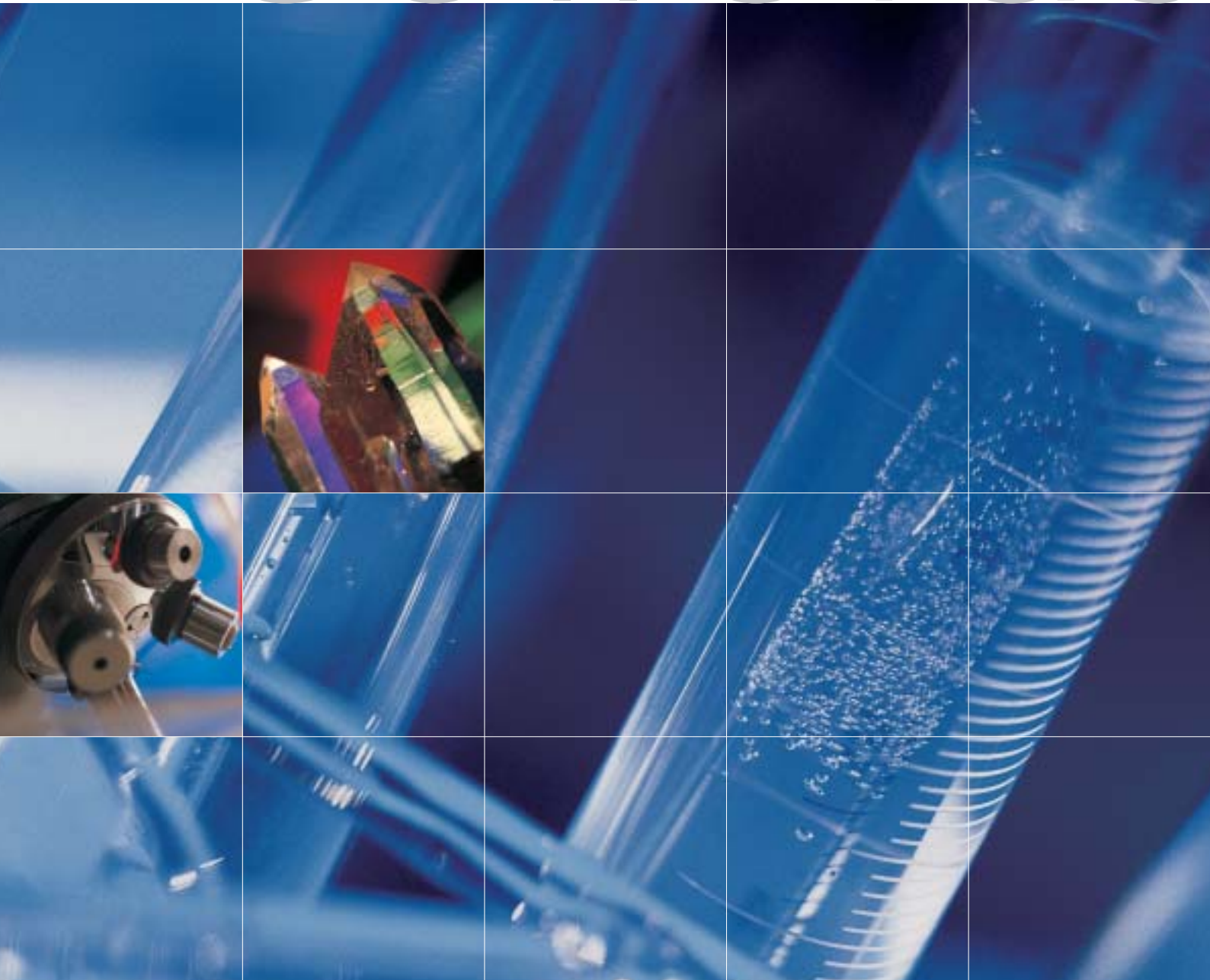




UNIVERSITY
of BRISTOL

Working with

COLLOIDS



The Colloid Group and
Bristol Colloid Centre working
together to offer the best in
research and development.



