be much the same in different species. That this is generally true is evident in a huge body of data revealing that genes responsible for patterning the body of the fruitfly have similar functions in vertebrates.

Several questions remain open. What, for instance, are the critical molecules whose distribution is being controlled by ciliary beating? What mechanisms determine the direction of ciliary rotation within each ciliated cell? Why is *Nodal* the first asymmetrically expressed gene common to all vertebrates, whereas other factors are variable? And in the chick embryo, the earliest molecular asymmetry seems to be the right-sided localization of the *Activin-receptor IIA*[3] just before the earliest expression of *LRD* and the appearance of nodal cilia[1], which raises the question of whether other symmetry-breaking mechanisms might exist at earlier stages of development. ■

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Materials science

Crystallization of silicon ideas

John Robertson

The more desirable form of silicon for use in display screens is also the more expensive to manufacture. Understanding how crystalline silicon forms could be a key to cheaper communications devices.

Amorphous silicon is the leading electronic material for large-area applications, used in solar cells and in the thin-film transistors that make up liquid-crystal displays. However, amorphous silicon suffers from an electrical instability that causes a gradual loss of conversion efficiency in solar cells. There is another form of silicon, nanocrystalline silicon, that is more stable and whose charge-carriers (electrons and holes) are more mobile, making it more attractive for use in these applications.

Amorphous silicon can be made easily by deposition from a silane (SiH_4) plasma, and nanocrystalline silicon can be made by the same process, under slightly modified conditions. But the exact means by which nanocrystalline silicon, rather than amorphous silicon, forms has been the subject of debate. Now Sriraman and colleagues[1] might have found the answer: on page 62 of this issue, they propose that hydrogen atoms from the silane plasma catalyse the rearrangement of Si–Si bonds, triggering a solid-state transformation of the random amorphous-silicon network into the more ordered network of nanocrystalline silicon.

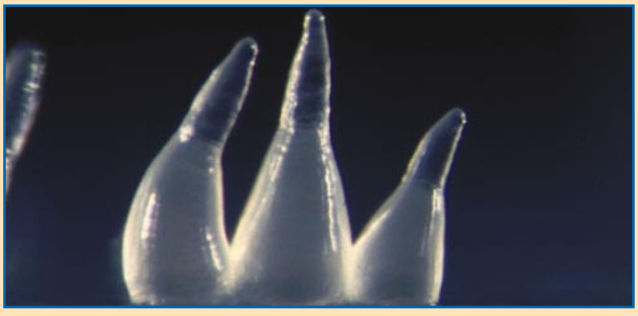
Nanocrystalline silicon can be deposited from a silane plasma that has been heavily diluted with hydrogen so that there is a high concentration of atomic hydrogen in the plasma. The most popular explanation of the deposition process has been that nanocrystalline silicon and amorphous silicon are deposited simultaneously, and then the atomic hydrogen etches away amorphous silicon more quickly, leaving mostly nanocrystalline silicon[2]. Once formed, the two solid phases can then only interconvert via the gas phase.

An alternative explanation is that atomic hydrogen permeates the film of amorphous silicon, lowering the energy barriers to the rearrangement of the silicon network into a more stable, more ordered nanocrystalline lattice[3]. But, until now, the precise mecha-

Genome sequencing

Stick it in the family album

You may feel that you have some relations that resemble the cellular slime mould *Dictyostelium discoideum*, shown here. If so, you would be right. For years there has been debate about where this organism sits on the tree of life, and whether it belongs with plants or animals. But a partial genomic sequence — that of chromosome 2, described by Gernot Glöckner *et al.* in this issue (*Nature* **418,** 79–85; 2002) — confirms its closer kinship with animals.



R. KAY/MRC

Dictyostelium — *Dicty* to its friends — is a soil amoeba but nonetheless a eukaryote: an organism with a membrane-bound nucleus. It has long been recognized as an excellent model organism. It shows much of the genetic flexibility of yeast, and has complex signalling pathways as well as chemical-sensing behaviours like those seen, for instance, in white blood cells.

