

Influence of the Ablation Liquid on the Phase and Magnetization of Laser-generated Fe-Ni Nanoparticles

I. Y. Khairani^{1*}, Q. Lin², J. Landers³, S. Salamon³, C. Doñate-Buendía¹, E. Karapetrova⁴, H. Wende³, G. Zangari², B. Gökce¹

¹ Chair of Materials Science and Additive Manufacturing, School of Mechanical Engineering and Safety Engineering, University of Wuppertal, 42119 Wuppertal, Germany

² Department of Materials Science and Engineering, University of Virginia, Charlottesville, VA 22903, United States

³ Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

⁴ Advanced Photon Source, Argonne National Laboratory, Argonne, IL 60439, United States

*khairani@uni-wuppertal.de

Abstract

Fe₅₀Ni₅₀ nanoparticles are employed in biomedicine, catalysis, and magnetic actuators due to their soft magnetic response and large magnetization. However, the nanoparticles' properties are determined by the material phase (FCC, HCP, L1₀), alloy composition, as well as core-shell structure. Pulsed laser ablation in liquid (PLAL) allows the synthesis of high-purity colloidal alloy nanoparticles by ablating a bulk alloy target in a selected solvent. The modification of the ablation solvent can alter the core-shell structure of the generated nanoparticles, and, as a result, provides the opportunity to tune their properties. Organic solvents are usually preferred to minimize nanoparticle oxidation, but economical laboratory and technical grade solvents contain water impurities, which is a potential source of oxidation. In this study, we investigated the influence of water impurity in acetone by using molecular sieves (3 Å) to capture water molecules and compared the properties of the generated Fe₅₀Ni₅₀ nanoparticles with the nanoparticles produced in acetone without molecular sieves treatment and Milli-Q (deionized) water. Our investigation showed that the nanoparticles' size, crystallographic phases, core-shell structure, oxidation level, and the magnetization of Fe₅₀Ni₅₀ nanoparticles produced by PLAL are influenced by the water content in acetone. XRD synchrotron analysis revealed that the high-pressure HCP FeNi phase was found in the sample produced in acetone and dried acetone, but not in water. Mössbauer spectroscopy showed that the FeNi NPs oxidation in dried acetone is reduced by 8% compared to acetone. The saturation magnetization value of Fe₅₀Ni₅₀ ablated in water is the highest, 68 Am²/kg, followed by ablation in dried acetone, 59 Am²/kg, and in acetone, 52 Am²/kg. The core-shell formation in these three liquids is also a distinctive feature of the solvent (Fig. 1), opening the possibility to tune the core-shell structure by reducing water impurity in the organic solvent [1].

References

- [1] Khairani, I.Y.; Lin, Q.; Landers, J.; Salamon, S.; Doñate-Buendía, C.; Karapetrova, E.; Wende, H.; Zangari, G.; Gökce, B, *Nanomaterials*, 2023, 13 (2), 227

Figures

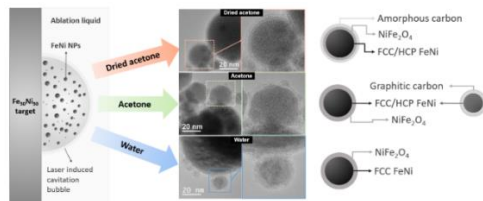


Figure 1: Schematic illustration of laser-ablated FeNi NPs in various liquids. The formation of diverse core@shell structures can be observed depending on the ablation liquid; FCC/HCP FeNi@NiFe₂O₄@amorphous carbon in dried acetone, FCC/HCP FeNi@NiFe₂O₄ and FCC/HCP FeNi@graphitic carbon in acetone, and FCC FeNi@NiFe₂O₄ in deionized water.