The Nanoparticle Toolkit (extended abstract)

Introduction

The advances that have been made in the understanding of nanoparticle properties have lead to an explosion of interest into how these materials might be used commercially. A rapid scan of the literature reveals a multitude of proposed uses for these materials. Richard Feynman's clarion call that there's plenty of room at the bottom appears to be the guiding phrase for this wonderful new area of technology.

However we can also take an alternative view: reality is another country, they do things differently there. There are a plethora of nanoparticle papers promising property enhancements beyond the technologists' wildest dreams. But, in this speaker's opinion, the transfer from promise to reality has been less than might have been hoped. This is not to say that significant advances towards commercialisation have not been achieved. Genuine nanoparticle technology is being used in the formulation of self-cleaning glass, in the formulation of protective coatings for wood, and in the fabrication of stronger tennis racquets, amongst others.

The successful use of nanoparticles requires the formulator to take into account one important fact. These materials cannot be treated conceptually or physically in the same manner as macro sized particles; they are not just smaller versions of normal particles. I believe that this is a factor that is often overlooked when their use is considered and presents a barrier to their successful utilisation. I cannot hope in this short talk to do justice to the subtleties that surround this area, but hopefully it will provide an insight into certain simple precautions that might prevent a brilliant idea from becoming an intractable mess.

Discussion

As mentioned previously a wide range of nanomaterials have been synthesised; however not all of these are readily available commercially. It is often overlooked that for a successful commercial coating process you need a source of raw materials that can be delivered with consistent quality. This is not easy to achieve for materials that are "fresh from the development lab". The manufacture of a raw material might be perfectly tractable at the scale of several grams, but scaling up to the kilogram scale and beyond is not a necessarily a simple matter. This fact must be taken into account when any coating process is considered.

Also to be remembered is the fact that there are issues to be considered when using nanoparticle powders; especially those of dispersion and health and safety. In many respects it is more useful to use dispersions of nanoparticles, but the number of commercially available nanoparticle dispersions is less than that for powders. It is also a fact that the solvent

present in the dispersion might not be suitable for the particular manufacturing process under consideration. This is a further issue which must be confronted.

Above all, in nanoparticle technology, size matters. As the particle radius decreases the relative surface area increases by a factor of 3/r; stated simply smaller particles have more surface area relative to larger particles. This leads to the following important points that must be remembered by anyone who wishes to use nanoparticles as part of a formulation. It should also be noted that these points are common to all nanoparticles.

1. Reducing particle size leads to relative increases in surface area.
2. Increases in surface area lead to greater inter-particle attraction.
3. Greater inter-particle attraction can lead to particle agglomeration.
4. Agglomeration leads to instability and failure of the formulation.

These simple issues are surprisingly often overlooked when the use of nanoparticles are considered.

To combat the effects described above it is invariably the case that stabilisation of the nanoparticle is required. Much serious effort has been expended in developing stabilising agents for nanoparticles and discussions on this topic could well fill an entire conference. For the purposes of this talk it is important to remember a few more points.

1. There is no universal stabilising agent.
2. The nature of the stabilising agent will depend on the particle under consideration.
3. It is vitally important that the particle and the stabilising agent are considered as a whole.
4. When formulating with nanoparticles the stabilising shell must enter consideration; it is not passive.

Even when a stable formulation has been achieved risk has not been removed. The following important point is very easy to state, but much more difficult to implement.

1. The nanoparticle formulation must be considered as part of an entire coating process.

This holistic approach sounds very simple to achieve; in practice it is rather more problematical. There are often parts of the coating process that do not produce any issues with “standard formulations”, but which can introduce the possibility of mix destabilisation for nanoparticle dispersions. If this occurs during a production trial this, at the very least, incurs significant cost and possibly the cancellation of the project.

There is no simple remedy to avoiding the problem stated above other than meticulous attention to detail and a willingness to understand more thoroughly what might be considered to be a well understood process.

Conclusion

If these factors are remembered then the successful use of nanoparticles is not guaranteed; however many simple mistakes may be avoided and the chances of successful implementation are significantly increased. There's still plenty of room at the bottom, but you just might find yourself with a ladder to formulate your way out of the basement.

Dr Nigel H Holmes
MacDermid-Autotype
Grove Road
Wantage
OX12 7BZ
UK

Tel. +44 (0)1235 771111
E-mail. nholmes@macdermidautotype.com