Newsletter 3 (PCIG N3) - 30.11.2023

Welcome to the third edition of our newsletter!

PREFACE

This newsletter aims to serve as a means of internal communication of useful information and strengthen the engagement among the group members. This quarter's newsletter with the first edition (September – November 2023) consists of three main sections:

A. Research highlights, which represents the emerging technologies in particle characterisation.

A. RESEARCH HIGHLIGHTS

Nanoparticles: Small but versatile

Written by *Merel Bout*

As we move from sub-nanometre particles (atoms) described in the previous edition, the next up on the scale are nanoparticles: a new subject applied in a wide range of fields with lots of continuous research to uncover new possibilities for them.

Representation of relative sizes of materials/objects (Image Credit: M. Bloemen (2015))

As can be seen in the graphical representation above, nanoparticles are incredibly small with dimensions typically in the range of 1 to 100 nanometres. Despite their small size, different fields can recognize that its efficacy stemmed from the high surface area of graphite layers or its particulate nature.

Nanoparticles exhibit diverse characteristics based on their size, shape, and material composition. They can be organic (liposomes) or inorganic (gold nanoparticles). Another classification is material based, like carbon, ceramics, semiconductors, or polymers. Additionally, they can be classified as hard (titanium dioxide) or soft (liposomes).

Different types of nanoparticles divided into categories (Image credit: S. Silva (2019)

Another concrete example of nanoparticles is sunscreen. In the 1990's, sunscreen contained mainly titanium dioxide and zinc oxide as physical blockers to protect against UV radiation. However, these blockers remain visible on the skin as a white cream. This caused people to avoid wearing sunscreen as users found that its cosmetic appearance was unappealing. There are now alternatives available, wherein titanium and zinc nanoparticles are incorporated into sunscreen. These particles are much smaller than those used in the original formulations, with the result that the sunscreen cream is making the cream transparent as the particles are much smaller.

(Image credit: The Guardian (2011)

Which techniques are used for nanoparticle analysis?

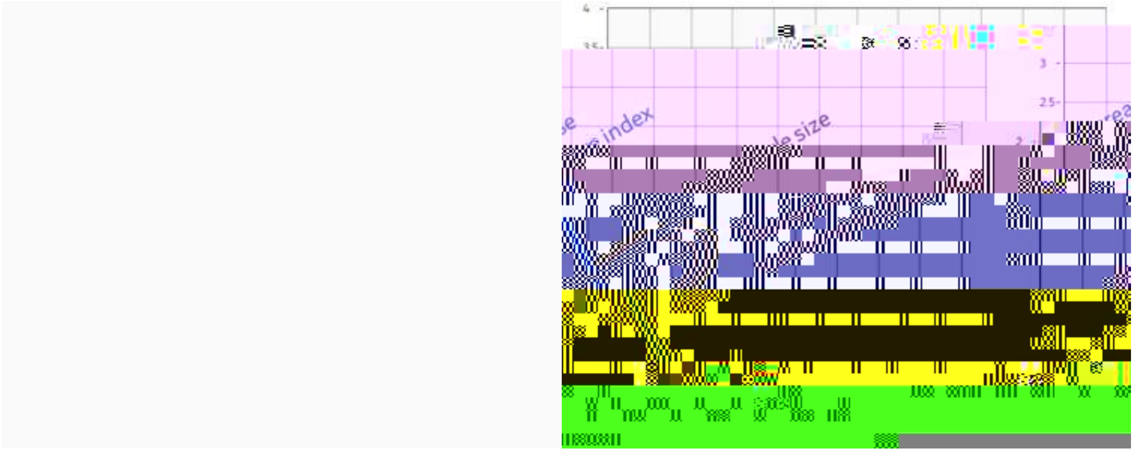
Two main categories of techniques are employed for nanoparticle detection: direct and indirect. For direct methods, microscopy techniques such as Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), and Atomic Force Microscopy (AFM) are typically used. These techniques enable imaging, size measurement, and shape inference but they are limited to studying a few particles at a time. In addition to that limitation, sample preparation for electron microscopy poses challenges such as introduction of artifacts or sample distortion. Nevertheless, these techniques are effective for obtaining fundamental nanoparticle information.

For indirect methods, X-rays or neutron beams are the techniques used to analyse the scattered or diffracted radiation from particles. Examples are: : X-ray diffraction (XRD), Small-Angle X-ray Scattering (SAXS), Small-Angle Neutron Scattering (SANS), GISAXS or GISANS (grazing incidence SANS or SAXS), and X-Ray or Neutron Reflectometry (XR/NR). The advantage of these techniques are that they enable simultaneously sampling and averaging large numbers of nanoparticles without specific sample preparation. Additionally, these techniques provide information about the composition and crystal structure of the samples as tested.