A multinational team of sequencing centres (www.uni-koeln.de/dictyostelium/consortium.shtml) is sequencing the roughly 34 million bases of the *Dicty* genome and mining them for insights into eukaryotic life. But sequencing is dogged by the problem of high A–T base-pair content, and subsequent analysis is also challenging because of the high repetitive content (around 10%).

To surmount some of the hurdles in sequencing, the various groups constructed libraries from each chromosome separately and carried out shotgun sequencing on each library. But the chromosomal libraries are only about 60% pure, so each group is also generating a whole-genome shotgun. By pooling the data from several libraries, Glöckner *et al.* could fish for the maximum number of pieces of chromosome 2 using known chromosome-2 genes as bait. Tying these pieces together and fitting them onto a backbone of clone-based sequences yielded a mostly complete chromosome sequence, which at 8.1 million bases is about 25% of the genome.

Analysis of chromosome 2 indicates that there are 2,799 protein-coding genes and 73 for transfer RNA. On this basis, the entire genome should contain 10,500 to 11,500 genes, with a density similar to that in budding and fission yeasts. Comparison with sequenced eukaryotic genomes revealed about 45% matches to protein-coding genes, and 55% unique to *Dicty*. Although this number seems high, it is in line with estimates for the available sequences of other eukaryotes.

At the same time, analysis of chromosome 2 has already uncovered more family resemblance, as it encodes proteins similar to several cytoskeleton-related and signalling proteins in animals.

With sequences of the remaining five chromosomes coming shortly, *Dicty* will soon need a page in the family photo album. **Chris Gunter**

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nism for this process — given the rather unappealing name of 'chemical annealing' — has never been fully specified.

Sriraman *et al.*[1] show how chemical annealing occurs. By substituting deuterium (heavy hydrogen, an isotope with a neutron as well as a proton in the nucleus) for hydrogen atoms, they were able to use the distinctive signature of deuterium in infrared spectroscopy to track the movements of these atoms as they enter the network of amorphous silicon from the plasma. They saw that the hydrogen atoms take up positions at the centres of Si–Si bonds. These Si–H–Si bonds are a high-energy configuration and, according to molecular-dynamics simulations, they decay into various lower-energy states, the most favoured being the crystalline state. Thus, an ordered network of Si–Si bonds forms, and the released hydrogen atoms diffuse away.

This work adds to our knowledge of the role of hydrogen in materials like amorphous silicon, or more strictly 'hydrogenated amorphous silicon'. The hydrogen atoms are more mobile than the silicon atoms, and the hydrogen content (5–10% in hydrogenated amorphous silicon) is known to tie off or passivate any broken silicon bonds (called dangling bonds). This hugely beneficial effect makes hydrogenated amorphous silicon a viable electronic material. But the mobility of hydrogen atoms can also be a problem. In hydrogenated amorphous silicon under illumination, or in a thin-film transistor turned on for a long time, the movement of hydrogen atoms causes Si–Si bonds to break, creating dangling bonds. This causes a reduction in solar-cell efficiency, or a shift of the electrical characteristics of a transistor. In contrast, the ease of movement of hydrogen in a silicon film helps to form nanocrystalline silicon; the trick is exploiting the hydrogen to achieve the nanocrystalline structure, and then getting rid of as much hydrogen as possible from the final film to improve its stability.

Plasma deposition is the only practical method of making nanocrystalline silicon over the large areas needed for solar cells, although the process is currently limited commercially by low growth rates. (Plasma-deposited nanocrystalline silicon nucleates on the bottom layer and then the grains grow upwards in a competing manner as the film thickens.) A better understanding of the growth process, coupled with the findings of Sriraman *et al.*, will help to optimize the trade-off between higher growth rates and maintaining crystalline quality.

