Raising the bar

‘TO SEE A WORLD IN A GRAIN OF SAND’ MAY BE REALISED WITH NANOPARTICLES, SAYS S ANANTHANARAYANAN

Barcoding has brought about a revolution in material handling. Just attach a tag printed with a series of dark or light lines to a product and it can be identified, out of thousands or others, by a hand-held sensor and a computer can use the information to create an invoice or bill, a list of items scanned, alert some process, create entries in a database, like the books taken out from a library, and so on. But there are places where the numbers run into millions or more, or the conditions are physically difficult, and there is need for a more compact, reliable and hard-wearing coding medium.

Patrick S Doyle.

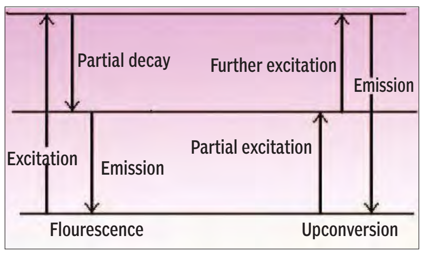
Patrick S Doyle and his team at the Massachusetts Institute of Technology report in the journal *Nature Materials* a technique of coding synthetic micro-particles with a pattern of different crystals that glow in different colours in infra red light. The technique would allow creating barcodes that could encode billions of objects or pieces of information with economy and efficiency, and also with great endurance in harsh conditions.

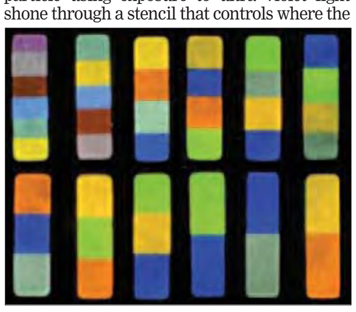
The simple black and white strip coding that we find on grocery or library books relies on a sensor reading the strips in the barcode, as representing the numbers, “0” for a dark strip or “1” for a light strip. Thus, each strip codes a choice out of two possibilities and two strips would code for one of 2x2=4 possibilities. A code with 10 strips would then code for a choice out of 2x2x2x2x2x2x2x2x2x2=1,024 possibilities. Twenty strips would code for a choice out of a million possibilities, and so on.

Once the codes for different objects are decided it is routine to print out the barcode and attach it to an object, along with additional information, like, in the case of a package in the post, the place of origin, destination, weight, category, quality of service paid for, etc. And at every stage of passage, the object can be spotted and a log kept of its progress.

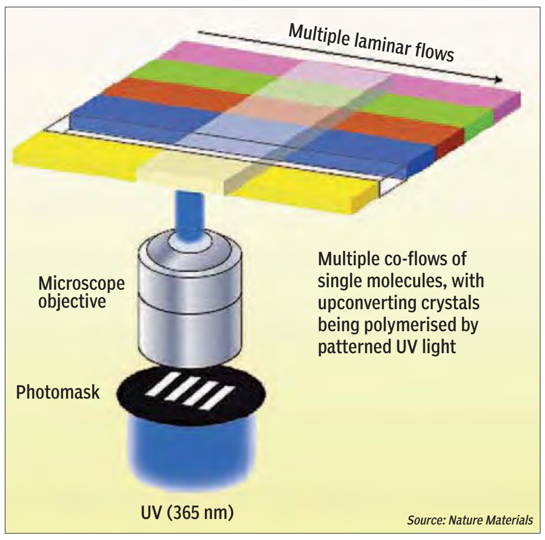
In many industrial applications, however, the numbers are very large and there is need for the label to be compact, apart from being easy to apply and fast to read, with accuracy, and also to survive corrosive environments or high temperatures. While simple barcoding cannot satisfy the requirements, a variation uses a two dimensional array of dark and light dots, but the capacity is limited to a few thousands. Using a series of colours for coding increases the range but presents problems in correct colour reproduction and sensing. Combining colour and graphics, using printing with magnetic inks, has also failed for similar reasons. In this context, the use of micro-particles that contain markers to serve as the carrier of information is attractive, so long as the need for ease of creation, decoding and durability can be met.

