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A Three Dimensional Analysis of Au-Silica Core-Shell Nanoparticles

Using Medium Energy Ion Scattering

Z. Zolnai\(^1\), P. Petrik\(^1\), A. Deák\(^1\), S. Pothorszky\(^1\), D. Zárbo\(^1\), G. Vértesy\(^1\), N. Nagy\(^1\), A. K. Rossall\(^2\) and J. A. van den Berg\(^2\)

\(^1\)Centre for Energy Research, Institute of Technical Physics and Materials Science (MFA), H-1525 Budapest, P.O. B. 49, Hungary
\(^2\)International Institute for Accelerator Applications (IIAA), University of Huddersfield, Huddersfield, HD1 3DH, UK

Motivation and background

Metallic nanoparticles (NPs) with or without a dielectric shell are potential candidates for many applications, e.g., in plasmonics, catalysis, or healthcare. Since the physical, chemical and geometrical properties are usually strongly linked, the tailoring of these properties on the nanoscale is of fundamental importance. The aim of this work is two-fold:

- To demonstrate the capability of the Medium Energy Ion Scattering (MEIS) technique, combined with a 3D spectrum simulation tool (RBS-MAST code [1]) to determine the shape, size, and atomic composition of Au-core silica-shell particles on the nanoscale.
- To better understand ion beam-induced structural and compositional changes of dielectric and metallic nanoparticles. The high-energy ion irradiation-induced shaping of dielectric and metallic nanoparticles has been previously reported [2, 3]. However, low energy ion implantation may be a potential nanofabrication tool for the doping and alloying of the particles. In this work we exposed spherical Au-core silica-shell nanoparticles to ion irradiation with a wide range of different parameters (ion mass, ion energy): 30 keV Ar\(^+\), 150 keV Fe\(^+\), and 2.8 MeV N\(^+\) irradiation. The geometrical changes were monitored using MEIS measurements combined with 3D spectrum simulation.

Experimental details

- **Samples**: Au-silica core-shell nanospheres (core \(\sim 25 \text{ nm}, \) shell \(\sim 40 \text{ nm}\)) were deposited on Si(100) substrates using the Langmuir-Blodgett (LB) technique. A thin, colloidial Stöber silica shell was grown on the Au cores with a sol-gel technique. Planar gold layers deposited on glass substrates were also characterized for comparison.
- **MEIS** analysis was performed at the IIAA Huddersfield using 100 keV He\(^+\) ions scattered through angles of \(\Theta = 90^\circ\) and \(\Theta = 125^\circ\). Backscattered ions were detected with a toroidal electrostatic analyser.
- **FESEM** analysis was carried out with a LEO 1540 XB microscope at MTA EK MFA in Budapest.

MEIS spectrum simulation

The RBS-MAST code is used to reconstruct the spectrum shape according to the 3D structure of the sample (without straggling contributions). The DEPTH [4] code is applied to calculate the energy resolution due to straggling, multiple scattering and system resolution. The SIMNRA [5] code is used to calculate the dual scattering contribution to the overall MEIS energy spectrum.

References


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Corresponding author: Zsó Zolnai – E-mail: zolnai@mfa.fki.hu – phone: (+36-1) 3922222/3150