Introduction

The Colloid Group and Bristol Colloid Centre form part of the School of Chemistry at Bristol University. The School is one of the largest in the UK and is an internationally recognised centre of excellence for research and teaching. In 2001 it was awarded the highest grade of 5* in the national Research Assessment Exercise of the Higher Education Funding Council for England. Only five other UK chemistry departments have reached this grade.

Colloid and interface science at the University of Bristol has a rich and continuous history going back nearly 100 years. The five successive Leverhulme Professors of Physical Chemistry during that period have all been researchers in this area. Nowadays the Colloid Group at Bristol is regarded as one of the strongest in the world.

In 1993 the Bristol Colloid Centre (BCC) was set up to meet 'outsourcing' needs of large companies and problem solving needs of SMEs in the area of colloid and surface science. Together, the Colloid Group and BCC offer industry the best in research and development.

Colloid Group

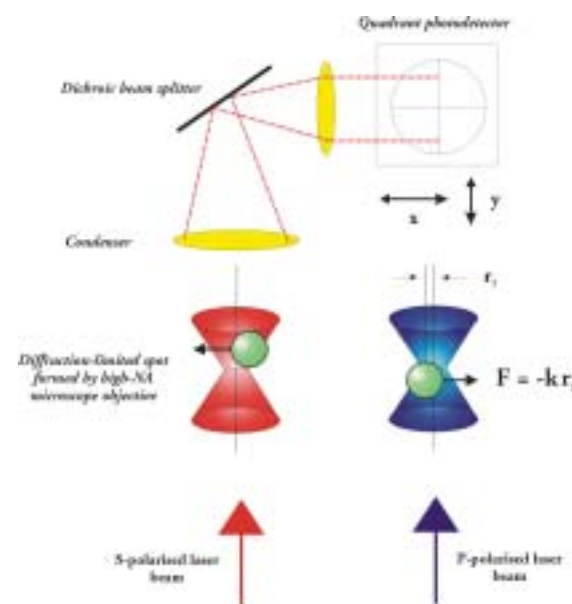
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Colloidal Structure and Dynamics

The colloidal state is ubiquitous in nature and manufacturing. It occurs in sectors as diverse as food products, paints, shampoo, pesticides and pharmaceuticals. The unifying connection between these diverse applications is the need to image and ultimately manipulate the structure on a mesoscopic length scale, which we may conveniently define as between 1nm and 10µm.



At Bristol, we are very fortunate in having access to an extensive suite of structural techniques including neutron, X-ray and light scattering, NMR and confocal imaging, which together allow us to span the whole colloidal length scale. Here we illustrate the potential of these techniques to provide insights into the complex behaviour of colloidal systems with examples taken from current research at Bristol.

The structure of colloidal gels

Gels are a common constituent of many industrial processes and products yet our understanding of their microscopic structure is surprisingly limited. To remedy this situation, we have recently begun to use confocal microscopy to image the three-dimensional microstructure of gels on scales from 0.1µm to 50µm. Our focus is on using this information to provide new insights into the time dependent rheological properties of these intriguing phases.