The authors of the paper in *Nature Materials* describe their innovation of constructing micro-particles using chains of molecules with control of the rate of formation of the chains. The method, called *Stop Flow Lithography*, amounts to punctuating the growth of the micro-particle using exposure to ultra violet light shone through a stencil that controls where the light falls. The method combines the high resolution, or detail, that is possible with optical methods with the fast production of micro-particles when the material of the particles is allowed to form long chains of molecules while in rapid flow.





Luminescent encoded particles of polyurethane acrylate.



Source: Nature Materials

Upconversion

The markers that were incorporated into the micro-particles were crystals of material that emit visible light when excited by infrared light. This is called *upconversion* and is the opposite of the more familiar phenomenon of fluorescence, as seen in the domestic tubelight. In fluorescence, higher energy photons of ultra violet light excite atoms of the material, which then decay in two steps, emitting lower energy photons of visible light in the process. In upconversion, it is the excitation of the atoms that takes place in two steps by the low energy photons of infrared light and the atoms are excited to a doubly high energy state. The atoms then de-excite in a single step, emitting higher energy photons in the visible region.

The elements whose atoms allow two-step excitation are the so-called rare earths (they are quite abundant, in fact) whose atoms have an electron configuration that allows transitions of electrons in shells other than the outermost shell. The MIT group prepared micro-particles by creating polymers, or molecule chains, with a periodic insertion of crystals of materials that support the upconversion of infrared photons. The method used, of flow lithography, enables speedy creation of the particles and the specific colours of emission enable decoding using simple hand-held devices. The variety of coding crystals that is possible, and the spacing, allows a label of very small dimensions to code for over a million distinct combinations and the error rate is found to be less than one in a billion.

Accuracy and capacity

The authors note that faithful colour reproduction is the key requirement of the coding to be efficient and reliable. It was found that the specific colours emitted were quite independent of differences in the process of formation of the particles. This ensures that coding carried out in different facilities would still be read in the same way by different decoding devices.

To demonstrate the high capacity created, the authors describe a method with almost limitless coding ability and with great robustness. A number of uniquely encoded micro-particles were laminated into the surface of objects using ultra violet light for hardening the surface, a common process in industrial packaging, with no injury to the micro-particles. While each micro-particle could encode some hundreds of thousands of unique objects, the capacity of a series of such particles, each one unique, would run into many trillions. As the particles are tiny, large numbers can be embedded in an object in a highly covert manner.

“Randomly embedding 10 particles from a set of just 1,000 unique asymmetric particles yields an encoding capacity of _(1,000)10, or 10^{30}, enough to uniquely barcode every manufactured product on earth,” say the authors in the paper. This kind of capacity could be used to mark pharmaceutical products, for instance, to differentiate the genuine from counterfeits.

“The mere ability to tune particle material properties without impacting encoding performance unlocks a vast potential for immediate in-line integration of encoded particles into complex manufacturing processes or even consumer products. With modest expansion of the available colour palette or number of stripes per particle, for which no foreseeable impediment exists, single-particle encoding capacities will increase very rapidly,” the authors say.

THE WRITER CAN BE CONTACTED AT simplescience@gmail.com

THE DISCOVERY OF INTRONS

TAPAN KUMAR MAITRA DESCRIBES THESE SEQUENCES WITHIN THE PRIMARY TRANSCRIPT THAT DO NOT APPEAR IN THE MATURE, FUNCTIONAL RNA

In eukaryotic cells the precursors for most mRNAs (and for some tRNAs and rRNAs) contain *introns*, which are sequences within the primary transcript that do not appear in the mature, functional RNA. The discovery of introns was a great surprise to biologists. It had already been shown for numerous bacterial genes that the amino acid sequence of the polypeptide chain produced by a gene corresponds exactly with a sequence of contiguous nucleotides in DNA. This relationship was first demonstrated in the colinearity experiments of Charles Yanofsky in the early 1960s and, as rapid methods for sequencing DNA and proteins became available, was confirmed by direct comparison of nucleotide and amino acid sequences. Biologists naturally assumed the same would turn out to be true for eukaryotes.

