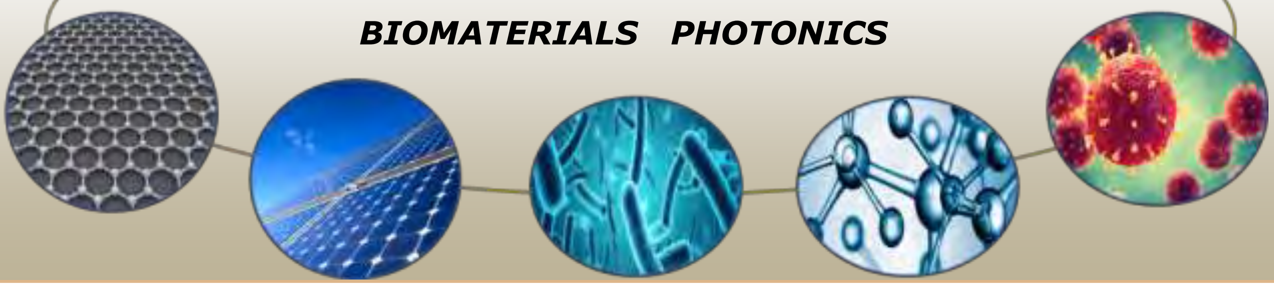
NL-UHV

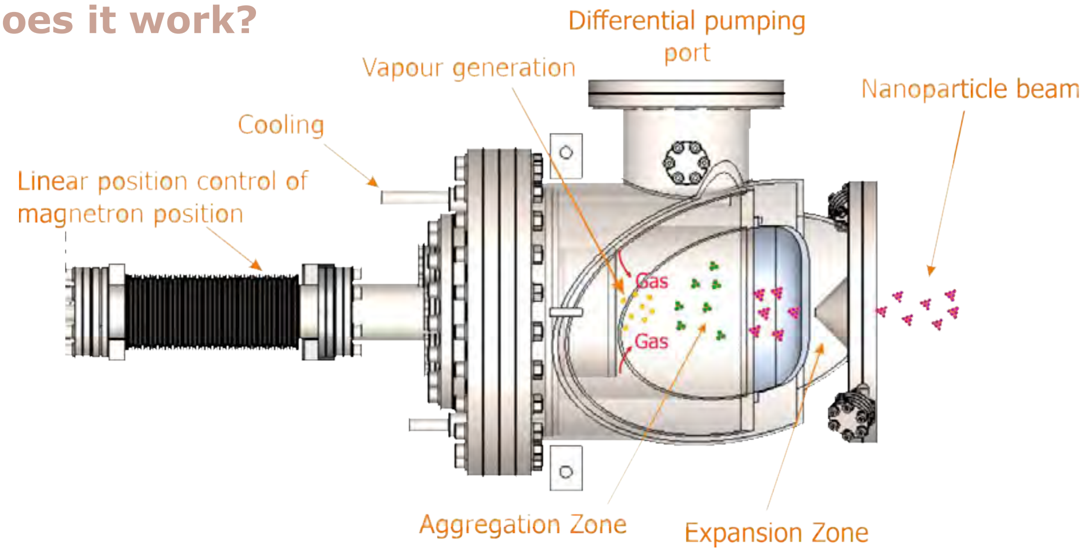
NANOPARTICLE DEPOSITION SOURCES

Generate and deposit ultra pure nanoparticles directly onto your sample to create functionalized surfaces for ...

ENVIRONMENT SENSORS ENERGY ELECTRONICS
BIOMATERIALS PHOTONICS



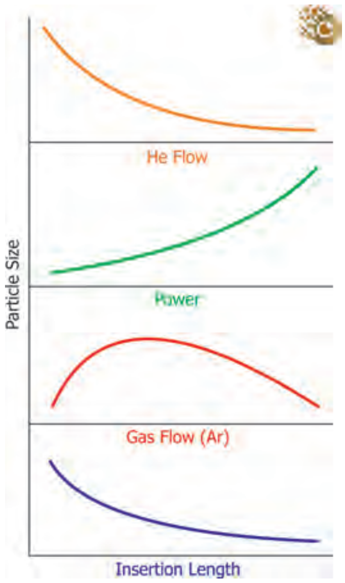
How does it work?



