nanomaterials news

Vol Three Issue Seven 12 June 2007

Stretchable silicon for high-performance electronics

Materials scientists at the University of Illinois at Urbana-Champaign, US, have developed ultra-thin sheets of stretchable silicon that could be used to construct high-performance electronic devices with complex shapes.

Silicon is normally rigid, which is suitable for computer chips, but not so for wearable electronics and flexible displays. For this reason there is much interest in organic films for flexible electronics.

The problem with organic polymers, however, is that they do not offer the same level of performance as silicon, and therefore cannot be used for computationally-intensive tasks.

Building on their earlier success with one-dimensional ribbons of stretchy silicon, John Rogers and his Illinois colleagues have now developed two-dimensional sheets of silicon, which they say could make it possible to put electronics on spheres and surfaces with complicated geometries.

The sheets, which range in area from 3 to 5mm^2, and in thickness from 55 to 320nm, are fixed to a stretched-out sheet of rubber. When the tension is released the silicon buckles to form a herringbone-like pattern, and it is these snaking patterns of waves that allow the sheets of silicon to stretch to two dimensions.

'Stretchable is fundamentally different from flexible,' says Rogers. 'Flexibility only allows the system to be rolled into a cylinder or wrapped around a cone. Stretchability is required for anything else – e.g. integration on a surgical glove, conformal shaping to a sphere, etc.'

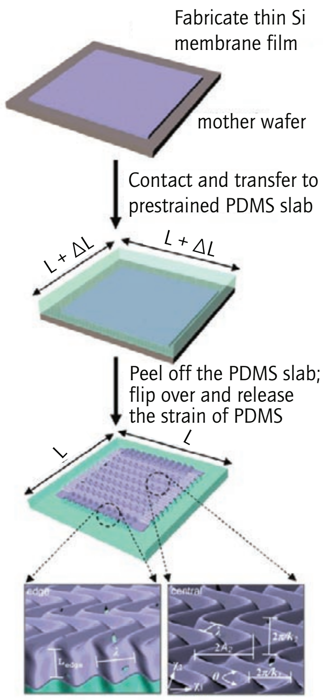
The researchers have so far made functional diodes out of the two-dimensional stretchy silicon, and they are currently working on developing an electronic eye.

'We will have a working prototype – at the resolution of a few hundred pixels and the form factor of a human eye – before the end of the summer, probably sooner,' says Rogers.

Rogers recently founded a company – Semprius – to commercialise systems that use printed silicon and other semiconductors, and provide a outlet for the stretchable silicon.

Click here for more information

Schematic of silicon membrane fabrication



Source: American Chemical Society

Nanomaterials Symposium
25–27 June 2007
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In this issue ...

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Surrey NanoSystems launches new carbon nanotube growth tool

Surrey NanoSystems – a joint venture between the University of Surrey's Advanced Technology Institute and CEVP – is launching what it claims is the most versatile tool for carbon nanotube fabrication ever produced.

Called NanoGrowth 1000n, the new hardware is designed for chemical vapour deposition (CVD) and plasma-enhanced CVD (PECVD) processing at temperatures in the 450–1,000 °C range, as well as nanotube growth at lower temperatures.

Features of NanoGrowth 1000n include an ultra-high purity gas delivery system, and flexible closed-loop control that allows users to define target tolerances in order to achieve high levels of repeatability during all phases of the process. Hardware modularity allows the tool to be expanded and configured to meet users' specific fabrication requirements.

Processing options include inductively coupled plasma (ICP) techniques, dual sputter sources for catalyst deposition, and modules such as an automated wafer transport load/lock system, integrated etching capability, and a PECVD module for deposition of thin-film silicon-based materials.

'The NanoGrowth 1000n system was developed with the aim of applying strict design rigour while delivering flexibility to the end-user,' says Guan Yow Chen, chief scientist at Surrey NanoSystems. 'At this point, the NanoGrowth series is the first to provide the end user with the means to adapt the hardware to their ongoing research work.'

NanoGrowth 1000n is managed via touch-screen SCADA (supervisory control and data acquisition) software, which uses MIMIC displays of the system to provide fine control over all stages of the process. The system comes with a number of ready-to-use software templates that may be adapted by users for their own applications.

Surrey University researchers have in recent years been working on low-temperature growth of carbon nanotubes, and Chen took over the work with the aim of developing a CMOS-compatible process. In 2003, Chen started working with Ben Jensen at CEVP on developing hardware for the ATI's PECVD system, and in 2006 Surrey NanoSystems was formed.