But more important than the manufacture of solar cells is the rapidly growing use of liquid-crystal displays in electronic communications — for laptop and desktop computer monitors, personal digital assistants and cellphones. In most current display technologies, amorphous-silicon transistors at each pixel store the picture information. Although amorphous silicon is unstable, the pixel transistors are only switched on for a very short time, so their effective lifetime is artificially long. Other components in the liquid-crystal display known as driver transistors are usually mounted in integrated circuits at the edge of a display plate. But there is a trend to mount driver transistors directly on the display plate, as this reduces the cost and complexity of the display. Driver transistors are generally switched on continuously, so they must be stable[4]. Hence, nanocrystalline silicon is required for this purpose.

Nanocrystalline silicon for displays is currently made by laser crystallization of amorphous silicon. Lasers are expensive, but, so far, this is the only feasible method. Could plasma deposition be used instead? Certainly the insight provided by Sriraman *et al.*[1] suggests this is a promising avenue to explore. There are still issues to be addressed, such as control of the size and orientation of the nanocrystalline grains, but the easy manufacture of stable transistors by plasma deposition would have a major impact on the display-technology industry. ■

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Planet formation

Enigmatic emission

Takeshi Oka

The detection of infrared emission from the dusty disk around a distant star signals the presence of the H_3^+ ion. The finding may provide a vital clue to how hydrogen and helium condense into gas-giant planets.

Although there is some consensus on how stars form from interstellar matter, how planets form is less certain. Observations of infrared and radio emissions from dust in protostars have established the presence of protoplanetary disks — regions where dust particles accumulate to form rocky planets like the Earth. But it's a different story for giant planets like Jupiter and Saturn. How the primordial gas of hydrogen and helium in the region condenses to form giant planets is still a mystery, although it is generally believed that the condensation occurs within a short period.

On page 57 of this issue, Brittain and Rettig[1] report their observations of a protoplanetary disk around the star HD 141569, 320 light years from Earth, in which a giant planet might be in the process of forming. Particularly startling is the detection of strong emission of the hydrogenic ion H_3^+, which, according to one model, might originate from a gas-giant protoplanet. If the findings are confirmed, Brittain and Rettig have discovered a new astronomical object, opening up a new avenue for the study of the formation of giant planets.

A crucial question is whether protoplanetary disks contain sufficient raw material, H_2 and He, to form Jupiter-like planets. Observations have been controversial, even on this most fundamental issue. Zuckerman, Forveille and Kastner[2] observed radio emission from CO molecules in the disks surrounding many young stars that are considered to be going through the period of planet formation; assuming the standard ratio of H_2 to CO (about 10^4), they concluded that the amount of H_2 available was far short of that needed for the formation of a giant planet. However, using data from the Infrared Space Observatory, Thi *et al.*[3,4] reported an abundance of H_2 in some of the same stars, as much as a mass equivalent to that of Jupiter. But this finding was subsequently challenged for one of the stars, β-Pictoris, by Lecavelier des Etangs *et al.*[5] using data from the Far Ultraviolet Spectroscopic Explorer. More recent infrared observations by Richter *et al.*[6] also seem to negate the claim of Thi *et al.*

Does this mean that Jupiter-like planets cannot form around those stars? Or have giant planets or protoplanets already formed[5] in those systems, so that there is little H_2 left over in the disk to observe? Giant planets are clearly present in our Solar System and are also observed as extra-solar planets orbiting other stars. Are these giants exceptional? Questions abound.

Brittain and Rettig[1] introduce a new observational tool in this field — the infrared vibration–rotation spectrum of H_3^+ at a wavelength of 4 μm. The H_3^+ ion is an H_2 molecule with an extra proton attached. The third hydrogenic species (after H and H_2), it has only recently been introduced into astronomical observations, but its excellence as an astrophysical probe is rapidly being recognized[7].

The H_3^+ spectrum has been seen in a wide variety of objects: in the giant planets

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