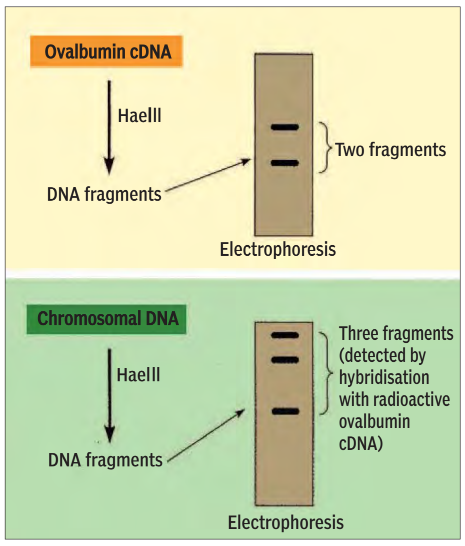
It was, therefore, a shock in 1977 when several research groups reported the identification of eukaryotic genes that did not follow this pattern but were instead interrupted by stretches of nucleotides — introns that were not represented in either the functional mRNA or its protein prod-act. The existence of introns was first shown by R-looping, a technique in which single-stranded RNA is hybridised to double-stranded DNA under conditions that favour the formation of hybrids between complementary regions of RNA and DNA.

To understand how this technique led to the discovery of introns, let us first examine what happens with a gene lacking introns. It depicts the expected result when a prokaryotic mRNA is allowed to hybridise with double-stranded DNA corresponding to the gene from which the mRNA was transcribed. The mRNA hybridises to the template strand of the DNA, leaving the other displaced strand as a single-stranded DNA loop that can be easily identified using electron microscopy.

If eukaryotic genes were constructed from contiguous linear sequences of coding nucleotides, their mRNAs would be expected to generate a similar looping pattern, However, in actual R-looping experiments with eukaryotic mRNAs coding for such proteins as human *b*-globin and click ovalbumin, the surprising result was that multiple loops were seen. This unexpected result indicated that the DNA sequences coding for a typical eukaryotic mRNA were not continuous with each other, but instead were separated by intervening sequences that did not appear in the final mRNA. The intervening sequences that disrupt the linear continuity of the message-encoding regions of a gene are the introns (intervening sequences) and the sequences destined to appear in the final mRXA are referred to as *exons* (because they are expressed).

Once they had been reported for a few genes, introns began popping up everywhere, especially as restriction enzyme techniques came to be applied to a wide variety of eukaryotic genes. It illustrates how restriction mapping can be used to identify the presence of introns. In such studies, restriction maps of chromosomal genes are compared with the restriction maps of the corresponding cDNAs (complementary DNAs) made by transcribing a gene’s mRNA with reverse transcriptase. If significant differences are observed in the restriction maps of a gene and its corresponding cDNA, it suggests the presence of introns in the gene that are not represented in the final mRNA.

The use of restriction mapping and DNA sequencing techniques has led to the conclusion that introns are present in most protein-coding genes of multicellular eukaryotes, although the size and number of the introns can vary considerably. The human *b*-globin gene, for example, has only two introns, one of 120 bp and the other of 550 bp. Together, these account for about 40 per cent of the total length of the gene. For many mammalian genes, an even larger fraction of the gene consists of introns. An extreme example is the human dystrophin gene, a mutant form of which causes Duchenne muscular dystrophy. This gene is over two million bp long and has 85 introns, representing more than 99 per cent of the gene’s DNA!\



Detection of introns using restriction enzymes: Cleaving purified chicken ovalbumin cDNA with the restriction enzyme HaeIII yields two fragments, indicating the presence of one HaeIII site in the cDNA molecule. In contrast, cleaving chicken chromosomal DNA with the same enzyme, HaeIII, generates three fragments containing ovalbumin sequences, thereby indicating the presence of two HaeIII sites in the ovalbumin gene. The extra HaeIII site is situated within an intron and therefore does not appear in the final ovalbumin mRNA molecule from which the ovalbumin cDNA is derived.