NanoGrowth1000n

Source: Surrey NanoSystems Ltd

Nanoglue that sticks almost anything together developed

Researchers at the Rensselaer Polytechnic Institute in New York, US, have developed an adhesive that can bond materials that do not normally stick together.

The glue material, which is based on self-assembling nanoscale chains, is not new, but a new modification dramatically enhances its stickiness and heat resistance.

The material – mercapto-propyl-trimethoxysilane – is normally highly susceptible to heat and degrades when exposed to high temperatures. The modified glue is inexpensive to make, and its molecular bonds strengthen when exposed to heat.

Ganapathiraman Ramanath's team sandwiched a nanolayer of the material between thin films of copper and silica, thinking that the extra support would help strengthen the nanolayer's bonds and boost its adhesive properties.

When exposed to heat, the middle layer of the sandwich did not break down, and the nanolayer's bonds became stronger when exposed to temperatures above 400°C. Repeated testing confirmed that heating the sandwiched

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nanolayer increases its interface toughness by five to seven times.

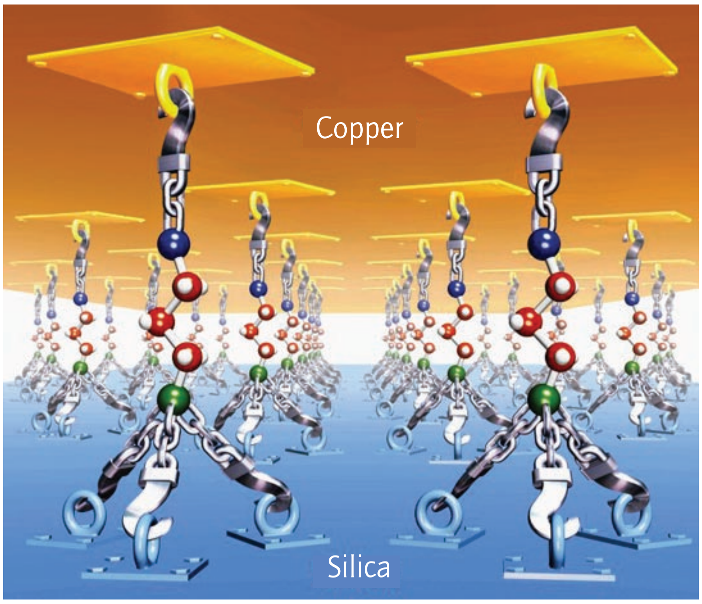
In integrated circuits, copper current carriers do not adhere well to silicon-oxide-based insulators, and copper atoms mix rapidly with silicon oxide, adversely affecting device reliability and performance. A common practice is to separate the metal and insulator with a 10–15 nm layer of tantalum metal or one of its compounds. This prevents atomic intermixing, but takes up valuable space.

'Our solution obviates these disadvantages,' says Ramanath. 'It is easy to form continuous layers of the molecules – they assemble by themselves in an organised formation. We can obtain adhesion strengths at least as high as can be obtained by earlier solutions, but using much thinner molecular layers that are also cheaper to begin with.'

Ramanath adds that many venture firms have expressed interest in the technology, and he and his colleagues may spin off a company to exploit the research findings. In either case, the focus will be on developing technology solutions rather than releasing new products.

Click here for more about the research

A new method allows a self-assembled molecular nanolayer to become a powerful nanoglue by 'hooking' together any two surfaces that normally don't stick well



Source: Rensselaer/Ganapathiraman Ramanath

Australian nanotech to get new national strategy

Australia's nanotechnology industry is set to benefit from new public investment to the tune of AUS$21.5 million (€13.3 million) over four years, and a national strategy along the lines of those implemented in other countries.

Announced recently by prime minister John Howard and industry minister Ian Macfarlane, the Australian National Nanotechnology Strategy is intended to draw together industry, researchers and regional governments to capture the benefits of nanotechnology for Australia.

Specific actions include the establishment of a nano-metrology capability at the country's National Measurement Institute, and addressing health and safety, regulation and standards issues. The strategy will provide targeted assistance to business associations, and a community and industry consultation and education programme. It will also facilitate Australian participation in international nanotechnology policy forums.

'The strategy will help Australia capture the benefits of nanotechnology while effectively addressing community interest about health, safety and the environment,' says Patrick Dessi, a manager in the Australian Office of Nanotechnology, which is part of the Ministry of Industry, Tourism and Resources.

