EDITORIAL

A fertile domain for nanoscience

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Since Democritus first proposed the hypothesis that matter was comprised of indivisible ‘atoms’, the concept of the atom has been constantly re-invented. In the early twentieth century the ‘plum pudding’ description of atomic structure as a sphere packed with ‘currants’ of positive and negative charge was replaced by a structure largely comprised of empty space with orbitals of electrons surrounding a nucleus of positive and neutral particles. In 1937 a group of investigators at Columbia University demonstrated that not only electrons but even neutrons possess an intrinsic magnetic moment [1]. Introducing a magnetic field on a liquid sample such as water, in which the nuclear magnetic moments of the protons are randomly oriented, causes a tiny surplus of the moments to become aligned parallel with the applied field. When this field is removed the sample releases a detectable signal. Nowadays such magnetic resonance effects are routinely used in medical imaging and diagnostics, and constitute a field of fruitful activity in nanotechnology research.

As with most physical concepts, magnetic properties of materials reveal various subtle intricacies as the dimensions are scaled down to nanometer sizes. In very small magnetic materials less than 50 nm in size the magnetic moment can reorient spontaneously, an effect referred to as superparamagnetism, first demonstrated by Elmore at Massachusetts Institute of Technology [2]. Advances in nanoparticle synthesis procedures have allowed a greater control in the distribution of physical parameters, such as size, shape, crystallinity and coating, making it possible to study the effect that varying these parameters has on the magnetic properties, such as the saturation magnetization and susceptibility [3].

There has also been progress in developing techniques to prepare magnetic nanoparticles in different forms, such as stably dispersed in an aqueous solution [4]. The ability to form a stable aqueous dispersion of magnetic nanomaterials is essential for a wide range of environmental and biomedical applications, including magnetic resonance imaging. The magnetic nanoparticles used in magnetic resonance imaging have themselves become increasingly sophisticated. Size effects can be exploited, and dextran coatings have been used to allow the particles to be conjugated with a variety of antibodies, peptides and proteins for targeting specific tissues [5]. However the dextran coating contributes significantly to the particle’s size, which may limit tissue distribution and metabolic clearance. An alternative is to coat magnetic iron nanoparticles with gold. The gold can be conjugated with biomolecules and provides a potential platform for optical absorption and emission caused by the collective electronic response of the metal to light [6].

The optical contrast potential of gold-coated nanoparticles has now been demonstrated by researchers in Texas [7]. The plasmonic gold layer presents opportunities for use in photothermal therapy applications. The thermoresponse of magnetic nanoparticles has been the subject of much promising research activity and hyperthermia cancer treatment has been demonstrated using multimodal magnetic nanoparticles [8,9]. In the US, a collaboration of researchers has developed a new multimodal technique that uses ultrasound imaging of magneto-motive excitation to identify tissue-based macrophages containing iron oxide nanoparticles [10].

The potential of magnetic nanoparticles has beguiled many scientists into highly rewarding avenues of research over recent years. In this issue researchers at the Tokyo Institute of Technology and Toyohashi University of Technology...
provide an overview of the role of functionalized magnetic nanoparticles in biorecognition and medical diagnostics [11]. The review covers topics from synthesis and functionalization procedures to Hall biosensors and a label-less homogenous procedure referred to as ‘magneto-optical transmission sensing’, where the optical transmission of a solution containing rotating linear chains of magnetic nanobeads is used to detect biomolecules with picomolar sensitivity and a dynamic range of more than four orders of magnitude.

In 1944 Isidor Isaac Rabi won the Nobel Prize for physics in recognition of his work in developing a resonance method for recording the magnetic properties of atomic nuclei. He recognized the possible application of his work in time keeping but it was not until the work of later researchers that the potential in medical imaging became apparent. Decades later, in 1988 Rabi was reported to have said: ‘It was eerie. I saw myself in that machine. I never thought my work would come to this’ [12]. The comment was provoked by the sight of a distorted image of his face, reflected on the inside cylindrical surface of a magnetic resonance imaging machine. Rabi died a few weeks later, but his work and that of fellow scientists have brought advances in medical imaging that have enabled the detection of malignant disease at early treatable stages. That his contribution has allowed timely diagnosis and treatments that have saved countless lives brings an added poignancy to his words. And there are, no doubt, many more breakthroughs in medicine and technology to come.

References