# Return to the fast lane

**A ceramic material may turn out to be the next silicon, says** s ananthanarayanan

THE silicon-based transistor places a limit on how fast a computer processor can work. The discovery of a new kind of transistor, reported in *Science* by a team at the Massachusetts Institute of Technology and the University of Augsburg, Germany, may lift that speed barrier.

The atoms of the elements consist of a heavy, positively charged core surrounded by negatively charged electrons, groups of which move in successive orbits. Each orbit packs electrons till they balance in the most stable formation before the next orbit is started. The outermost orbit, however, is not stable with more than eight electrons and is the most stable with just two or eight electrons.

In chemical combination, then, atoms that need to gain or yield an electron to gain stability pair up with other atoms and "lend or borrow" so that both atoms benefit and the atoms stay together because of the electrical force that arises from the transaction. Metals, like copper or iron, are usually the "lenders", and can be electric conductors; and non-metals, like oxygen, are the "borrowers" and are usually insulators.

Carbon and silicon have the "halfway-house" count of four electrons in the outer orbit – which allows them to be both lenders or borrowers or, as in organic chemicals where carbon forms rings of the same element, both borrower and lender at the same time. Carbon, because of its density and other traits, is the centre of the empire of living things, while silicon shows its mettle in forming crystals and behaving as both a conductor and an insulator – a *semiconductor*.

If a silicon crystal is *doped*, or spiked with an impurity of an element whose atoms have either five or three outer electrons, then the crystal lattice ends up with either an extra and hence *floating* electron, or a shortfall, which can also be floating, as a *hole*. Now, if two bits of silicon, doped in the opposite ways, are brought together then current can flow from the side with the extra electron to the side with the shortfall, but not the other way about – *a one-way conductor*. And to add to that, if there is a third region, just at the junction of the two types of silicon, to provide a source of free electrons, then the current through the junction can be vastly increased, or shut off, just by tweaking the third terminal, which is called the *gate*, a wee bit.

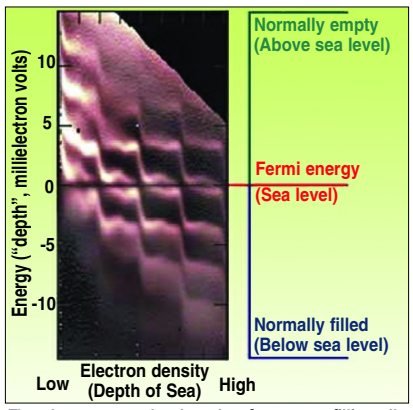
This is the transistor, which allows a bit of silicon in an electrical circuit to control the direction and extent of current flow based on a feeble input at the gate terminal. Before the transistor, electronics was based on vacuum tube valves, which did the same thing — control the flow of current in a circuit, using bulky and power-hungry devices. The entry of the transistor revolutionised the field, with the development of very high quality of sound and image transmission and, more important, massive digital computing capacity.

### The trouble

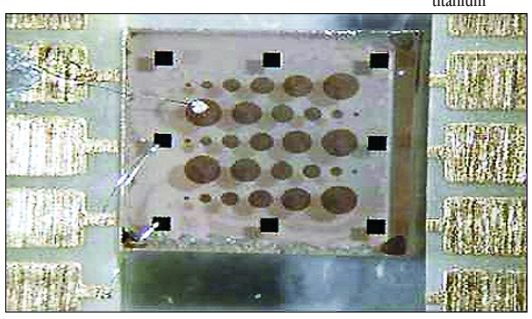
The transistor had the field all to itself for over four decades and saw itself transformed into *prefab arrays of transistors* in the form of integrated circuits, where hundreds of transistors are created on the same chip of silicon and whole electronic devices, even a working digital computer, are contained in the size of a postage stamp. As the power and usage of computers increased, it became important to speed up the cycle of operations in the computer chip, rising to thousands or even millions of operations a second, affecting the transistors embedded in the chip.

This is where the silicon-based transistor presented a problem. The design of the transistor is such that the gate has a very small capacity to contain electrical charge. When charging any container of charge, the transfer is very fast at the start, but tapers off, to very slow transfer, as the charge approaches capacity. The transfer of charge to the transistor gate thus, because of its low capacity, slows down very soon. The only way to keep things moving is to then use higher voltages that pump more charge. The computer processor chip, which has thousands of transistors working, thus handles huge power, which heats the chip.

This is the reason that the processor is provided with its own cooling fan and in the case of very high performance processors it needs a more elaborate cooling arrangement. But for all that, there is a limit and that limit was reached about a decade ago.