Part of the Australian government's AUS$1.4 billion Industry Statement, the strategy includes an extension to the existing 175% tax concession for R&D investment. This will allow companies to claim the tax concession for projects undertaken in Australia, even if the intellectual property is held offshore. The move is intended to attract overseas investment into the Australian nanotech sector.

Australia's existing nanotech capability includes over 40 projects funded by the country's national science agency, CSIRO, and universities, and some 65 commercial entities whose activities are supported by AusIndustry innovation programmes. Over the last three years there has been a threefold increase in the number of companies involved in the nanotech sector, and it is estimated that nanotechnology-related processes, products and services could be worth AUS$50 billion in the next decade.

Click here for more information

UK government on environmentally-beneficial nanotechnologies

The British government's Department for environment, food and rural affairs (Defra) has published a report focusing on nanotechnologies that may prove to be environmentally beneficial.

In the Defra study, five nanotechnology applications are looked at in detail. It is claimed that in these particular areas, the use of nanotechnology could contribute to a reduction in greenhouse gas emissions in the UK of up to 2% in the near term, and 20% by 2050.

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'The purpose of the study is to identify and examine nanotechnology applications which could contribute to the reduction of greenhouse gas emissions,' says Defra spokesman Steve Morgan. 'Our consultants were tasked to consider both the feasibility of these applications, and any obstacles which might impede or prevent their adoption.'

Fuel additives – Nanoparticle additives could increase the efficiency of diesel engines by around 5%, which would result in a maximum saving of 2–3 megatonnes per year of CO_2 equivalent (CO_2e).

Solar cells – High prices are inhibiting widespread adoption, but nanotechnology may lead to cost savings. If solar generation were to meet 1% of the UK's electricity demand, around 1.5 MT CO_2e per year could be saved.

Hydrogen economy – Using current methods of hydrogen generation, 79 MT per year of CO_2e could be saved. Nanotechnology could improve the efficiency of hydrogen fuel cells, but widespread adoption is estimated to be decades away.

Electricity storage – Despite recent advances, there remain major issues surrounding battery charging times. The use of nanotechnology may improve the situation, and, with the current energy mix, maximum savings of 42 MT per year of CO_2e could be realised.

Insulation – Cavity and loft insulation is cheap and effective, but solid-walled buildings make up approximately one third of the UK's housing stock. Nanotechnology may provide a solution that results in a maximum saving of 3 MT per year of CO_2e.

Some of the findings and recommendations of the Defra study echo those of last year's Stern Report, but the more optimistic figures rely on predictions of technological breakthroughs that may or may not occur.

Quantum dots for laser applications

Scientists at the Los Alamos National Laboratory in New Mexico, US, have created a new type of quantum dot nanocrystal that can be used as a lasing material.

The new nanocrystal is a so-called 'soft' optical material that can be easily processed in solution, thereby providing flexibility for laser design. Potential applications include optical interconnects in microelectronics, lab-on-a-chip devices, telecommunications and quantum information processing.

Semiconductor nanocrystals have excellent light-emission properties, but achieving sufficient optical amplification for lasing has proved problematic. The reason for this is that the nanocrystals generally require at least two excitons – or electron-hole pairs – which are the precursors for light emission. Owing the crystals' tiny size, however, the excitons transfer energy to each other and decay before optical amplification can occur.

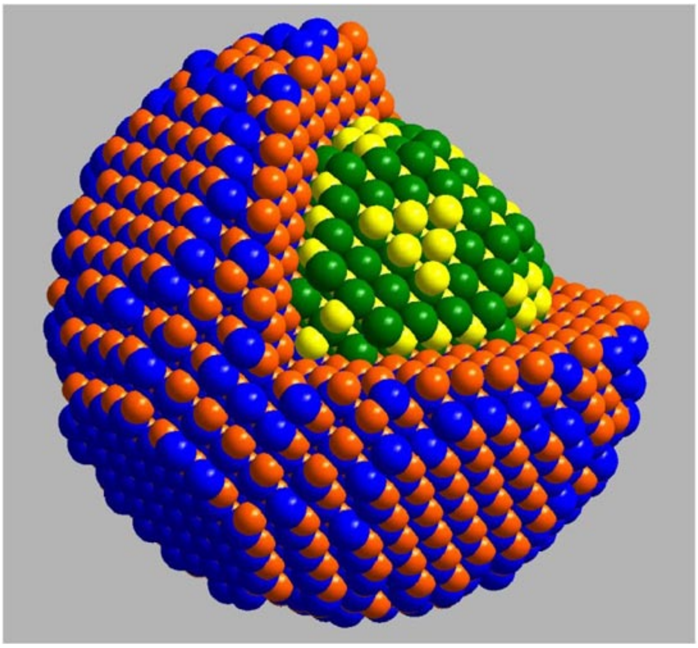
What Victor Klimov and his Los Alamos colleagues have done is demonstrate a practical approach for obtaining optical gain with single-exciton materials. They manage this using nanocrystals with cores and shells made from different semiconductor materials, arranged in such a way that electrons and holes are physically isolated from each other.

