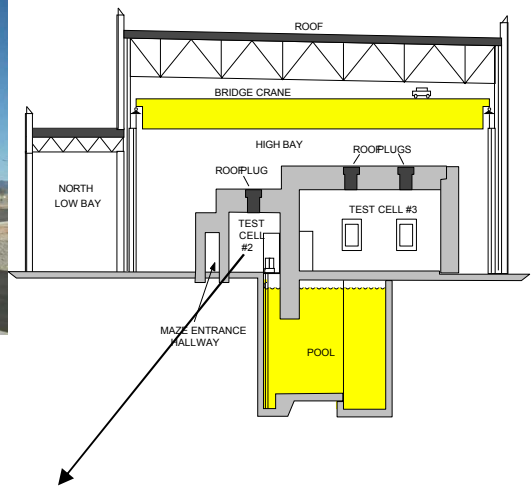
Approach:
Room Temp Radiolysis at SNL's GIF Facility

Radiolysis is a method in 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.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Belloni, *Catalysis Today*, **2006**,*113*,141

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



QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

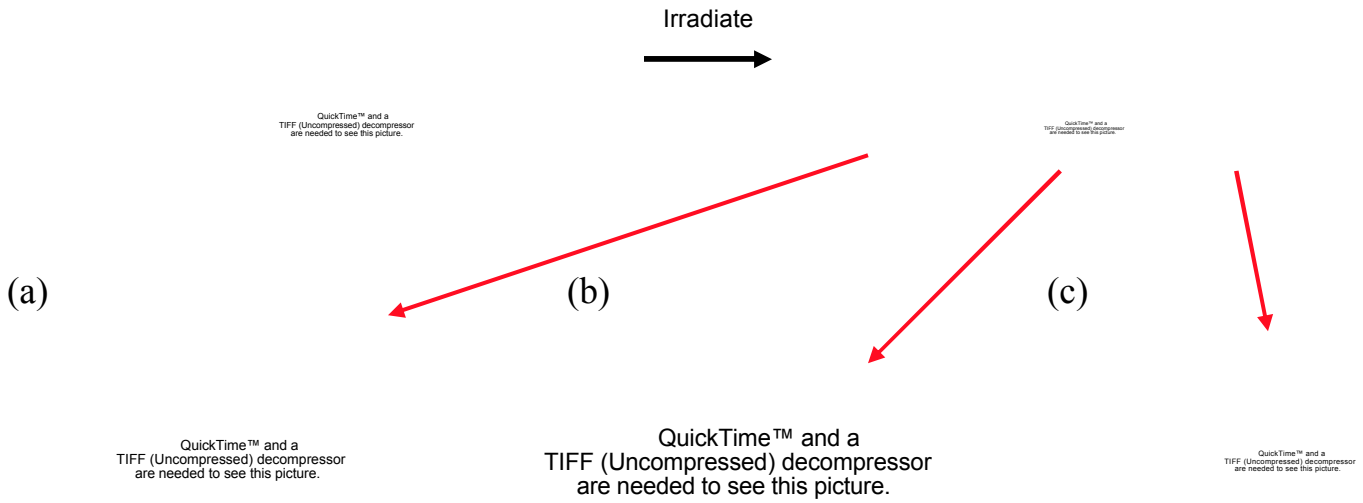
Co source
A
B
C

T. M. Nenoff, tmnenof@sandia.gov

Results: Gold Nanoparticles, Morphology Determined by Dose Rate

Reaction Conditions: 25ml solutions in 100ml vials
$HAuCl_4 \cdot 3H_2O$ (1000ppm Au in dilute HNO), poly(vinyl alcohol) (PVA, MW of 88000), DI H_2O
Purged solution with N_2, sealed and stored in dark
Exposed solutions to γ-irradiation; allowed to age and crystals to grow