*The electrons can be thought of as a sea, filling all the lowest places available and with a surface at sea level. The dark line across the centre is the sea level. Bright lines show where the energy levels are. The distance of the lines from the sea level shows how large their energy is, with lines below the centre showing states that are normally filled (underwater) and lines above the centre showing states that are normally empty (up in the air). Tracing the energy levels as the number of electrons in the system is changed, from left to right in the plot, scientists can learn how electrons behave together in large groups. Graphic courtesy:Ashoori Group Lab.*



*The researchers' experimental set-up consisted of a sample of the lanthanum aluminate-strontium titanate composite, which looks like a slab of thick glass, with thin electrodes deposited on top of it.*

*Raymond Ashoori.*

### Perovskites

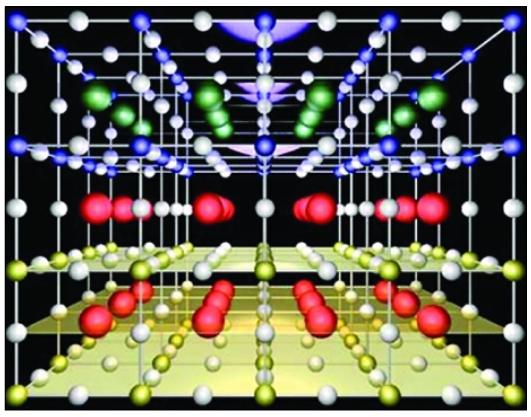
This is where the work of the MIT-based group, on a category of ceramic materials, may have the answer. Ceramic materials are inorganic, non-metal solids, usually prepared by heating and cooling. The common example is clay, including China clay, which consists of aluminium silicate or aluminium, silicon and oxygen, and is used in pottery. Treatment of heating and cooling creates a crystal structure that has a variety of uses. One category of ceramics is the group of *Perovskites*, which generally have the structure of calcium titanium oxide, or consist of an atom which has three outer shell electrons, an atom with four outer shell electrons and three oxygen atoms – like this: $ABO_3$.

Perovskites, although they include an atom with four outer shell electrons, are not semiconductors like silicon, but they have a host of special electrical and physical properties. One area where they are intensively studied is in higher temperature superconductivity. Superconductivity, where some materials lose all resistance to the flow of electricity, could transform the economics of electrical transmission and machinery. But the trouble is that it shows up only at very low temperatures, almost absolute zero, or -273° Celcius. Except that Perovskites have shown superconductivity at temperatures as high as -70° Celcius, which is the temperature of liquid nitrogen and, hence, quite practical.

The MIT-Augsburg group worked with the Perovskite *lanthanum aluminate*, in combination with *strontium titanate* and came up with a new kind of junction that mimics the silicon transistor. Lanthanum aluminate consists of alternating layers of lanthanum oxide and aluminium oxide. As the lanthanum-based layers carry a light positive charge while the aluminum-based layers have a negative charge, the result is a stack of electric fields that are lined up in one direction, which can create a strong electrical tension between the top and bottom surfaces of the material. If the structure gets thicker, the tension can rise and cause a *leakage* of current through the material, changing from insulator to conductor.

The MIT-Augsburg group found that if a junction of lanthanum aluminate was created with another Perovskite, strontium titanate, as an electron source, the gate could show a huge capacity to accept charge, at low voltage, and multiply thousandfold the current through the main channel. "The channel may suck in charge — shoomp! Like a vacuum," says MIT professor Raymond Ashoori. "And it operates at room temperature, which is the thing that really stunned us."

The finding, although seeming to solve the problem of high voltages for function, and hence the need to massive cooling, is still to show the speed of operation which the computer processor needs, which is the final objective. This slow speed could be because the samples used were impure — lanthanum is a material that is difficult to isolate, in fact, its name comes from the Greek *lanthanein,* meaning "to be concealed". But research should be able to find a way around – the main thing is a possible solution to the speed limit on present day transistors!



*The MIT-Augsburg team investigated the curious electrical properties of a material produced by stacking layers of lanthanum aluminate on layers of strontium titanate.*

**The writer can be contacted at simplescience@gmail.com**

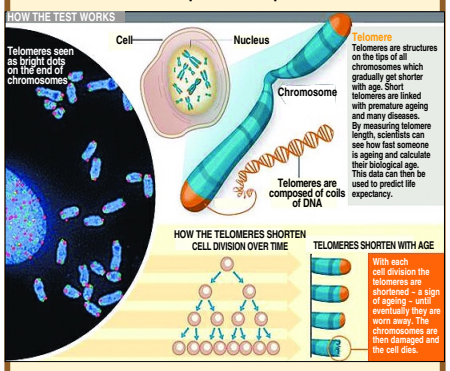
# How long you'll live

**DNA breakthrough heralds new medical era ~ and opens a Pandora's box, writes** steve connor

**A BLOOD test that can show how fast someone is ageing – and offers the tantalising possibility of estimating how long they have left to live – is to go on sale to the general public in Britain later this year. The controversial test measures vital structures on the tips of a person's chromosomes, called telomeres, which scientists believe are one of the most important and accurate indicators of the speed at which a person is ageing.**