The crystals have cadmium sulphide cores and zinc selenide shells. 'To ensure a high quantum yield in the final product, the interface between the core and the shell should be as smooth as possible,' says Sergei Ivanov, who was responsible for the nanocrystal synthesis. 'Chemistry-wise, the synthesis should be easily scalable, since neither of the two stages (core synthesis and shell deposition) require fast injections.'

Klimov adds: 'The next step in our research will be the demonstration of continuous-wave lasing using type-II nanocrystals. Eventually, we hope that this approach will also allow the realisation of pumping via electrical injection.'

Commercialisation remains some way off, as more work is required to improve the quality of the nanocrystals and the reproducibility of the synthesis procedures. In the meantime, the researchers have filed a patent on the subject of single-exciton lasing.

Schematic of a quantum dot nanocrystal with a cadmium sulphide core and zinc selenide shell. The diameter of the crystal is c. 7nm



Source: Sergei Ivanov, Los Alamos National Laboratory

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‘Friction reduction and damping are common applications of ferrofluids in automotive and heavy industry’

Technology spotlight

On the brink

Ferrofluids are poised for adoption in many new applications

A now well-established class of engineered nanomaterials is ferrofluids. Known also as magnetorheological fluids, ferrofluids are liquids that become strongly polarised in the presence of a magnetic field. Ferrofluids are composed of magnetic particles typically of order 10nm suspended in a carrier liquid such as an organic solvent or water. The particles are coated with surfactants to prevent agglomeration and facilitate dispersion in the liquid.

Applications of ferrofluids are many and various. They are, for example, used to create hermetic seals in pumps and the spinning shafts of computer disk drives. Ferrofluids are also used as a liquid coolant in loudspeaker coils.

Friction reduction and damping are common applications of ferrofluids in automotive and heavy industry, and there is now interest in the use of ferrofluids as seismic dampers in buildings. In the aerospace and defence sectors, ferrofluids are used in radar absorbing paints, and fabrics that turn into body armour at the flick of a switch. Biomedical applications include tumour targeting and drug delivery.

A striking visual example of the behaviour of ferrofluids can be seen in a video made by Sachiko Kodama and Yasushi Miyajima at the University of Electro-Communications in Tokyo, Japan. This dynamic sculpture makes use of helical iron shapes, an electromagnet and a pool of ferrofluid. A textual description could never do it justice. Watch and be amazed!

Turning now to research developments, Bruce Finlayson, a chemist at Washington University, US, and his John Hopkins University colleague Kristopher Schumacher, have used fluid dynamics models to study oil-based ferrofluids as the working fluid in electrical transformers. ‘Electrical transformers are primarily cooled by natural buoyancy of the working fluid,’ says Schumacher. ‘Cooling can be significantly increased by substituting the transformer’s oil with an oil-based ferrofluid. This additional cooling increases efficiency and/or allows the size of the equipment to be reduced.’ Finlayson and Schumacher are now looking at turbulence in ferrofluid flow, with a view to developing models that can be used in industrial applications.

