Metal clusters and nanowires prepared in superfluid helium droplets: structure, phase transitions and alloy formation at atomic resolution

M. Schnedlitz*, M. Lasserus*, D. Knez†, A. W. Hauser*, F. Hofer†, and W. E. Ernst* [1]¶

* Institute of Experimental Physics, Graz University of Technology, A-8010 Graz, Austria
† Institute for Electron Microscopy and Nanoanalysis, Graz University of Technology, A-8010 Graz, Austria

Synopsis: Metal nanoparticles are created in superfluid helium droplets, deposited on solid surfaces and investigated by scanning electron microscopy. Temperature dependent studies allow for the observation of phase changes at atomic resolution.

Superfluid droplets of 10^4 to 10^7 helium atoms (He_N) are doped with foreign atoms or molecules that move freely in or on the droplets and may form complexes in this cold environment. In our labs, large Cu; Ag, Au, and Ni aggregates of different morphology are generated in helium droplets [e.g. 1, 2] and their landing on a solid substrate was modelled in a molecular dynamics simulation [3]. Employing different pick-up cells for doping the droplets, nanowires and core-shell clusters with one metal surrounding a core of a different species can be created. Time scales for metal-cluster formation inside the droplets are derived from helium density functional theory and molecular dynamics simulations [4].

After surface deposition on various types of substrates, they are removed and taken to the neighboring electron microscopy facility [5, 6]. A vacuum transport chamber helps to avoid contamination. Analysis using a scanning transmission electron microscope with atomic resolution including tomographic reconstruction allows to obtain 3-D images of the particles.

Element specific methods like energy-dispersive x-ray spectroscopy (EDXS) and 2D electron energy-loss spectroscopy (EELS) identify the conditions for generating single or double core clusters [7]. As it turns out, the temperature of the substrate [6] and the doping rate [8] have an important influence on the final cluster or wire structure.

References

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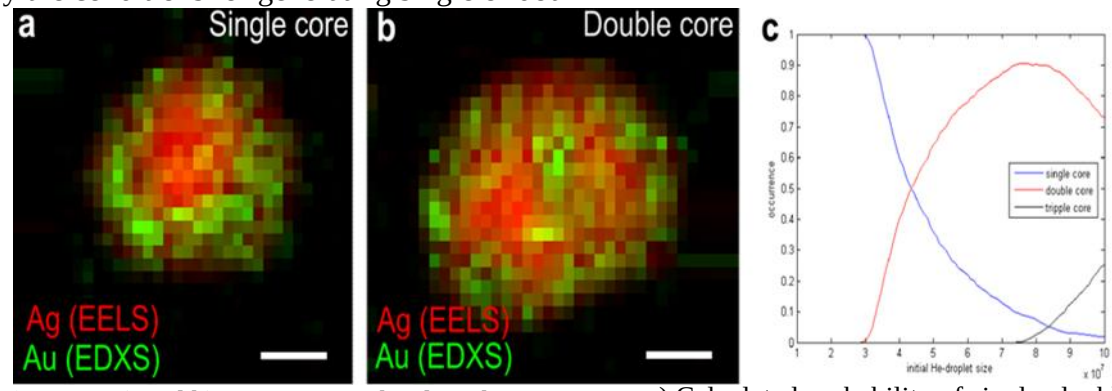

Figure 1: a) and b) composition, bar length 2 nm, c) Calculated probability of single, double and triple core clusters as a function of cluster size [7].

[1] E-mail: Wolfgang.Ernst@tugraz.at