Colloid-liquid crystal composites

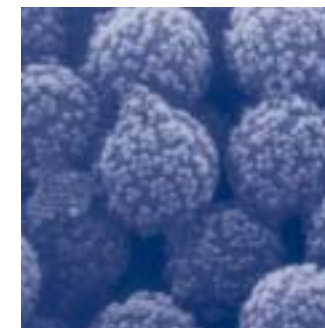
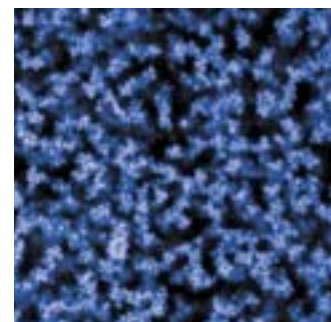
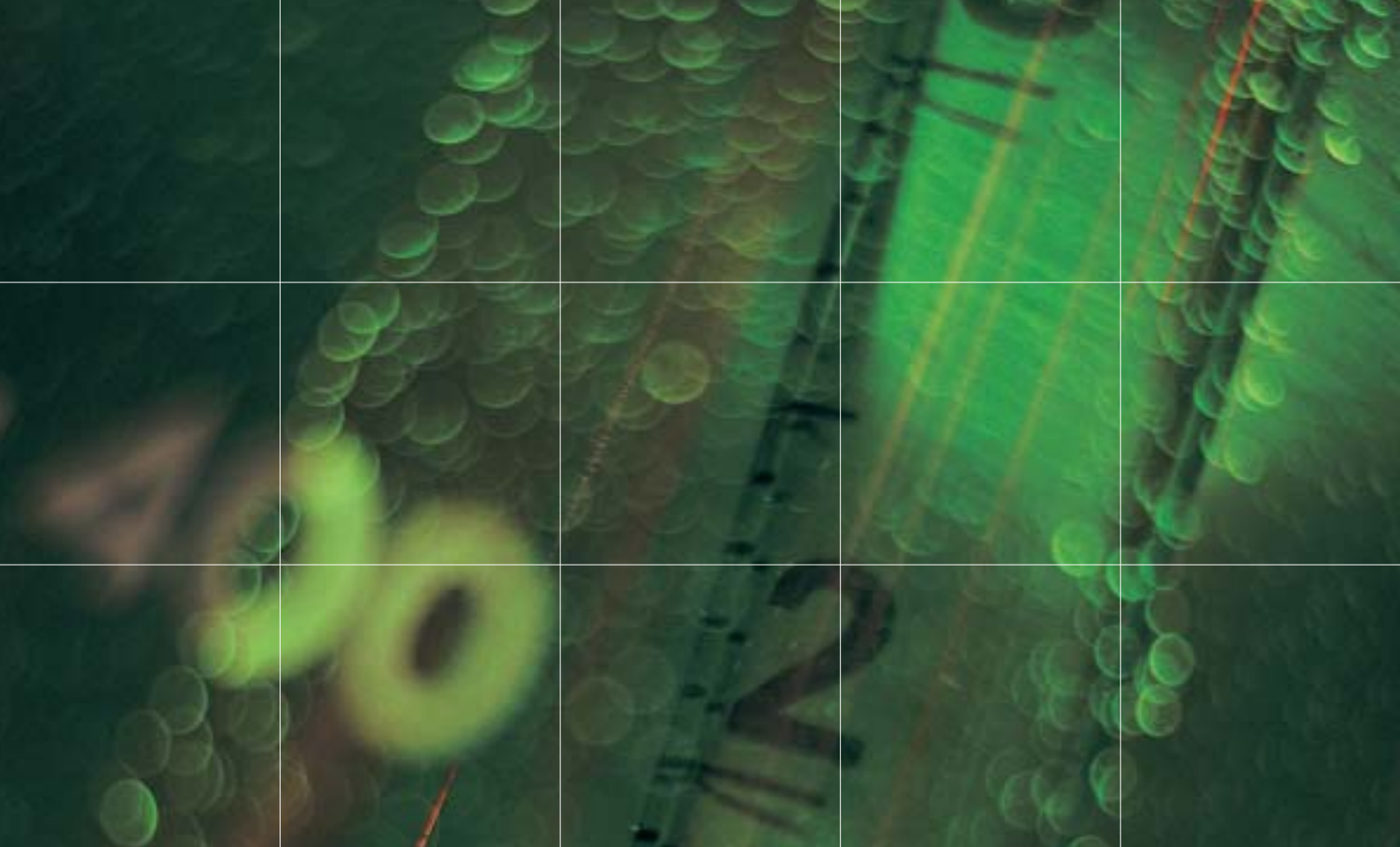
Dispersions of colloidal particles in a liquid-crystalline solvent have generated considerable interest as potential substrates for new electro-optic displays. We have been exploring the anisotropic forces between colloidal particles suspended in liquid crystalline phases by using optical tweezers (see diagram).