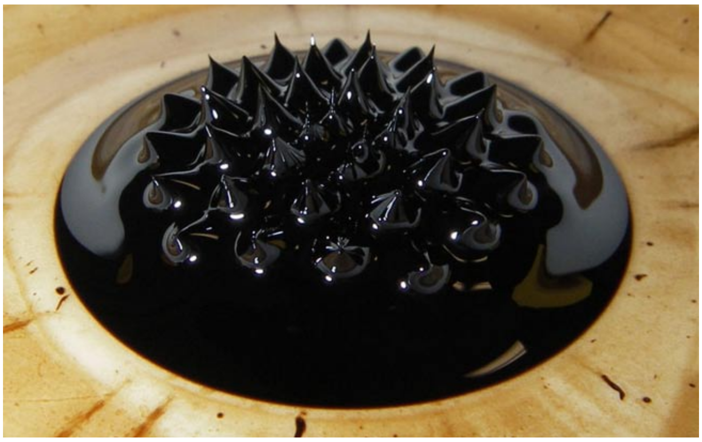
Sam Safran at the Weizmann Institute in Rehovot, Israel, is interested in the structure of dilute ferrofluid systems. Safran and his colleagues have conducted experiments with colloidal dispersions, and shown direct evidence for self-assembled strings and networks in such systems. ‘Only recently did our group ask if the chains are finite or form networks,’ says Safran. ‘The networks have different thermodynamic properties as well as different rheology compared with finite chains.’ Safran adds that this phenomenon is a general property of self-assembling systems.

Edinburgh University chemist Philip Camp is using Monte Carlo and molecular dynamics simulations of model ferrofluids to try and understand unusual condensation transitions and aggregation mechanisms. ‘Computer simulations have been used to provide critical tests of theory,’ says Camp. ‘For example, we have been able to test theoretical methods for determining the distribution of particle sizes in real ferrofluids; the comparison between theory, simulation, and experiment is now essentially perfect.’

Markus Zahn at the Massachusetts Institute of Technology in Cambridge, US, has been investigating the possibilities of using ferrofluids for pumps, generators, and other nanoscale devices.

Ferrofluid technology is now almost four decades old, millions of devices are produced every year that include magnetorheological fluids, and many new applications are on the horizon. The full potential of ferrofluids has yet to be realised.

A ferrofluid in a magnetic field a showing normal-field instability caused by a neodymium magnet beneath the dish



Source: Steve Jurvetson/Wikipedia

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EPA urged to act now on nanotechnology

In a report commissioned by the Washington DC-based Project on Emerging Nanotechnologies, former Environmental Protection Agency (EPA) policy expert J Clarence Davies examines the agency's role in nanotechnology oversight, considers various ways of dealing with nanotechnology, and puts forward an action plan for government, industry and other stakeholders.

Developments in nanotechnology provide an opportunity for an oversight system that will be more effective and less intrusive than existing forms of regulation, argues Davies, and nanotechnology can also be a catalyst for the revitalisation of the EPA.

'All regulation is intrusive,' says Davies. 'However, some regulation is excessively intrusive. An example is the Clean Water Act technology-based standards. Rather than setting goals or standards, and leaving it to the manufacturer to decide how best to meet them, the act requires the EPA to prescribe the technology to be used by the manufacturer.'

A better scientific understanding of what characteristics of nanomaterials are associated with what types of ecological and biological behaviour is required, and Davies feels that not enough effort is being devoted to this. Also, while the definition of 'nano' is rather broad, in the US all chemicals are regulated under the Toxic Substances Control Act (TCSA), and 'chemicals' is a much broader category.

'In the short term (next couple of years) we will have to make do with the TSCA,' says Davies. 'It is conceivable that in the longer term Congress could amend the TSCA to make it an effective oversight instrument, but this will be difficult to make happen politically. It is a very flawed act now.'

Much in his report could also be relevant to the European Union, although Davies points out that a big difference between the EU and US is REACH: the new EU legislation on chemicals. 'It is too early to tell for sure, but my impression is that REACH is much more stringent than the TSCA, and unlike the TSCA it puts the burden of proof on the manufacturer.'

Nanopasta: nonlinear nanotubes and fibres in electronics

Looking a little like nanoscale pasta twirls, the nonlinear nanotubes and fibres being studied by researchers at the University of California San Diego (UCSD) and Clemson University in South Carolina have completely different electronic properties from their non-spiralling cousins.

UCSD materials scientist Prab Bandaru, his Clemson colleague Apparao Rao, and their respective research groups are studying these differences in the hope of creating new kinds of electronic components, including switches, logic elements, frequency mixers and inductors.

