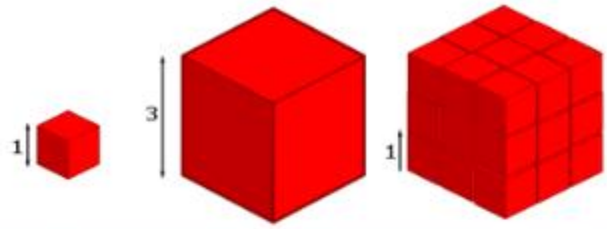
Why SEM is a valuable characterization technique for nanoparticles

By Antonis Nanakoudis - May 4, 2017

The continuous increase of microscopic particles' use in a huge range of applications has created the need of accurate control of their properties. I will explain why the use of precise monitoring and characterization of particles is required and how scanning electron microscopy can prove to be a valuable characterization method for you. Especially due to its versatility and superior spatial resolution.

The term "particle" is quite a general term as it describes any discrete sub-portion of a substance. It can range from the subatomic scale with the study of particles (size of 10^{-15} m), to the microscopic range with atoms (0.3Å) and molecules (nm-μm), up to the macroscopic scale that can include particles of dust, dirt, skin (mm-cm) or even planets of a galaxy (~ 10^{-6}m in the case of Earth). So, the understanding of a precise definition for "particles" is quite a difficult task. Therefore the common understanding is that particles can vary greatly in terms of size and shape.

But let's focus on one of the categories of particles as described above, the microscopic particles. This category of particles is exceptionally interesting since they are used in a huge range of applications, such as ceramics, the food industry, electronics, polymers and plastics, cosmetics and pharmaceuticals. It has been proven that the size and shape of such particles influence the properties of the materials. In principle, most of the materials are size dependent; the physical properties of materials at the nanoscale can differ from the constant physical properties of the same material existing in bulk form. There are several factors for this behavior. First, as we move to nm dimensions, classical mechanics can no longer describe the processes and should be replaced by quantum mechanics. Moreover, the surface to volume ratio increases greatly, potentially affecting certain properties of the materials (Fig 1).



Surface	1x1x6x1= 6	3x3x6x1=54	1x1x6x27= 162
Volume	1x1x1 = 1	3x3x3 =27	1x1x1x27 =27
S/V	**6**	**2**	**6**

Figure 1: Increased surface to volume ratio for materials comprised of particles compared to bulk.

There are many examples of nanomaterials with altered properties compared to their bulk counterparts. For instance, the optical properties of gold are very different in bulk and in nanoscale. We all know that gold is yellow, however this is not true for gold nanoparticles. Their color can vary from purple to red, depending on their size (Fig 2). Also, ZnO nanoparticles do not scatter visible light in contrast to their bulk counterparts, which are used for sunscreen creams.

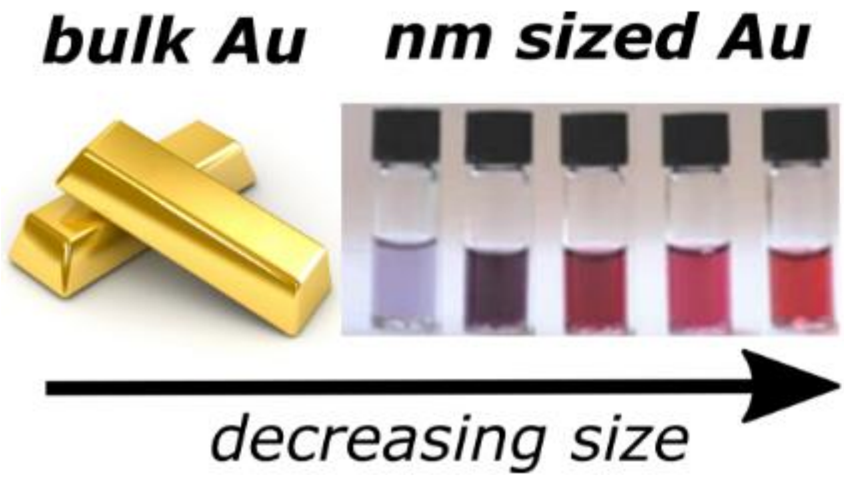


Figure 2: Change in the optical properties of gold as the size of its particles decreases.

But it is not only the optical properties that alter, the electrical properties can also differ at the nanoscale. Some materials that act as conductors in bulk can become semiconductors and vice versa. So it becomes evident that the size of the particles is an important factor that can affect their properties in many diverse applications. For example, it can affect the delivery efficiency in medical applications, the reactivity and the dissolution rate in catalytic processes, their appearance when used as coatings and inks, and the porosity of the products in ceramics. Particles of such size are very appealing for medical applications as drug delivery agents due to their increased surface to volume ratio and their ability to absorb and carry several compounds.

Besides size, the shape of the particles is also a decisive factor that can affect the properties of the materials and thus the product in which they are used. In a similar manner as size, shape can alter the texture and feel of food ingredients, the flowability and reactivity of agents used in medical or other applications. Furthermore, other particle characteristics, such as convexity and circularity, are important as they can also affect their properties.

It is obvious that the tunability of these particles is fascinating and has gathered the focus of many research groups around the world due to their great potential in applications and their huge variety. In principle, the properties of materials can be finely tuned by engineering their size and shape. To achieve this, many characterization techniques have been employed in order to obtain the so-called particle shape and size distribution. Obtaining images of particles comes along with challenges as usually a statistical outcome of the measurement would be ideal. For such purposes an automated analysis program such as Particle Metric (Fig 3) can help. It combines high-resolution electron imaging with an automated analysis and classification of particles in your image. This depends not only on their size and shape, but also many other characteristic such as the convexity, circularity, surface and volume of the particles.

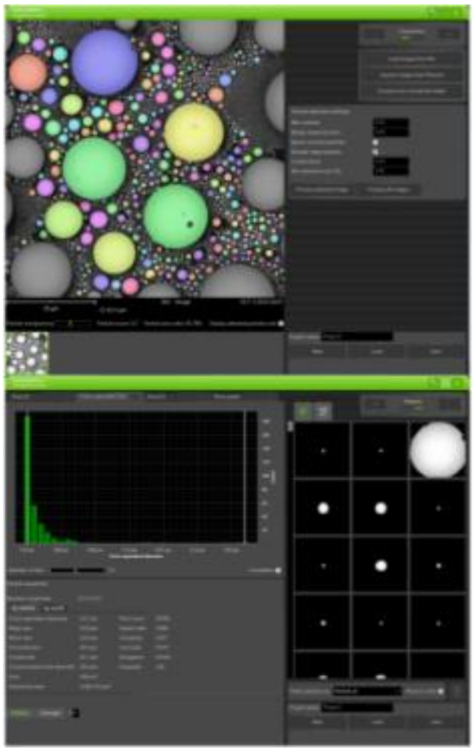


Figure 3: Particle metric workspace. On top, the acquired SEM image is processed and the particles are identified. At the bottom, the results of the analysis are shown; size and shape distribution as well as important characteristics of the particles are shown.