Introduction to the Colloid Group

The academic group covers a wide area of research, ranging from synthetic methods through physical measurement to theory and modelling. The group has strong links with the Department of Physics, the Interface Analysis Centre and the Centre for Organised Matter Chemistry.

The laboratories of the Colloid Group and BCC are equipped with some of the latest instrumentation covering virtually all the modern techniques in the area:

- static and dynamic light scattering
- acousto- and electrokinetic methods
- rheological techniques
- SAXS
- pulsed-field-gradient and solid state NMR
- ellipsometry
- optical and electron microscopy
- confocal microscopy
- photonic force microscopy
- atomic force microscopy
- surface and interfacial tension
- SANS and neutron reflection (NIST, ILL, ISIS)



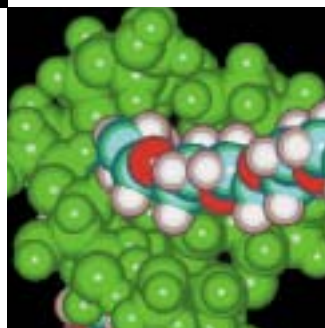
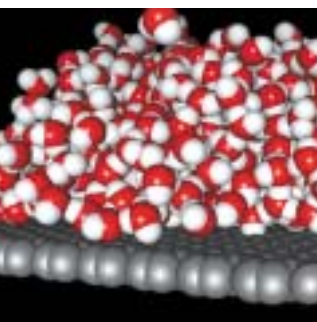
Computer Simulations

Molecular modelling using our own computer programs and commercial packages can simulate many aspects of colloid science. Molecular dynamics and Monte Carlo methods have been used to investigate a very wide range of colloidal systems.

By studying molecular conformations and dynamics it is possible to interpret and predict important practical properties of dispersions such as system stability and interfacial structure. For example, there are experimental systems which show shear thinning, shear thickening and thixotropy. The underlying interactions which govern these effects are not well understood and with computer simulation it is possible to understand these effects in terms of interfacial structure and aggregation.

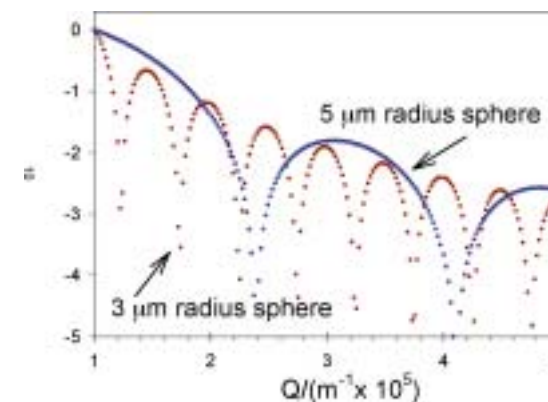
Additional examples of colloidal systems being investigated using molecular dynamics include the study of polymer species at surfaces. From these simulations it is possible to determine the underlying driving forces for dispersion and flocculation. In particular, polymers on the surface of clays have implications in the ceramic, paper, fabric and petrochemical industries. Simulations of large surfactant layers have been performed investigating effects of solvent, salt and concentration. Modelling surfactants can help establish under which conditions micellisation will occur. Further studies include the threading of sugar molecules onto polymer chains and the simulation of wetting by creating nanodroplets on surfaces.

Molecules or particles that are strongly non-spherical, that is either rod-like or disc-like, tend to form liquid crystalline phases that display a degree of order in between an isotropic liquid and a crystal. We use Monte Carlo computer simulations to study how the properties of molecules, such as their shape, flexibility and the presence of polar groups influences the structure and behaviour of the liquid crystalline phases. Lyotropic liquid crystalline phases can also be formed in suspensions of non-spherical particles. The behaviour of colloidal platelets, to which non-adsorbing polymer is added to induce depletion attractions, is also an area of current interest.



