years, which provided data sufficient for the prediction of stream flow under any given conditions of precipitation. In 1956 a 16 hectare watershed was clear-felled and planted with eastern white pine (*Pinus strobus*). For the next six years the streamflow was greater than that predicted for the forest stand, in the initial period by as much as 15%. Subsequently streamflow fell below predicted annual values and for the past 6 yr it has been between 15 and 20 cm (equivalent to 15–20%) below that expected from a hardwood stand on the same site.

Monthly streamflow values over the course of a year are particularly interesting because they show that between June and October the monthly streamflow is less than 1.5 cm below the expected value, whereas in November, December, April and May streamflow is over 2.0 cm below expected. Thus the additional losses of water from a conifer stand take place mainly in winter and spring; the possibility of this being the case had already been postulated by Penman (in *Forest Hydrology*, edit. by W. E. Sopper and H. W. Lull, Pergamon Press, Oxford, 373; 1967) on the basis of very little observational evidence.

The difference is likely to be caused by both the increased interception and the higher transpiration rates in the conifers in winter and spring. The leaf area index of hardwoods in winter is low (<1) in comparison with white pine (9.9), which indicates the much larger surface area with pine available for the interception of precipitation.

This provides one more good reason for caution in replacing hardwood forests with conifers, especially in water catchment sites.

Field effect seen in glassy semiconductors

from Andrew Holmes-Siedle

AT the start of the solid-state age, Bardeen and colleagues attempted to modulate the conductivity of a slab of germanium by putting a metal plate near to the surface and applying a high electric field. Unexpectedly, the conductivity of the slab did not change and, because of this, the idea of the 'field-effect transistor' lay dormant for over ten years while the reasons for failure were explored. Meanwhile, in order to meet the urgent pressure for a working solid-state amplifier, the device makers (Sockley and colleagues) went on to develop the less elegant point-contact and diffused bipolar transistor principles.

The field-induced 'accumulation' or 'inversion' of current carriers in the germanium did not take place as predicted because immobile charge was generated in surface states. The sheet of charge 'screened' the interior of the semiconductor and prevented the required bending of energy bands. Nowadays, surface states in crystalline semiconductors are under fair control and the metal-oxide–silicon field-effect transistor is a standard component in computer circuits. It might now be said that we are at the start of the 'glassy solid state' age; it is perhaps a good omen that, despite a slow start, the field effect experiment can apparently be performed successfully in some glassy semiconductors. This is fortunate because the penetration of a semiconductor by a field provides a probe of band structure which is particularly appropriate for the glassy semiconductors.

Table 1 Estimated densities of localised states in chalcogenide glasses deduced from field-effect experiments

	Fritzsche	Egerton	Tick *et al.*
Typical composition	$As_{35}Te_{28}S_{22}Ge_{15}$	$Te_{50}Si_{12}Ge_{10}As_{10}$	$Te_2As\,Si$
Form	Evaporated	Evaporated	Melted and drawn
Bulk states ($eV^{-1}\,cm^{-3}$)	6×10^{19}	10^{19}–10^{20}	3×10^{17}– 2×10^{19}
Surface states ($eV^{-1}\,cm^{-2}$)	not estimated	2×10^{13}	2×10^{12}– 3×10^{16}

Spear and le Comber (*J. non-cryst. Solids*, **8–10**, 727; 1972) gained some information on localised states within the band gap of amorphous silicon, but H. Fritzsche failed to find any effect in the 'switching' materials, of chalcogenide composition, despite painstaking attempts (*Ann Rev. Mater. Sci.*, **2**, 697; 1972). R. F. Egerton (*Appl. Phys. Lett.*, **19**, 203; 1971) reported definite field effects which were, however, too small to be useful in determining the nature of the localised states. Now, by special methods of preparation, Tick and Watson of Corning Research and Development labs and Hindley of the University of Birmingham (*J. non-cryst. Solids*, **13**, 229–242; 1974) have prepared samples which have lower apparent densities of localised states and which thus give a higher response to the field effect. There is, therefore, some hope of using the field effect to determine the distribution with energy of the localised energy states in this very important group of materials.

The fabrication technique used was unusual. It is a fair assumption that the evaporated glass layers used by many investigators are more disordered than glasses cast and cooled from the melt. But a field-effect experiment on a sizeable cast block of glass would be hopelessly swamped by the conduction currents in the bulk of the sample. In order to make the bulk volume of the sample commensurate with the thin field-modulated region on the surface, Tick and co-workers used a thin filament of chalcogenide with an unusual form of surface passivation. The filament was produced by melting and drawing down a sample of chalcogenide powder enclosed in a special silica glass jacket. The result was a thin silica glass rod of diameter 7 mm with a very thin central filament of chalcogenide, of diameter only 0.01 mm. When this was sliced, one could gain contact to the ends of the filament with probes while the glass disk contributed support for an annular metal field plate as well as providing surface passivation and mechanical strength. For normal semiconductors and high fields, the surface space-charge regions are of the order of micrometres, so with these dimensions there is a chance that the field will influence a fair fraction of the filament volume.

In fact, negative fields of the order of 10^6 V cm^{-1} modulated the bulk conduction by about 5%, though greater fields produced little further effect; this could be termed a saturating dependence on field. Positive fields (metal positive) gave a much smaller effect. The simple analysis which best fits the saturating characteristic is that of a density distribution of localised states which is uniform with energy all across the band gap. The field dependence of current predicted for a sharply peaked distribution of localised states, such as that called for in the Davis–Mott model for chalcogenides (see for example Mott and Davis *Electronic Processes in Non-crystalline Materials*, Clarendon Press, Oxford, 1971) is of a very different form from that observed.

The model proposed also postulates a significant density of surface states. The figures for density are compared with the estimates made by Egerton and by Fritzsche in Table 1. The values given for certain samples in this latest work are seen to be considerably lower than in the earlier efforts—possibly a hopeful sign that we are learning better control of the preparation of glassy semiconductors.

These results, while not constituting a definitive disproof of the commonly accepted peaked energy distribution of the Davis–Mott model show that the field-effect method is a tool which, with perseverance, may provide definitive evidence on this question.