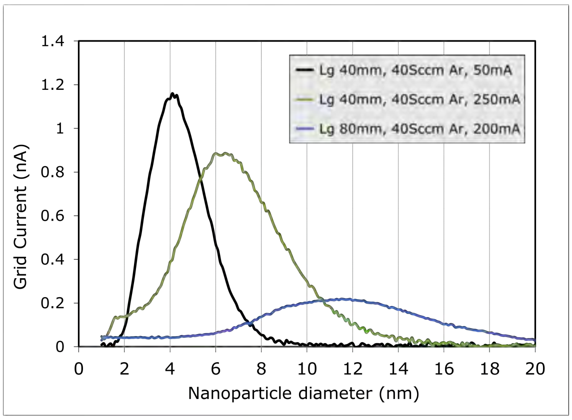
The NL-UHV series of deposition sources generates a beam of nanoparticles in vacuum from ultra pure source materials using a combination of plasma assisted sputtering and **gas phase condensation**. A magnetron, mounted on a linear drive, is inserted into the LN2 or water cooled Aggregation zone. Sputter gas is introduced into the Aggregation zone to produce a high pressure (~0.1Torr) and the subsequent application of a dc power to the magnetron generates a plasma. Atoms sputtered from the high purity target enter the high pressure aggregation zone where they quickly thermalize and coalesce to form nanoparticles. The nanoparticle beam is then extracted by the pressure gradient, through the expansion zone and emerges in the deposition chamber.

Size control

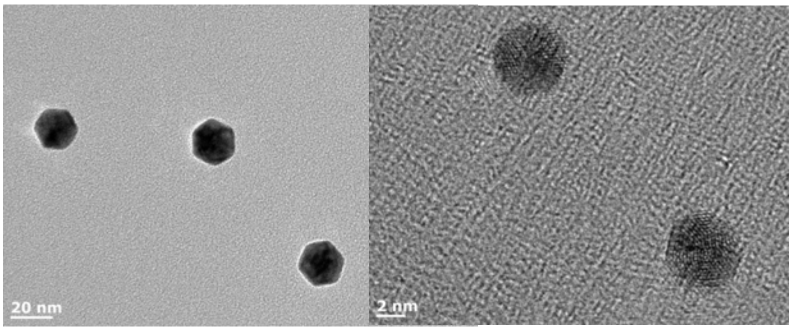
The NL-UHV source produces a distribution of nanoparticles, which can be influenced by the process conditions inside the aggregation zone. By changing the size of the aggregation zone (***insertion length, Lg***), the Magnetron ***Power***, *type of* ***Power source*** *(dc or pulsed dc),* the Argon ***Gas Flow*** or by introducing ***Helium***, it is possible to tune the distribution of the nanoparticles produced. Argon plays a dual role of increasing the available sputtered material and also at higher gas flows, to cool the nanoparticles and inhibit growth. Helium acts simply to cool the nanoparticles and thus produces a distribution of smaller nanoparticles. The aperture size at the exit of the expansion zone also affects the nanoparticle size. The NL-UHV is supplied with a selection of interchangeable aperture plates with different aperture sizes. Through varying the process parameters and apertures size nanoparticles with sizes from a few nm to 20nm can be generated.



Schematic showing generalized effect of process parameters on the nanoparticle size

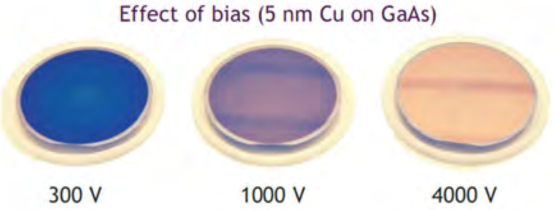


Cu Nanoparticle distribution for varying insertion length (Lg) magnetron Current (mA) and Ar gas flow (Sccm)



TEM image of 23nm Au nanoparticles (centre) and 5nm Au nanoparticles (right) produced with different process conditions