Currently, research efforts focus on the improvement of production methods aiming to synthesize a range of different nanoparticle types with appealing characteristics. This focus can then drive further advancements in a large variety of scientific and industrial fields.

References:

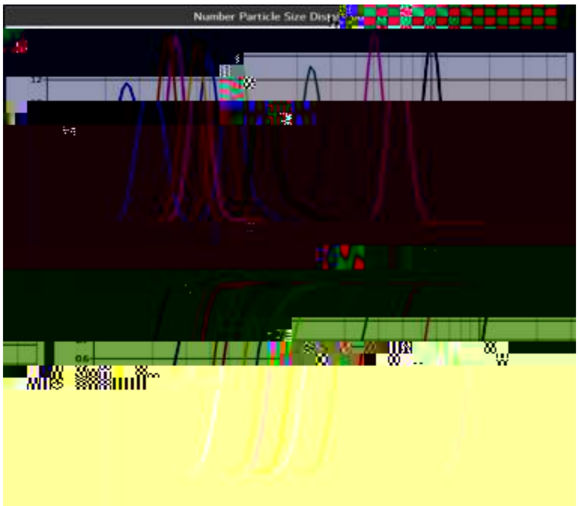
1. https://www.researchgate.net/publication/281278530_Immunomagnetic_separation_of_bacteria_by_iron_oxide_nanoparticles#fullTextFileContent



The refractive index is related to the particle's properties.

The two parameters (C_{ext} and α) are plotted as X and Y coordinates, respectively, to produce a two-dimensional histogram plot for all the particles in the measured sample. From the plotted coordinates, clouds develop on the histogram which are based on the optical properties of the particles within the sample. Particles of the same composition but with varying sizes produce elongated clouds, while particles of different compositions give rise to separate clouds on the histogram. From these histograms, the grey tones of the clouds indicate the numerical concentration of the particles at different sizes. Clouds can be isolated by the software and the characteristics of the particles within the clouds determined. These characteristics include but are not limited to particle size distribution, numerical concentration, sample loading and coating, as well as particle agglomeration.

Analysis can be performed on single samples or acquired in continuous flow analysis mode and particle size distributions can be determined as shown below.



Particles of different compositions produce separate clouds on the histogram.

How do you (re)gain your motivation in work/research at some challenging time?

Jon Binner (now at the University of Birmingham) told me "Never take yourself too seriously". If you have a big ego you have a long way to fall when you fail or start to struggle! Humility helps. I would also say walk away from the challenge for a while then come back refreshed.

Can you share with us the inspiring quote(s) that you will never ever forget?

I'll give you two! "Knowledge is Confidence". So, the more you work in your chosen area, the less likely you are to come across challenges that floor you. Instead, you are more likely to have previous experience to call upon and re-apply.

Inspiring stories

Do not hesitate to share your stories to motivate other researchers and students. You can write about the people, the events that motivated you throughout your learning, working and research (either the good or the bad things happened). We look forward to hearing from you.

C. UPDATE CORNER

A: It was a two-day event comprising a mixture of oral presentations and posters. The sessions featuring quickfire, 5-minute presentations (ideal for students who had just started their research work) were especially informative. Attendees were almost exclusively academic. The quality of presentations was excellent with a sound awareness of the healthcare needs and novel end products that research could ultimately deliver.

Image credit: Photo provided by Phil

Q: So, what are some of the key healthcare needs?

A: There was a lot of research presented on bone replacement driven by osteoporosis and diabetes. Including anti-bacterial coatings to prevent infection after implant was a strong driver as was the need for making gradient materials to mimic bone to soft-tissue cartilage junctions. Other hot topics included wound dressings, avoiding urinary tract infection from catheters, alternatives to antibiotics (in, e.g. inhalable drugs) and getting therapeutic actives to a key target area in the body.

Q: Where do you see particle characterisation playing a significant supporting role in biomaterials development?

A: The short answer is "everywhere"! But there were some especially strong connections for me. For example, with additive manufacture (AM) using powder / polymer composites featuring strongly in biomaterials research, understanding how weight% powder and powder particle size distribution affect rheological properties at room temperature (e.g. AM via ink jet printing) and elevated temperature (AM using Fused Deposition) becomes important.

Nanomaterials such as nano-hydroxyapatite are being seen as an important player in targeted drug delivery, so reliable nano-particle sizing becomes a strong need. The ability of the afore-mentioned nano-particles to attract and hold optimum levels of drugs or (positively charged) anti-bacterial agents depends very much on the initial surface charge (ζ-potential). Nano-

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