The discovery of introns that do not appear in mature mRNA molecules raises the question of whether the introns present in DNA are actually transcribed into the primary transcript (pre-mRNA). This question has been addressed by experiments in which pre-mRNA and DNA were mixed together and the resulting hybrids examined by electron microscopy. In contrast to the appearance of hybrids between mRNA and DNA, which exhibit multiple R loops where the DNA molecule contains sequences that are not present in the mRNA, pre-mRNA hybridises in one continuous stretch to the DNA molecule, forming a single R loop.

Scientists have, therefore, concluded that pre-mRNA molecules represent continuous copies of their corresponding genes, containing introns as well as sequences destined to become part of the final mRNA. This means that converting pre-mRNA into mRNA requires specific mechanisms for removing introns, as we now describe.

THE WRITER IS ASSOCIATE PROFESSOR, HEAD, DEPARTMENT OF BOTANY, ANANDA MOHAN COLLEGE, KOLKATA, AND ALSO FELLOW, BOTANICAL SOCIETY OF BENGAL, AND CAN BE CONTACTED AT tapanmaitra59@yahoo.co.in

Managing heavier payloads

NASA IS ALL SET TO TEST A ‘FLYING SAUCER’ MARS LANDER IN PREPARATION FOR MANNED MISSIONS. JAMES VINCENT REPORTS

The National Aeronautics and Space Administration has announced that it will begin tests of a new “flying saucer” that could one day help land people on Mars. Unfortunately for conspiracy buffs, this isn’t the space agency finally confessing to developing those classic-look UFOs that plagued rural types in 1950s America, but the public’s first look at a new type of planetary lander known as the Low Density Supersonic Decelerator.

This June, residents of the tiny Hawaiian island of Kauai will be treated to the unusual sight of this vehicle plummeting to the surface of the ocean after being hauled up to a height of 55 km through a combination of rockets and high-altitude balloons.

The LDSD will fall from this height with its descent slowed from a speed of Mach 3.5 to lower than Mach 2 through a combination of inflatable discs and a single giant parachute that will drastically increase the craft’s atmospheric drag.

It is hoped that this technology will allow Nasa to land even larger payloads on the surface of Mars — a planet whose thin atmosphere (it is only one per cent as dense as earth’s) makes touching down without a bang extremely difficult.

“It may seem obvious, but the difference between landing and crashing is stopping,” Allen Chen from Nasa’s Jet Propulsion Laboratory told *New Scientist*. “We really only have two options for stopping at Mars: rockets and aerodynamic drag.”

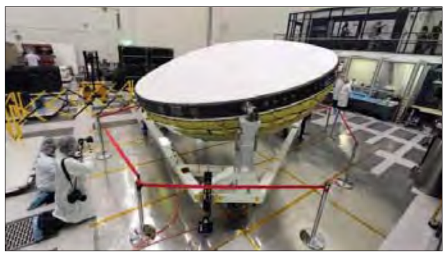
Nasa’s current landing techniques have been in use since the 1976 *Viking* mission which deployed parachutes and rockets to safely drop a pair of landers on Mars. However, as these robots get heavier and more complex, scientists are having difficulty ensuring their safe descent.

The car-sized *Curiosity* rover weighed just under a tonne but Nasa calculates that future manned missions could require anything between 40-100 times heavier loads. Rockets powerful enough to slow down this sort of load would end up destabilising the craft. This is bad enough when you’re risking a $2 billion lander like *Curiosity*, but out of the question if humans are the payload.

The LDSD is attempting to solve this quandary through the use of balloon-like cushions that would rapidly inflate around the payload, increasing its surface area and consequently its atmospheric drag. A 33.5-metre parachute could then be safely deployed once the craft has been slowed.