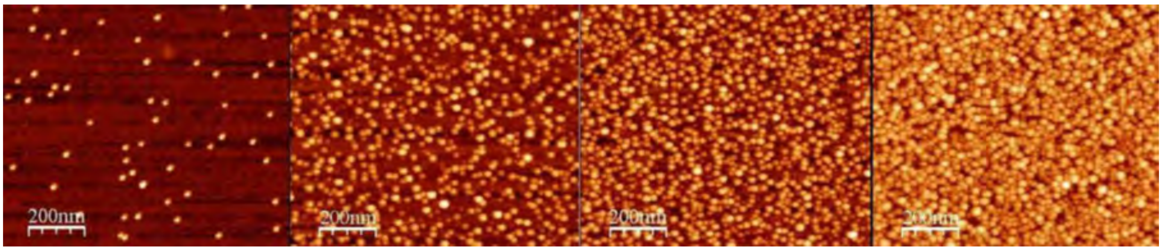
Nanocoating porosity



The NL-UHV generates both charged and neutral nanoparticles, but the larger proportion of nanoparticles carry a negative charge. The charged state of the nanoparticles means that they can be electrostatically manipulated, either through focusing, deflection or acceleration. By applying a positive accelerating bias to the sample the porosity of the deposited nanoparticle layer can be controlled. For a low accelerating bias (~few 100V) the nanoparticles are soft landed and form a highly porous layer. At higher acceleration energies (~1kV) the nanoparticles undergo a small degree of interface mixing and are more adherent to the substrates. At very high acceleration energies the deposited nanoparticle layer reverts to bulk properties and for soft substrates can even undergo implantation into the substrate material. Through control of the accelerating bias and choice of the substrate material a range of different coatings, from soft landed **nanoporous** layers (ideal for delicate substrates, such as polymers and graphene) to **highly adherent** and in some cases **implanted nanoparticle** coatings can be created. Coatings with graded porosity can also be created by varying the accelerating bias throughout the deposition.

Nanocoating Density

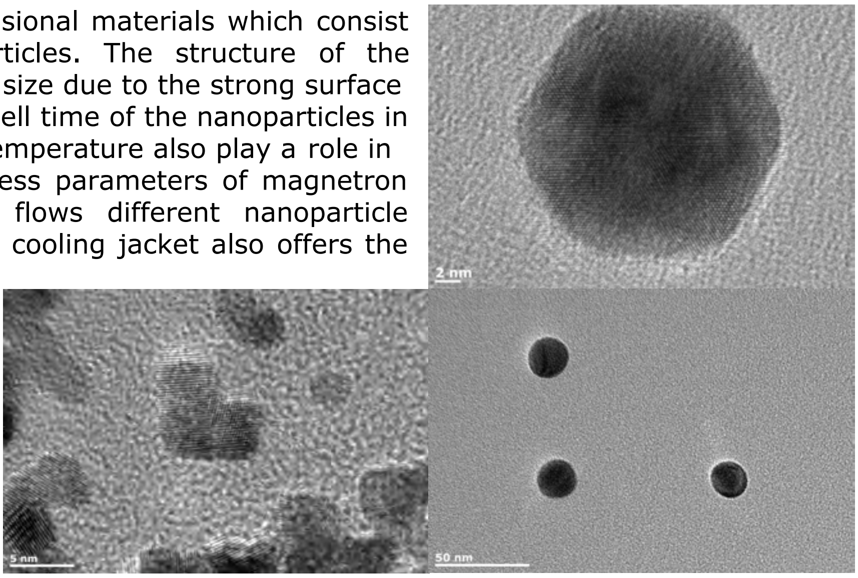
The loading and distribution of nanoparticles on the surface can be controlled to through careful control of the sample surface, nanoparticle landing energy and the deposition time. For low loadings a **monodisperse** coating of equally spaced nanoparticles can be generated. For longer deposition times the spacing between nanoparticles is reduced and in some cases the nanoparticles will start to interact and coalesce to form larger agglomerates on the surface.



AFM image of Ag nanoparticles with increasing deposition density (left to right)

Nanoparticle structure

Nanocoatings are typically three dimensional materials which consist of crystalline or amorphous nanoparticles. The structure of the nanoparticle is heavily influenced by its size due to the strong surface energy compared to 2D or bulk. The dwell time of the nanoparticles in the aggregation zone and the plasma temperature also play a role in formation. Through tuning of the process parameters of magnetron power, aggregation length and gas flows different nanoparticle structures can be formed. The NL-UHV cooling jacket also offers the option to choose between water cooling or LN2 cooling. The use of **LN2** cooling allows extended control over the temperature of the aggregation zone, which can be particularly useful for materials such as Si that nucleate (form nanoparticles) at very low temperatures. LN2 has been shown to increase the deposition rates of Si by several orders of magnitude.



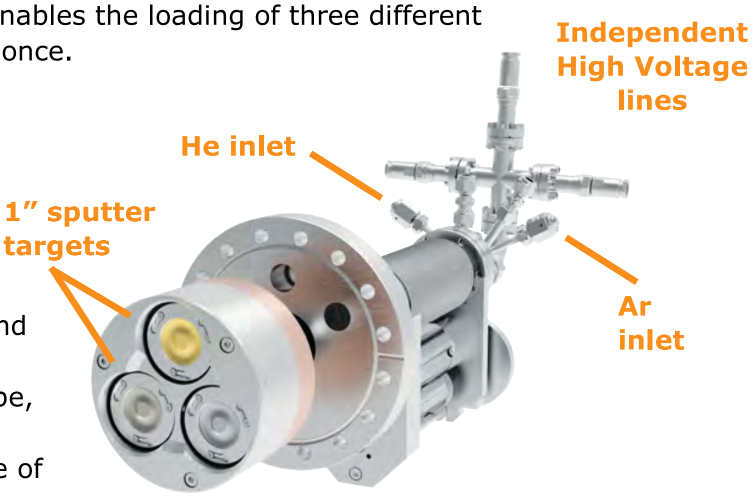
Cubic platinum nanoparticles (left), spherical silver nanoparticles (right) and icosahedral gold nanoparticle (top)