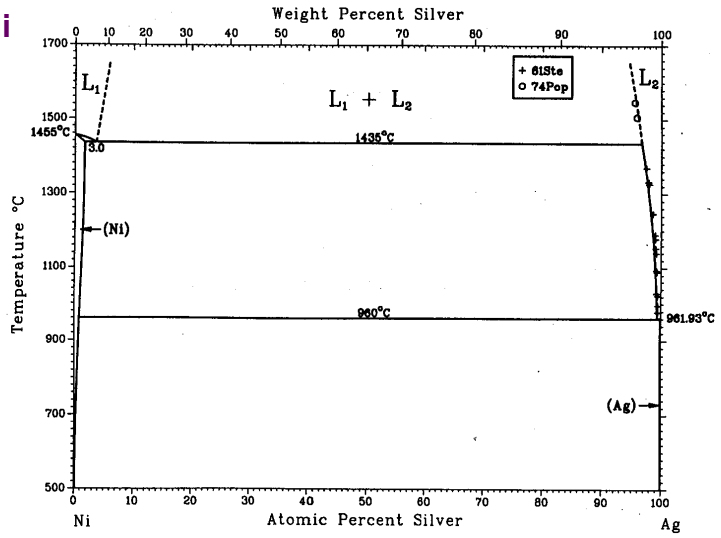
(a) 770, (b) 72.3, (c) 7.07 rads/sec for 3 min dose (≈10^3 rad)



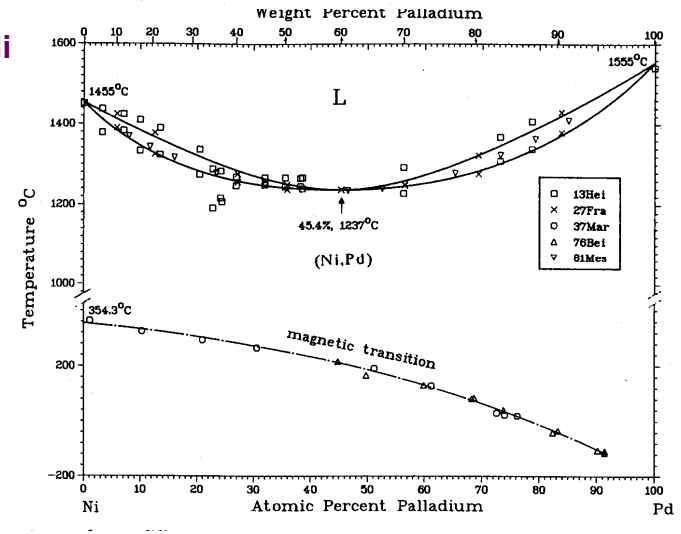
All **Gold Nanoparticle Clusters or single crystals** shown ≈ 30 nm in size

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

Ag-Ni



Pd-Ni



T. B. Massalski, *ASM International*, 2nd Ed., **1990**

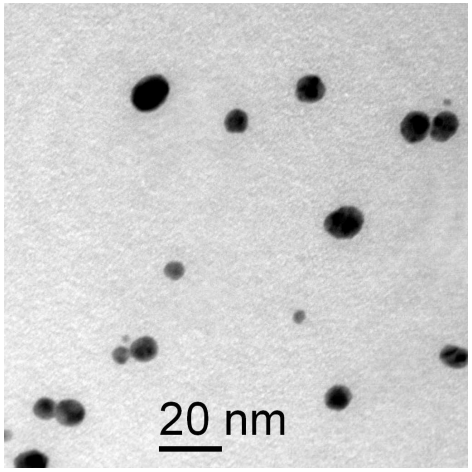
Theory of NP alloy formation via radiolysis

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

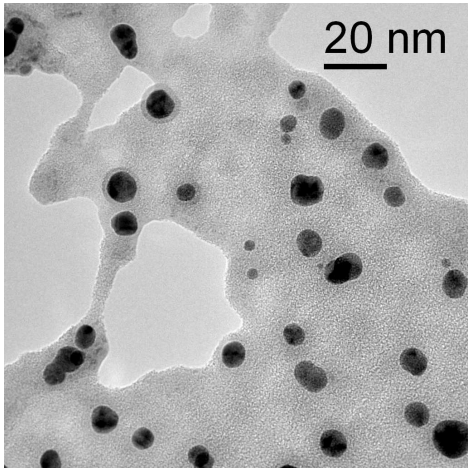
Belloni, *Catalysis Today*, **2006**,*113*,141