Nasa thinks this design could support payloads between one and 10 times heavier than *Curiosity* and will be testing the system over the next couple of years.

THE INDEPENDENT



Journalists dressed in special suits are briefed inside the Clean Room at Nasa's Jet Propulsion Laboratory in Pasadena, California on the agency's Low Density Supersonic Decelerator project on 9 April 2014.

The design of the LDSD was inspired by the Hawaiian puffer fish which increase size without adding mass.

PLUS POINTS

Avoiding death

Swatting a fly has never been easy and now scientists have found out why — the insect has perfected a cunning, high-speed technique for a quick U-turn. Despite having a brain not much bigger than a grain of salt, a fly is able to coordinate its movements so rapidly that the turning technique has until now escaped scientific analysis.

An experiment with a set of three high-speed cameras working at 7,500 frames per second has captured the moment when a fruit fly is able to change its direction of flight with just a few beats of its wings. Scientists have found that the fly is able to change the angle of its wings so that in less than a few hundredths of a second its body begins to rotate first in one direction and then in the other to produce what is called a “banked turn” similar to the rolling turns of a fast-moving jet fighter.
Rolling its body in mid-flight gives the insect much greater agility and control than had previously been thought possible, according to Michael Dickinson of the University of Washington who led the study published in the journal *Science*.

“Although they have been described as swimming through the air, tiny flies actually roll their bodies just like aircraft in a banked turn to manoeuvre away from impending threats,” Professor Dickinson said. “We discovered that fruit flies alter course in less than one-hundredth of a second, 50 times faster than we blink our eyes, and which is faster than we ever imagined.”

The experiment involved filming fruit flies within a cylindrical flying arena, at the centre of which was an intersection of two laser beams which, when broken by a fly, triggered an expanding shadow to simulate the sudden appearance of a potential predator. The cameras captured about 40 frames for each beat of a fly’s wing, which enabled the researchers to see how the insects managed to roll their bodies from side to side in preparation for a quick U-turn.

“The brain of the fly performs a very sophisticated calculation in a very short amount of time to determine where the danger lies and exactly how to bank for the best escape, doing something different if the threat is to the side, straight ahead or behind,” Professor Dickinson said. “How can such a small brain generate so many remarkable behaviours? A fly with a brain the size of a salt grain has the behavioural repertoire nearly as complex as a much larger animal such as a mouse. That’s a super interesting problem from an engineering perspective.”

The next stage of the research is to work out how the tiny brain and muscles of the fly are able to control these remarkably fast movements that have been honed by evolution for tens of millions of years.

STEVE CONNOR/THE INDEPENDENT

Weird sighting

Weather experts are baffled by the appearance of a black ring in the sky above Leamington Spa, UK, on the evening of 11 April 2014. Schoolgirl Georgina Heap was playing tennis with her mother Jo when she saw this phenomenon in the sky near Warwick Castle. The ring remained in the sky for around three minutes before disappearing completely.

Georgina, who is studying for her GCSEs, described the circle as “the weirdest thing I have ever seen… I looked up at it and thought, ‘What the hell?’, it was amazing. It was just floating there like a cloud and then it disappeared. It wasn’t birds either. There were about 10 of us who stopped what we were doing and watched”.

The 16-year-old photographed the circle on her iPhone but so far experts have been unable to offer explanation for the unusual sighting. While the circle resembled a giant smoke ring, Warwickshire Fire and Rescue service said there had been no reports of a fire in the locality at the time of the sighting. The Met Office said the ring did not appear to be weather-related.
Nick Pope, an expert on UFOs and a previous government advisor on unexplained phenomena, said he believed the circle to be “organic… It’s a truly bizarre image. It looks like a smoke ring, but I can’t see where it could have come from. Other alternatives would include some sort of unusual meteorological phenomenon.

“One other possibility is that the shape is made up of millions of bees or other insects, but I’ve never heard of insects behaving in this way before, so if this is the explanation, it’s a real-life X-File,” he said.

PRIYA JOSHI/IB TIMES