**Scientists behind the £435 test said it would be possible to tell whether a person's "biological age", as measured by the length of their telomeres, is older or younger than their actual chronological age. Medical researchers believe that telomere testing will become widespread within the next five or 10 years, but there are already some scientists who question its value and whether there should be stronger ethical controls over its wider use. In addition to concerns about how people will react to a test for how "old" they really are, some scientists are worried that telomere testing may be hijacked by unscrupulous organisations trying to peddle unproven anti-ageing remedies and other fake elixirs of life.**

**The results of the tests might also be of interest to companies offering life insurance policies or medical cover that depend on a person's lifetime**




**risk of falling seriously ill or dying prematurely. However, there is a growing body of scientific opinion that says testing the length of a person's telomeres could provide vital insights into the risk of dying prematurely from a range of age-related disorders, from cardiovascular disease to Alzheimer's and cancer.**

**"We know that people who are born with shorter telomeres than normal also have a shorter lifespan. We know that shorter telomeres can cause a shorter lifespan," said Maria Blasco of the Spanish National Cancer Research Centre in Madrid, who is the inventor of the new commercial telomere test. "But we don't know whether longer telomeres are going to give you a longer lifespan. That's not really known in humans."**

**"What is new about this test is that it is very precise. We can detect very small differences in telomere length and it is a very simple and fast technique where many samples can be analysed at the same time. Most importantly, we are able to determine the presence of dangerous telomeres – those that are very short," she added.**

**Dr Blasco is more certain of the benefits. "It will be useful for you to know your biological age and maybe to change your lifestyle habits if you find you have short telomeres," she said.**

**The Independent, London**

# Breeding ground

**The mechanism of meiosis explains the alteration of the frequency of alleles in a population, writes** tapan kumar maitra

MEIOTIC drive has been defined by scientists Sandler and Novitski as that phenomenon which is a consequence of the mechanics of meiosis and which affects the breeding structure so as to alter the frequency of alleles in a population. Thus in an organism, heterozygous for a pair of alleles, the transmission of these alleles will depart significantly from a 1:1 ratio. This may occur in several ways.

One of the first instances of meiotic drive is that discovered in *Drosophila,* where it exists in several species (for example, *obscura, pseudoobscura,* and *persimilis)*, and leads to an abnormally high frequency of daughters in a population. The "sex ratio" condition is dependent upon some factor in the X chromosome and leads to a differential ability of X- and Y-bearing sperm in fertilisation. The meiotic events are reasonably normal but the Y-bearing sperm fails to function properly. As a consequence, the great majority of viable sperms carry the X chromosome to give, at fertilisation, female zygotes. The factor responsible for the "sex ratio" condition is without effect in females but can be transmitted by mothers to their sons.

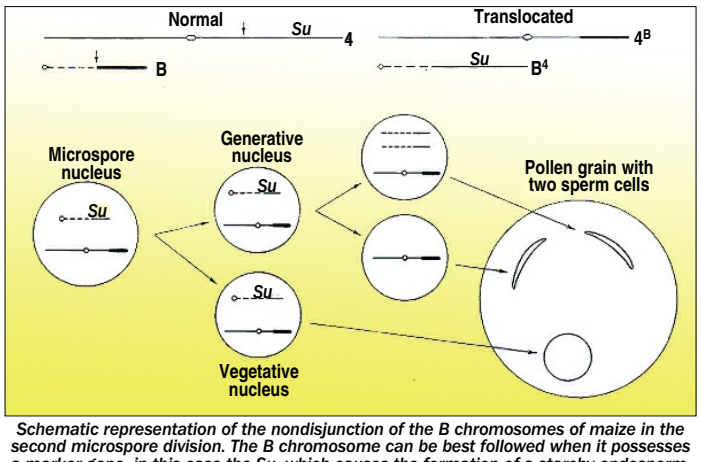
A superficially comparable, but basically dissimilar, situation has also been described in *Drosophila* by Poulson. Once again, the males in the population are very few in number but their infrequency in this instance is due not to a lack of male zygotes but to their selective lethality in embryonic stages. The basic cause of unisexual broods is a spirochete carried in the hemolymph and ooplasm of the mother. The presence or absence of the spirochete is dependent on the genotype of the mother, the spirochete is transmitted through the egg and the occasional males produced result from those eggs in which the spirochete failed to enter or which possessed a resistant genotype. Spirochete-free mothers of the proper genotype may be infected by the injection of ooplasm or hemolymph from a carrier fly. If the presence of the spirochete had remained undetected, it would have been described as an instance of cytoplasmic or maternal inheritance. A third condition, also found in *Drosophila melanogaster*, is that due to a factor in chromosome II known as Segregation-Distorter. The SD factor is, again, without effect in females; it is operative in males only when in a heterozygous condition and is effective only when the SD chromosome is synapsed with its normal homologue. Meiosis is normal and motile sperm are formed but the sperm carrying the normal chromosome II (SD+) are largely nonfunctional. This species regularly forms two functional and two nonfunctional sperm from each spermatocyte but the orientation of chromosomes in meiosis is such as to segregate regularly the SD-bearing chromosomes into the functional sperm. The SD-bearing chromosome is consequently perpetuated and this, of course, has consequences of evolutionary importance in that it drives a population of organisms in a specific genetic direction. The basic difference between functional and nonfunctional sperm is not clear but their existence, and the fact that the functional sperm come to contain preferentially a particular chromosome, provides an explanation for a number of segregational abnormalities reported in *Drosophila* stocks carrying deficiencies or translocations in a heterozygous condition.