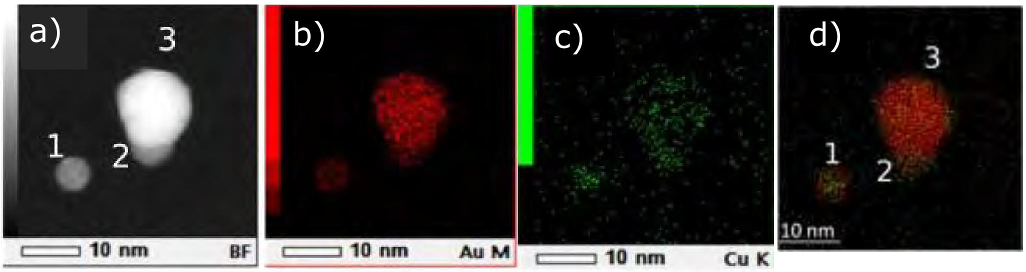
Alloy and hybrid nanoparticles

The NL-DX3 is a triple headed source which enables the loading of three different target materials into the aggregation zone at once.

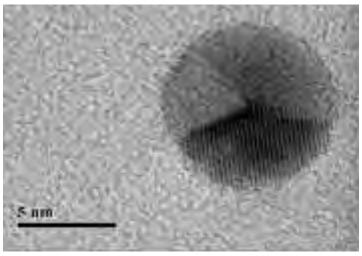
- Independent power control of each target
- Generate complex alloy nanoparticles
- Alternate between materials in vacuum
- dc or pulsed dc operation

The DX3 offers the chance to explore alloys and mixed materials. Through careful control over the deposition parameters of gas flow, gas type, aggregation length and the power supplied to each source the user can deposit a wide range of complex structures.





HRTEM and EDX images of Cu-Au nanoparticles generated with the DX3. Bright field image (a), spatial distribution of gold atoms (b), copper atoms (c) combined distribution of gold and copper atoms (d). ***J. Phys. Chem. C 2019, 123 (43), 26481***



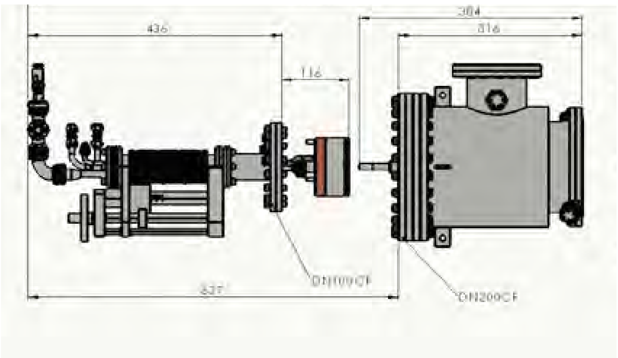
TEM image of Mo-Au nanoparticle generated with the NL-DX3.

Possible Complex nanoparticle structures

The structure and composition of the nanoparticles generated using the DX3 is strongly governed by chemistry as well as thermodynamics inside the aggregation zone. Due to the high surface energy at the nanoscale, materials no longer follow well known bulk phase diagrams. For very small nanoparticles the high surface energy can drive phase separation leading to the formation of core shell structures.

- Core–shell
- Alloy
- Phase separated
- Multi-core structures
- Phase separated
- Generate complex alloy nanoparticles
- Alternate between materials in vacuum
- dc or pulsed dc operation

NL-UHV Specifications



Modular dimensions of the NL-DX3 and NL-UHV.
Note: All dimensions are outside vacuum

Mounting Flange	DN160CF		
Power	630V Dc or pulsed DC		
Gas	Argon/Helium, 2-100 sccm		
Cooling Jacket	Water or LN2. Flow rate 2L/min (0.52 US GPM)		
Pumping	120L/m (4.2 CFM) backing pump 300L/m (10.6 CFM) Turbo pump		
Source Options	**NL-D1**	**NL-D2**	**NL-DX3**
Source Output	75W dc	100W dc	3x75W dc
Sputter targets	1 x 1”	1 x 2”	3 x 1”
	0.5 - 3mm thick		