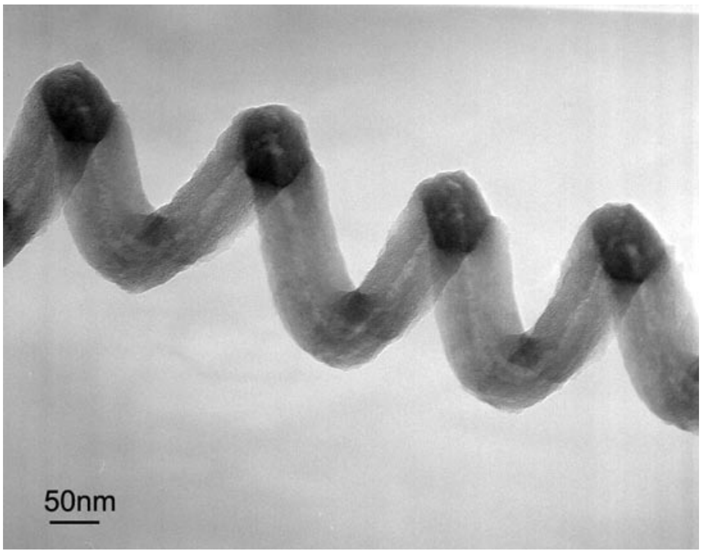
Bandaru and Rao are working on the controlled synthesis of carbon nanotubes with a variety of shapes through chemical vapour deposition processes. Transmission electron microscopy is then used to perform structural analyses of the nonlinear nanostructures.

It turns out that spiral-shaped nanotubes could prove useful for new kinds of nanoscale switching and memory storage devices. At the twist in the nanotube helix, the usual hexagonal arrangement of atoms is replaced by pentagon-heptagon pairs, and pentagons and heptagons have been shown to have an excess and deficit of charge.

'This "native" charge could be used for intrinsic gating of the structures,' says Bandaru. 'The intrinsic charge could also be used for bistability and hysteresis characteristics, and be used as a memory element.' Another advantage is that the spiral form lends itself to nanoscale inductors. The disadvantages are that the structures are difficult to fabricate and arrange periodically on a scale necessary for commercial electronics devices.

Bandaru is first author of a recent paper in the *Journal of Applied Physics* that outlines

Coiling nanofibre, or 'nanoscale pasta'



Source: Prab Bandaru (UC San Diego) & Apparao Rao (Clemson University)

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a mechanism for the growth of nanotubes and fibres, and the model predicts the conditions under which coiling can occur. The next stage is to develop greater control over the properties of nonlinear nanotubes.

'The future is hard to predict!' says Bandaru. 'The biggest hurdle is with the controlled, large-scale assembly of nanotube-based structures. However, a lot of smart people are working on this problem, and hopefully it will be solved very soon!'

Organon and Philips join forces to study drug effects in the brain

Organon – the biopharmaceutical subsidiary of Azko Nobel – and Philips Research have teamed up to develop new drugs and therapies for mental disorders and cancer.

As part of the collaboration scientists from Organon will work at the Philips Life Sciences Facilities in Eindhoven, the Netherlands.

With Organon's expertise in biomarkers – molecules or cells associated with particular biological functions – and Philips's non-invasive imaging technology, the two companies intend to measure the effects of drugs in the brain at a molecular level. In this way they hope to speed up the development and approval of new drugs, monitor the effect of the therapies and customise treatment programmes accordingly.

Particularly promising is the development of reliable and quantitative methods in the diagnosis of psychiatric disorders. Physicians at present have to rely on qualitative and less reliable rating scales of emotion.

'The exact cause and mechanisms underlying psychiatric disorders is still unknown, but it is thought that they arise through an imbalance in neurotransmitters,' says Hans Hofstraat, VP in Philips Research. 'Non-invasive in-vivo imaging techniques such as magnetic resonance imaging and spectroscopy provide unique opportunities to get quantitative information on neurotransmitter concentrations and brain function.'

Organon's strategy is to select drug compounds for development, only if it has identified biomarkers allowing the demonstration of an interaction with the molecular target of interest in relevant organs and tissues, and which are predictive for efficacy and safety.

'Animal studies with our proprietary compounds allow selection of the appropriate development compound,' says David Nicholson, Organon's VP Research and Development. 'They are also utilised to select the most appropriate biomarkers and associated readout technologies for their measurement.'

Many aspects of this strategy were used in the development of Organon's schizophrenia and acute mania treatment Asenapine, with positron emission tomography used to measure dopamine receptor occupancy in the brain.

Non-invasive imaging technology

Source: Philips Research NV

> 'Particularly promising is the development of reliable and quantitative methods in the diagnosis of psychiatric disorders'

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ISSN 1478-7059

Published fortnightly by
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Produced by
Moot Editorial and Design Services

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