Whither 'nano' or 'bio'? | Rob Ritchie

While the nano revolution has taken materials science by storm, it is the union with biology that has real potential for life-changing advances

Rob Ritchie | *University of California, Berkeley and Lawrence Berkeley National Laboratory* | roritchie@lbl.gov

So what's all this *hype* about 'nano' and 'bio'? These days, rarely a sentence is uttered by a materials scientist that doesn't contain one or both of these words. Indeed, I've heard numerous people glibly state that, unless the title of your proposal has 'nano' or 'bio' in it, it has no hope of being funded. What is more alarming is that they're probably right!

The nano revolution has certainly taken our field by storm. One constantly hears of the new paradigm – we're going to design new materials 'atom by atom'. But of course, this is hardly the best way to fabricate a wrench! And most materials scientists tend to groan inwardly as they feel that they've been doing this all along. Isn't materials the science of relating macroscopic behavior to micro- or nanostructure?

The recent emphasis on the nanoscale has clearly been vital to certain aspects of our field. Nowhere is this more important than in electronic materials, where we are destined to follow the endless quest to maintain Moore's Law by cramming more and more devices onto a single chip, notwithstanding the problem of adequate heat sinks. But, in my own discipline of mechanical and structural behavior, one could sensibly come to the conclusion that, in large part, this has not been the right way to proceed. In essence, small is not necessarily beautiful!

While funding agencies hastily reprogram important and industrially relevant research topics, such as the development of structural materials that can safely operate above 1100°C or environmentally assisted fracture in metallic alloys, to jump on the nano bandwagon, we are confronted with pronouncements (even from politicians) that nanotechnology will lead to lighter, stronger, and tougher materials, etc. But where is the evidence for this?

Shrinking the structure of a material to nanoscale dimensions certainly will increase the strength, but few of our advanced structural materials are 'strength challenged'. On the contrary, they are invariably lacking in toughness. And, if nanostructured materials have one thing in common, it's poor toughness! Exactly why this is so has not been totally sorted out, although high strength is rarely associated with high toughness. In most micromechanical models for the many mechanisms of fracture, toughness scales with the square root of a characteristic structural length dimension. Although structural scale influences strength and ductility, which will also affect toughness, it seems that the severe reduction in this characteristic dimension is a major factor that leads to the brittleness of nanostructured materials.

Unless your proposal has 'nano' or 'bio' in it, it has no hope of being funded

To my mind, the bio revolution is infinitely more encouraging. The union of biologists and physicians with engineers and materials scientists is already paying significant dividends. Witness the endovascular/cardiovascular stent – ten years ago the word was hardly in the English language and now it represents a >$7 billion industry that is saving lives with minimally invasive procedures.

Indeed, since few biologists or physicians know much about engineering, and even fewer engineers know anything about medicine, the potential for future advancement seems boundless. Moreover, there's the funding: the aerospace, automobile, and power industries may wax and wane but people will always be concerned about health. This is reflected in the ever-increasing National Institutes of Health research budget each year.

What is perhaps most important is that there is a natural place for the materials scientist in the design of improved implant materials, the development of life-prediction strategies to assess how long implants will last, and, in what is perhaps the most exciting area, the realization that the aging of biological tissue and many disease states can be traced to changes in the physical and mechanical properties of tissues. Our biologist friends may find this highly unesoteric, but malaria and certain cancers are now known to have a profound influence on the stiffness and deformability of cells, radically affecting their mobility. Similarly, the well-known increase in the fragility of human bone with age, particularly in women, is now realized to be a result not simply of loss of bone mass but also of a marked age-related degradation in fracture toughness.

So, while the nano revolution may fade away in a few years in search of a smaller, as yet unnamed, dimension, the bio revolution is, to use an Americanism, *for real*. Mark my words – a significant proportion of the next generation of students will be biomaterials scientists, and this can only be good for our field.