T. M. Nenoff, tmnenof@sandia.gov

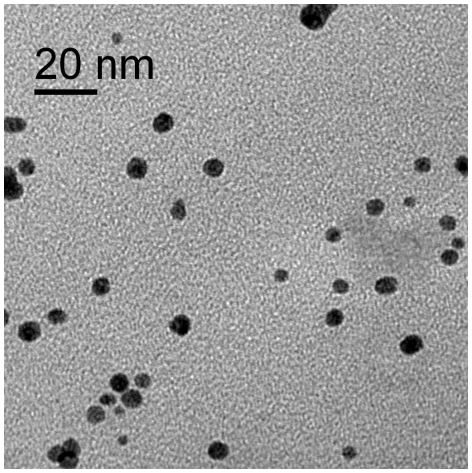
Reaction Composition Effect on NP sizes: TEM



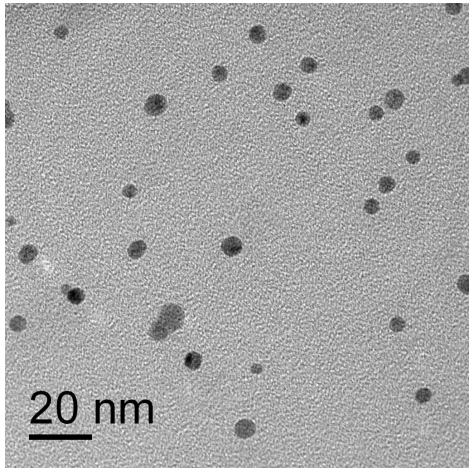
Pure Ag NPs



10% Ni, 90% Ag NPs



30% Ni, 70% Ag NPs



50% Ni, 50% Ag NPs

T. M. Nenoff, tmnenof@sandia.gov

AgNi Superalloy Nanoparticles

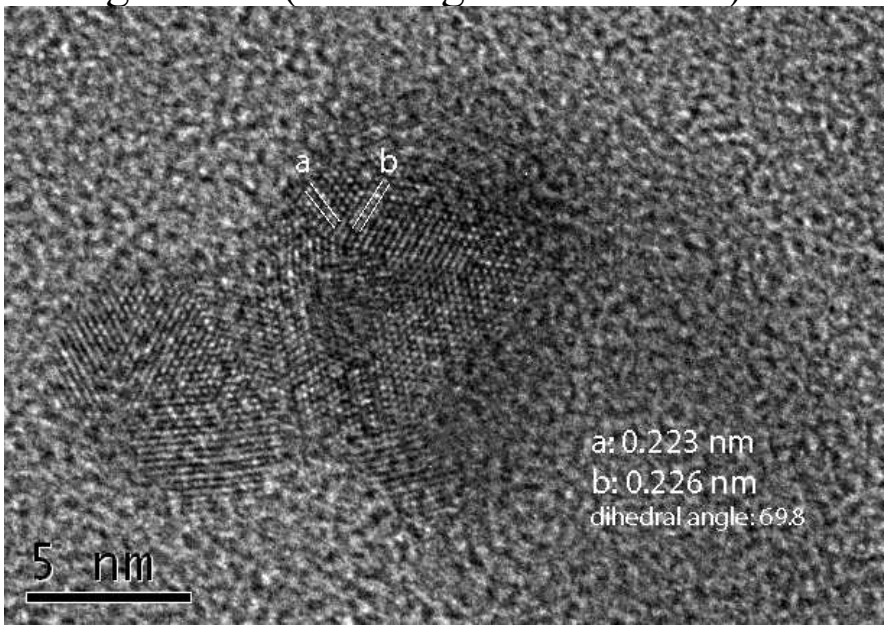
- HRTEM (CINT):