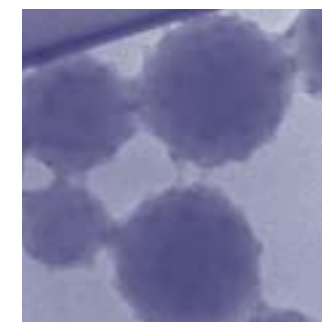
Polymer Complexes at Interfaces

The structure of an adsorbed layer can be viewed on various length and timescales and these features can be resolved using a combination of scattering, magnetic resonance and molecular simulation methods.



The motivation behind these studies is not merely academic but is based on the widespread use of surface active species in applications as diverse as cell recognition, oil discovery and drug delivery.

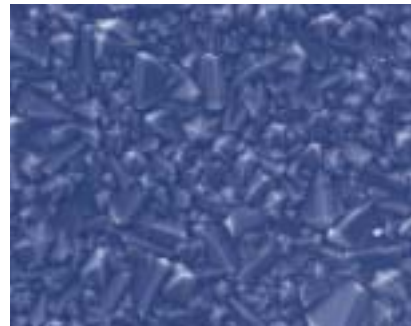
The formation of molecular complexes of polymers with surfactants, sugars and nano-particles are three new themes in the research of the Colloid Group. The simulation opposite shows an examples of the formation of a pseudo-rotaxane between poly(ethylene oxide) and α -cyclodextrin. These complexes can be formed at interfaces and used to control hydrophobicity and micelle formation. Future work is to find mechanisms to complex water insoluble polymers and to make them water dispersible.



Complexation at the interface of colloidal particles can lead to some very interesting structures. In a detailed study on the behaviour of block-copolymer polyelectrolytes at interfaces the remarkable structure shown by the electron micrograph was found. The block co-polymer micelles (small black dots) are adsorbed as charged individual spheres onto the larger spherical latex particles. The micelle spacing is determined by a balance of the interfacial energy and the mutual repulsion between the micelles. These systems are of interest in deposition studies and in a variety of industrial and medical applications.

Nanoparticles at Interfaces

Nanoparticle science is the study of materials that have dimensions less than 10nm. Semiconductor nanocrystals are presently generating excitement as they possess unique chemical and physical properties.



A SEM image of the surface of a boron doped diamond electrode.

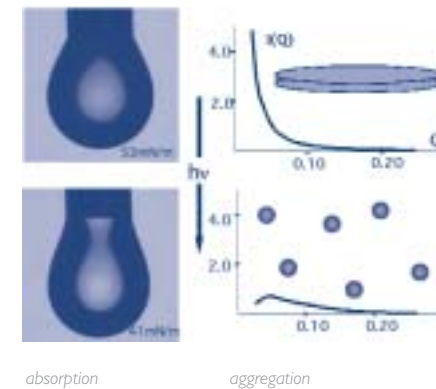
A wide range of applications for functional materials composed of nanoparticles has been predicted. In the Colloid Group methods of preparing and depositing nanoparticles onto conducting substrates are being investigated, and the resultant films are characterised using electrochemical techniques, electron microscopy and ellipsometry.

Research in the Colloid Group has focused on sols of semiconductor Q-particles, i.e. semiconductor nanoparticles that display quantum confinement effects. Methods of preparing Q-particle sols, which are stabilised with a variety of organic moieties, have been studied. We have reported how, via surface functionalisation, monolayers and multilayers of the particles may be deposited on to conducting tin oxide. Photoelectrochemical studies indicate that the methodology has permitted nanoscale heterojunctions to be prepared. Recently we have started a project aimed at assessing the possibility of depositing visible light-absorbing Q-particles on to a highly porous titanium dioxide nanoparticle layer. It is envisaged that such a structure will lead to a highly efficient solar cell.

Chemical vapour deposition has also been employed in the preparation of nanoparticle modified surfaces. We have been particularly interested in the deposition of boron doped diamond onto various substrates. The diamond substrates have been employed as heat sinks and electrodes. Electrodes formed from diamond can be metallic or semiconducting and are of interest as they are benign in a wide range of environments.

Surfactant Chemistry

Within the Colloid Group new functionalised surfactants (photo-surfactants, polymerisable surfactants, CO₂-active surfactants) have been developed for various applications. Molecular design, synthesis, NMR and mass spectroscopy are important aspects of our work.