The cases discussed above are examples of genic meiotic drive. Even the spirochete-engendered meiotic drive in *Drosophila* depends upon the proper genotype for its expression. Other circumstances are known, however, where the structure of the chromosome rather than its genic content appears to be the crucial factor in bringing about preferential segregation. Chromosome 10 in maize is a case in point. Two forms of chromosome 10 are known: the type most commonly found and whose behaviour is normal in all respects and an abnormal type distinguishable by a large heterochromatic knob at the end of the long arm. In plants homozygous for either of these chromosomes, segregation is perfectly normal and good Mendelian ratios are obtained for any genes on this chromosome. In heterozygous plants, however, distorted ratios are obtained and about 70 per cent of the megaspores contain the abnormal chromosome 10. The non-randomness of inheritance is not due to any particular gene found on the chromosome but is related strictly to the presence or absence of the knobbed portion. Preferential segregation also occurs for any genes linked with the knob and because the two types of chromosomes regularly cross over with each other genes on the normal 10 would be affected in segregation in proportion to the amount of crossing over between the specific gene and the knob.

The basal megaspore in the linear tetrad becomes the functional embryo sac in maize. It must, therefore, receive the abnormal 10 with a relatively high frequency. At least one crossover is regularly formed in the long arni; this means that at anaphase I in a heterozygous plant the segregating chromosome lOs would each contain a chromatid with a knob and one without. The abnormal 10 chromatid must then be in a position such that it passes into the nucleus of the basal megaspore.

This departure from random Mendelian segregation results from a further peculiarity induced by the abnormal chromosome 10. This chromosome also causes the appearance of neo-centromeres, that is, knobbed regions of the chromosomes that take over, at least partially, the function of the normal localised centromere. Anaphase movement of neo-centromeres is precocious to that of normal centromeres and if such movement of the neo-centromeres occurred in anaphase I and the orientation of chromatids was maintained until the next division, then the neo-centromere of the abnormal 10 would be nearest to the lower (the upper also) pole and would consequently be in a position to begin its anaphase II movement precociously to the outermost nucleus and hence into the basal cell. When no crossovers, or a two-strand double crossover, form in the long arms of the heterozygous bivalent, segregation of the knobbed chromosome from its knobless partner would take place in the first division and the opportunity for preferential segregation in the second division would be lacking. Abnormal 10 in a heterozygous state also induces a non-random segregation of other chromosomes possessing knobs. These knobs also acquire a neo-centromeric activity and show distorted ratios when they are heterozygous. When genetic tests are set up to follow the distribution of the knobbed chromosomes, genes closest to the knobs show the greatest distortion. Thus in chromosome 9, which possesses a knob in the short arm and also the genes *C, Sb,* and *Wx, Wx* being nearest the centromere and C nearest the distal knob, the *C* locus showed the greatest degree of preferential segregation, *Sb* was somewhat comparable but *Wx* was little disturbed.

It would appear that the determining influence in the preferential segregation of abnormal 10 relating to neo-centromeric activity emanates initially from the localised centromere of this chromosome. This is suggested by the observation that a fragment chromosome does not possess neo-centromeric activity in the presence of abnormal 10. The reason is unknown. Additional instances of a chromosomal type of meiotic drive have been found in a number of organisms. In *Drosophila*, heteromorphic homologues behave in such a way that the shorter of the two homologues is included in the functional egg nucleus with a higher frequency than the longer chromosome. In mice, the chromosome carrying certain tailless alleles may be found in up to 95 per cent of the sperm.




*Schematic representation of the nondisjunction of the B chromosomes of maize in the second microspore division. The B chromosome can be best followed when it possesses a marker gene, in this case the Su, which causes the formation of a starchy endosperm. One of the sperm cells will lack a B chromosome, the other will possess two of them; the latter sperm is the one most likely to fertilise the egg, thus perpetuating the B chromosomes through nondisjunction and selective fertilisation.*

**The writer is associate professor in botany, Anandamohan College, Kolkata**