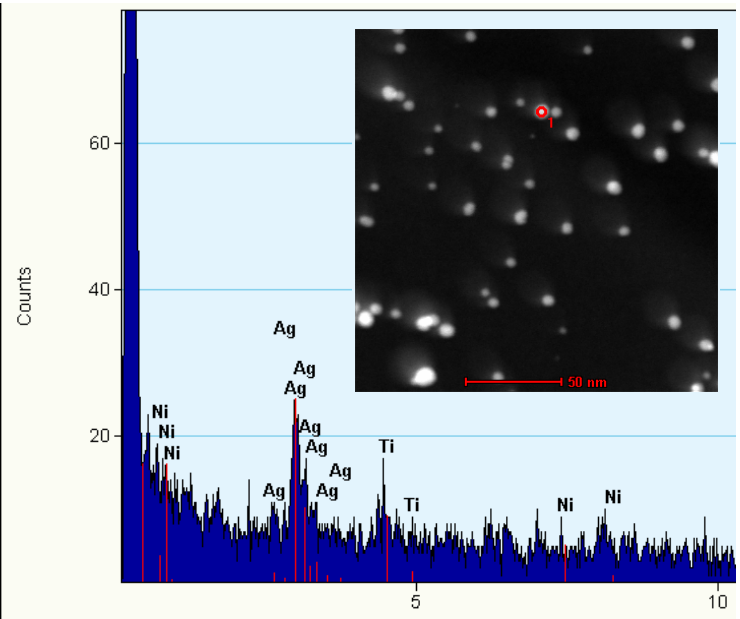
Ni (111) = 0.203 nm, Ag (111) = 0.236 nm

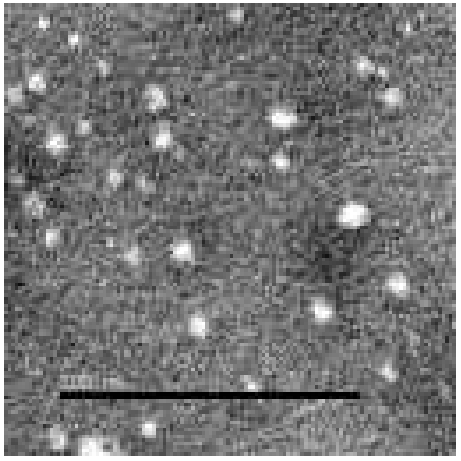
Ag-Ni alloy based on 50% Ni = 0.22 nm

- STEM & EDX: Single particle data indicates homogenous composition of Ag & Ni; confirmed by EELS maps

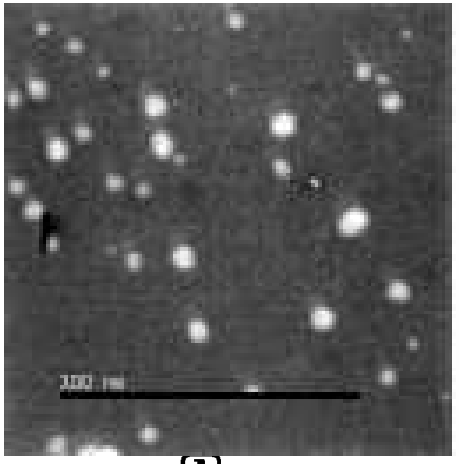
AgNi NPs (50% Ag : 50% Ni rxn)







Ag Map



Ni Map

Sandia National Laboratories

PdNi Superalloy Nanoparticles

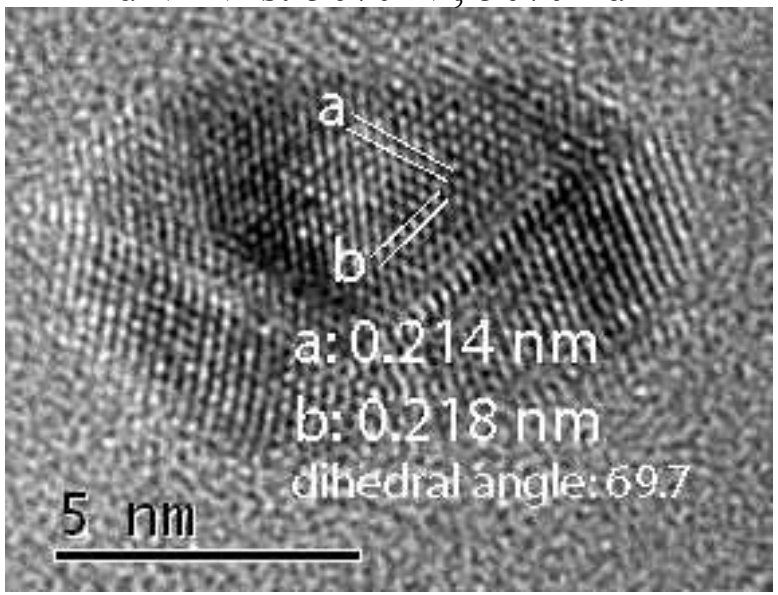
- HRTEM (CINT): (twinned crystal)

