immediate immobilization of cells, so that there is minimal disturbance of neoplastic cells; and the low temperature acts as its own anaesthetic. The fact that freezing damage is unselective means that nerves supplying the area are also destroyed—hence the extreme pain associated with some tumours could be relieved. It was emphasized that although the technique is a useful tool in treating benign tumours and can be valuable in relieving pain as part of the management of massive recurrent malignancies, it is in the second instance a palliative treatment only and should not be proclaimed as a cure for cancer.

SOLID STATE

Hard and Soft Bubbles

from a Correspondent

MAGNETIC bubble technology seems to have survived what could have been a serious setback—the discovery of the so-called "hard" bubbles, which have undesirable properties. A magnetic bubble is a cylindrical magnetic domain (diameter and length $\simeq 5\ \mu\text{m}$) magnetized along its axis; it can be formed in thin epitaxial layers of certain mixed or substituted rare-earth iron garnets. A suitable bias field, directed antiparallel to the magnetization of the bubble, maintains it at a constant diameter. By the use of overlaid patterns of conductors or soft magnetic material, magnetic bubbles can be replicated, translated and detected. Such operations render bubbles useful for serial digital storage, and solid state bubble domain stores will probably provide severe competition for the widely used electromechanical magnetic disk and drum stores.

A stumbling block was, however, identified by workers at Bell Telephone Laboratories (*Bell Syst. Tech. J.*, **51**, 1427; 1972) and at IBM (*Appl. Phys. Lett.*, **21**, 149; 1972), who reported the existence of a new form of magnetic bubble, namely the "hard" or "quantized" bubble. The hard bubble (as distinct from the normal or soft bubble) has many disadvantageous features: its diameter in a bias field is larger than that of a soft bubble; it can exist at different diameters (that is, it has levels of hardness); its mobility is much lower than that of a soft bubble and, instead of moving parallel to a field gradient, it moves at an angle to the gradient (at 80° in one material). From the standpoint of devices, the most worrying property of hard bubbles is their spontaneous formation during normal circuit operation, which leads to failure of the memory.

The properties of a hard bubble are now thought to be related to the structure of the 180° domain wall ($\simeq 300$ nm wide) which divides the bubble from the surrounding domain (*Phys. Rev. Lett.*, **29**, 946; 1972). Within the simplest domain wall—a so-called Bloch wall—the magnetic moments of the magnetic ions lie in directions which gradually change from one side of the wall to the other. Halfway through the thickness of the bubble domain wall, the magnetic moments are circumferential and in the plane of the epitaxial layer. The arrangement of the magnetic moments in such a wall resembles the steps on a spiral staircase and can be right or left handed. The domain wall of a soft bubble is thought to have this kind of structure.

A hard bubble, on the other hand, probably has a domain wall comprising segments of Bloch walls—alternately right and left handed—separated by Néel wall segments. The arrangement of the magnetic moments in a Néel wall is quite different from that in a Bloch wall: in particular, the magnetic moments halfway through the wall are radial. And Néel walls, like Bloch walls, can be right or left handed. Segmented domain walls have not been observed directly in garnets, but Professor Tebble and his colleagues at the University of Salford have detected such walls in thinned cobalt foils using the technique of Lorentz electron microscopy.

The suppression of hard bubbles in materials likely to be used in practical devices presented a serious problem, but one which seems to have been overcome in two ways by workers at Bell Laboratories. The first technique (*Bell Syst. Tech. J.*, **51**, 1431; 1972) uses a structure involving a double or triple magnetic garnet layer. A high magnetization layer capable of supporting bubbles is grown onto a low magnetization layer which itself has been grown onto a non-magnetic garnet substrate. The presence of the low magnetization layer, which is saturated by the bias field, provides a domain wall cap to the base of the bubble and leads to the exclusive formation of bubbles with walls which have two Néel and two Bloch segments. Such a bubble is the softest of the possible range of hard bubbles and behaves as a normal bubble.

The second technique for the suppression of hard bubbles (*Bell Syst. Tech. J.*, **51**, 1436; 1972) makes use of the implantation of hydrogen ions in the surface layer of the garnet. Such implantation causes an easy axis of magnetization to form in, and parallel to the plane of, the implanted garnet layer. The effect of the in-plane magnetization is to put a lid on a bubble domain and this leads to the formation of the "soft" hard bubbles as in the double layer technique.

Although the immediate problem of suppressing hard bubbles seems to have been solved, the two suppression techniques may create other problems in the manufacture of devices; in particular, the presence of an in-plane magnetization layer in a garnet with ions implanted will probably make bubble detection more difficult.

Black Hole Energy Extraction Problems

THE entertaining idea of extracting gravitational energy from a black hole by steadily lowering things into it—put forward not too seriously by Penrose a few years ago—is shown by Gibbons in next Monday's *Nature Physical Science* (November 27) to encounter insurmountable practical difficulties. Gibbons takes account of the stress on the rope used in such a procedure, and finds that the rope would break before any worthwhile amount of energy could be extracted.

If practical problems are ignored, the region of space around a black hole offers an apparently almost limitless supply of energy, because a particle lowered into a black hole could do gravitational work of up to mc^2 on apparatus at the other end of the constraining rope. This rather rapid glossing over of the process, however, conceals the fact that no account has been taken of the rope itself—what has really been suggested is that a particle be lowered into a black hole using a rope of negligible mass which is not affected by the peculiar properties of space–time around a black hole.

Gibbons has considered a more practical rope, made up of particles which each have their own four-velocity and define their own paths through space–time. Even an idealized rope must break before the particle being lowered reaches the ergosphere of the underlying hole, where its weight becomes infinite; for a non-rotating black hole the particle can be lowered to no closer than 1.14 Schwarzschild radii, and the energy extracted can be no more than 63.2 per cent of mc^2. Even worse, for a practical rope (Gibbons considers one made of piano wire) breakage will occur much sooner. In fact, no more than $\sim mc^2 \times 10^{-12}$ could be extracted—something like 100 J for each gram of matter—and the rope could be lowered no closer than 5×10^{11} Schwarzschild radii. This seems to rule out black holes as practical sources of energy.