A wide variety of techniques are employed to probe interfacial and self-assembly properties of these systems. Tensiometric methods are key to understanding these supramolecular structures. We have drop shape analysis, drop volume, maximum bubble pressure, spinning-drop and du Nouy-Wilhelmy equipment, as well as a custom-built surface light scattering rig at our disposal. Polarising light microscopy is used to characterise liquid crystal phase behaviour. Pulsed-field spin-echo NMR and small-angle X-ray scattering are used to study diffusion dynamics and aggregation. Neutron scattering methods are essential, and regular use is made of facilities at the ILL in Grenoble, France, and ISIS near Oxford, UK.

Novel Colloids

'Novel' or 'smart' colloids are those where the structure of the particles has been designed to impart some specific functionality to the system. Some recent examples developed at Bristol are:

- **Liquid Latex Particles.** We have made intrinsically charge-stabilised monodisperse emulsions of polydimethylsiloxane in water. We have also been able to cross-link the droplets. These systems are currently being used to test the theories of droplet deposition on surfaces and as models for silicone oil emulsions used in shampoos, etc.
- **Organic and Inorganic Microgel particles.** These are polymer particles that expand or contract depending on their environmental conditions. They can be used for rheology control, or for the controlled uptake and release of 'active' species, e.g. ions, polymers or nanoparticles.
- **Liquid-Core/Solid-Shell Particles.** The core of these composite particles can be aqueous or non-aqueous and the shell a polymer or an inorganic material. These materials can be used for controlled release applications.
- **Nano-sized Latex Particles.** We are able to prepare sub-10 nm latex particles without the use of large excesses of surfactant. These are currently being investigated for potential application in surface coating formulations.
- **Monodisperse Polymer Beads with Controlled Pore Size Distributions.** Used, in packed columns, for separation and catalytic applications, based e.g. on surface-bound enzymes and DNA. We have developed a rig for the continuous monomer emulsification and suspension polymerisation of these beads.

Introduction to BCC

The Bristol Colloid Centre was set up in 1993 to carry out the commercial activities of the Colloid Group. The concept of the BCC came from a demand for a short time-scale response unit to support businesses whose technology is underpinned by colloid science.

The close proximity of the long-established and internationally renowned Colloid Group is invaluable in achieving this objective. The BCC has dedicated staff consisting of a number of highly skilled and motivated scientific personnel with many years experience of both industry and academia. Professor Vincent (Leverhulme Professor of Physical Chemistry) and Professor Cosgrove are the current Director and Deputy Director; the Commercial Manager is Dr Paul Reynolds.

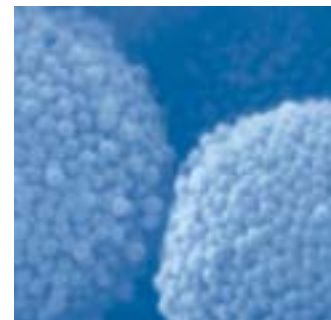
The BCC's business is to facilitate the transfer of colloid science and technology by providing industry with consultancy, research, training and information.

Consultancy

One of the greatest strengths of the Bristol Colloid Centre is its position at the heart of the Colloid Group. Whilst the BCC's permanent staff carries out the majority of consultancy work, we also have access to the expertise of some of the world's leading colloid scientists.

Drawing on this expertise means that the consultancy service is of the highest possible quality, and together with the BCC's experience of industrial applications, ensures a workable, up-to-date solution.

This relationship works well and still maintains the confidentiality required by our industrial customers.



Research

Contract research forms the primary activity of the Bristol Colloid Centre. We can tackle one-off measurements, medium-term trouble-shooting investigations or long-term generic activity.

Almost all contract work is carried out using the Centre's professional staff, but we are also able to call on the formidable resources in the Colloid Group. Whilst the research carried out by the academics in the Colloid Group has to be largely in the public domain, we can guarantee complete confidentiality. If necessary we will sign confidentiality agreements before the onset of discussing work.