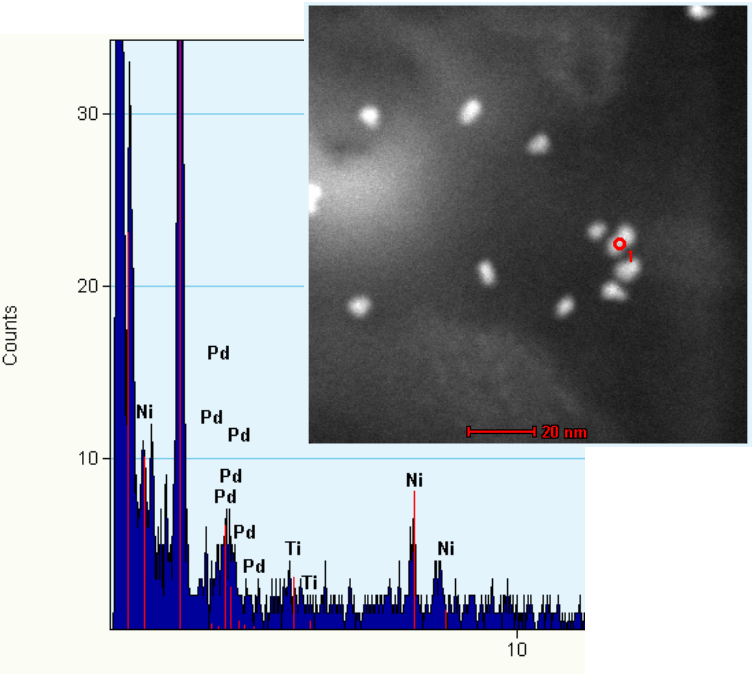
Ni (111) = 0.203 nm, Pd (111) = 0.225 nm

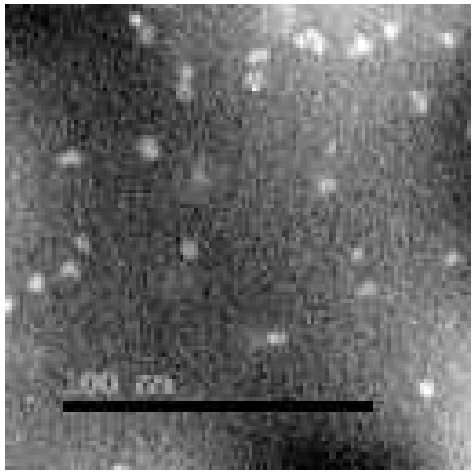
Pd-Ni alloy based on 50% Ni = 0.214 nm

- STEM & EDX: Single particle data indicates homogenous composition of Pd & Ni; confirmed by EELS maps

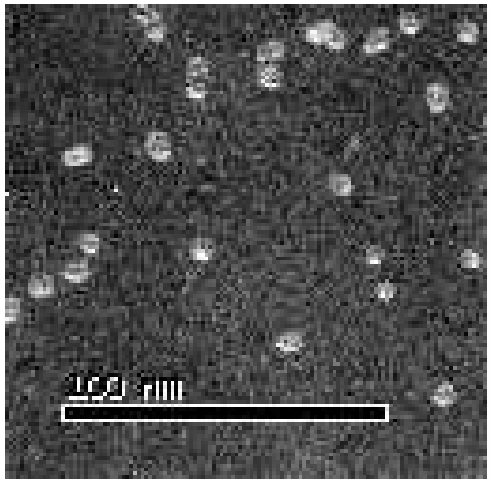
PdNi NPs: 50% Ni, 50% Pd







Pd map



Ni map

Sandia National Laboratories

Significance:

Long Term Science for SNL Business SMU's (NTM, ERN) plus DOE National Security Mission and Strategic Goals.

Defense, Energy, Science applications require SuperAlloys: light weight, 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