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Thermal plasma synthesis of alloy nanoparticles

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Synthesis of nanoparticles with desired size distribution through arc evaporation of precursor is an attractive route. Present study discusses the challenges involved in the arc synthesis of Cu-Ni alloy, a technically important alloy material whose properties are highly prone to its composition [1,2]. Interesting anomalies are observed when Cu-Ni alloy nanoparticles are synthesized via this route in the helium plasma at atmospheric pressure. The composition of nanoparticles differs significantly than the precursor composition when treated under a DC free burning arc plasma. In the entire composition range for Cu_xNi_{1-x} alloy, the dominating contribution in the formed nanoparticles is found to be from copper. Differences in vapour pressure of the alloying species may be one of the contributing agents for the observed discrepancy but is not enough to address the matter in totality. The study sheds light on the observed discrepancy through a computational fluid dynamic (CFD) simulation and particle nucleation and growth modelling [3,4]. Computational model is applied to simulate the thermal plasma arc and its interaction with anode precursor made of homogenously mixed copper and nickel. The thermal and velocity fields obtained through the CFD simulation are used in modelling the particle formation via a discrete sectional model of particle nucleation and growth. Obtained results point toward different contributing factors such as higher vapour pressure and activity of copper in the alloy and temperature distribution at the anode surface. The plasma forming gas and the thermo-physical properties of the alloy precursor [5] are found to play a critical role in anode heating. A thermodynamic approach indicated that difference in the evaporation rates of copper and nickel and hence different amount of energy lost in their evaporation may be responsible for their different monomer concentrations. Spectroscopic investigation followed by mathematical modelling on nucleation and growth revealed enhanced initial nucleation with copper species due to their increased concentration in the plasma. Hence a heterogeneous growth of nickel and copper vapours over the nucleating copper sites is hypothesized. This is forming alloy nanoparticles with atomic percentage different from their parent phase. Plasma forming species also found to play crucial role as the effective evaporation of alloying species is highly prone to precursor surface temperature. The study finds its applications where tuning of the alloy composition and the size of the nanoparticles are important.

References
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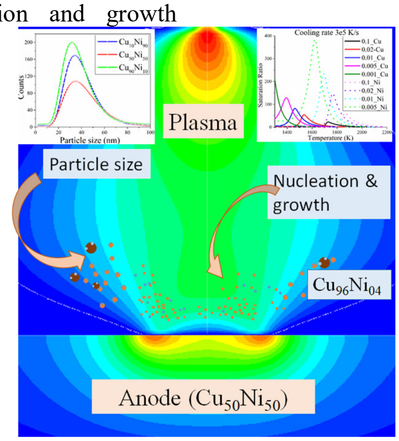

Figure 1 Schematic depicting the arc plasma synthesis of Cu-Ni alloy nanoparticles. Inset showing (left) particle size distributions of CuNi nanoparticles and (right) saturation ratio for Cu and Ni for different monomer concentration.