Typical problems include:

Shelf-life stable products

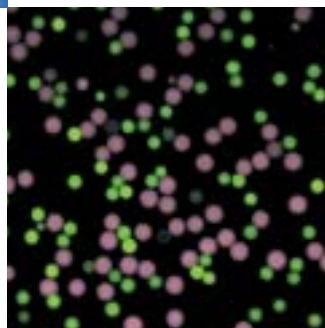
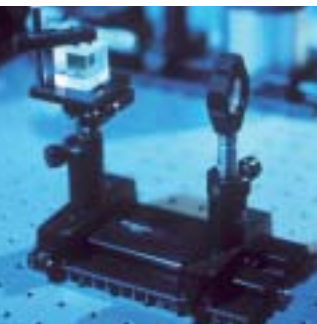
Many industries need to produce suspensions in which the dispersed phase does not sediment in its suspending medium. For example, the pharmaceutical industry is increasing its production of drug suspensions (especially for children), where they would like to eliminate the need to 'shake the bottle'.

Environmentally friendly formulations

Industries often find that replacing a component of an established formulation due to legislation (i.e. banned substances) can lead to a drastic decrease in the performance of that product. Colloid science gives an insight into the microstructural characteristics required from the replacement component. The BCC, in conjunction with an SME, has recently developed an environmentally acceptable paint stripper for use in the home, which resulted in a 'spin off' company being formed (Eco Solutions Ltd). The material has been patented by the company and has received a prestigious Millennium Award.

Designing formulations with sustainable components

Many industries use natural materials as a source of components for formulations. Colloid science can underpin the development of 'designer' molecules, which originate from a sustainable source.



Training

Despite the growing awareness that colloid and polymer science are fundamental to a large number of industries, few universities pay more than cursory attention to these areas. The demand for scientists with training in this interdisciplinary field is, however, increasing.

To redress this imbalance the Bristol Colloid Centre has developed a series of courses. The objective of these is twofold: firstly, to teach important concepts in colloid science and technology and secondly, to allow the application of these ideas to a commercial environment. The courses are firmly centred on the fundamental principles of colloid science with a wide ranging lecture programme which is combined with in-depth training in modern experimental techniques and practices. Each course incorporates a large practical element consisting of a mixture of 'hands on' experiments and instrument demonstrations. The BCC run a number of courses each year, one of which is the highly acclaimed Spring School in Colloid Science.

Courses have included:

- Dispersion Stability
- Creams, Gels & Thickeners
- Colloid Rheology – A Practical Approach
- Rheological Aspects of Formulation Science
- Solid Surface Characterisation
- Emulsions & Foams

We also organise in-house courses for companies. These can be specifically tailored to the company's needs or provide a general introduction to a wider area.

Information

An important part of our activity is to promote awareness of different aspects of colloid science. Each year we hold one awareness forum and one science day. These two events are designed as informal gatherings promoting information exchange between participants.

Awareness forums:

Awareness forums are discussions of a generic technology problem or development in an area of colloid science. They are only open to member companies of the BCC. Speakers are all experts from a wide variety of academic and commercial organisations.

Recent awareness forums:

- Total suspension stability
- Water-based formulation technology
- Particle size measurement in disperse systems
- Scattering techniques in colloid science
- Fluid interfaces – macro to micro

Science days

These are one-day events open only to member companies of the BCC. They represent an opportunity for members to be informed about the work within the Colloid Group.

IMPACT Faraday Partnership

The aim of this DTI and EPSRC funded partnership is to further the awareness of colloid science and its relevance to the manufacturing industry base in the UK.

IMPACT was set up in December 2000, with The Bristol Colloid Centre as the hub organisation. The Institute of Applied Catalysis (iAc) and the Campden and Chorleywood Food Research Association (CCFRA) now complete the partnership.

IMPACT provides funding for research in UK higher education establishments and encourages interaction between UK academia and industry. This process is facilitated by a team of technology translators. One of the major elements of IMPACT activity is the provision of online training in colloid technology.

Further information can be obtained through the website www.impactfp.org or by calling the offices on +44 (0)118 935 7000.



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