regard this rather controversial point, the tightest observational constraint on the theory is given by the deuterium abundance, which although very small depends very strongly on the rate of expansion of the Universe.

This agreement between the simplest theory and observation would probably be removed if even a fourth or more species of neutrino were discovered; *inter alia* the predicted helium abundance would be too large. There are more complicated versions of the theory which involve the Universe's being filled with degenerate neutrinos or antineutrinos, which might fit the observations, but these seem rather unattractive. A reduction in the neutron half-life of the amount found by Bondarenko *et al.* would make a small correction in the opposite direction. However, the main significance of the result for cosmologists is to remind us that the predictions of the hot big bang theory are not secure until the neutron half-life is really well known. A definite result that it could not be less than 9.5 minutes (say) would be extremely helpful. □

Amorphous semiconductors

from S.R. Elliott

THE dominant theme at a recent conference on amorphous and liquid semiconductors*, was the hydrogenated amorphous silicon (a-Si:H) system. This is perhaps not too surprising in view of its possibilities as a device material, for example in solar cells (see *News and Views* **275**, 93; 1978; **277**, 85; 1979). Many of the papers on a-Si:H dealt with aspects of material preparation (for example glow-discharge decomposition of SiH_4 or sputtering in Ar/H_2 atmospheres) or characterisation, such as the measurement of H content by thermal exodiffusion or infrared spectroscopy, and investigations of gap-state density by various field-effect or capacitance-voltage measurements. Few structural studies were reported, although R. Mosseri *et al.* (CNRS, Meudon) compared X-ray diffraction data on a-Si and a-Si:H, and D. Weaire *et al.* (Heriot-Watt University) discussed a hand-built 'ball-and-stick' structural model for a-Si:H containing about 20 at.%H. An entire session was devoted to photovoltaics and solar cell devices, discussed by workers from RCA, Exxon, Dundee and Osaka, and I. Shimizu *et al.* (Tokyo Institute of Technology) described how a-Si:H films could also act successfully as electrophotographic sensors in a manner similar to another amorphous material, selenium, used in copying machines.

A. Madan and S.R. Ovshinsky (Energy Conversion Devices) reported on fluorinated silicon, a-Si:F:H, (made by the glow-discharge decomposition of SiF_4/H_2 mixtures) which, they claimed, has a lower density of gap states than solely hydrogenated material and which therefore should lend itself to more efficient doping (see also *Nature* **276**, 482; 1978). Indeed, for material containing about 5 at. % F, doping with AsH_3 or PH_3 in the gas phase produced material having, at the highest doping levels, conductivities some three orders of magnitude higher than comparable hydrogenated material, although p-type doping with B_2H_6 was found to be comparable in both cases. With a band-gap some 10% larger (rather more suited to absorption of the solar spectrum), a-Si:F:H looks as if it might have considerable device potential. J. Knights (Xerox) presented an interesting paper on growth and morphology of a-Si:H, in which strong evidence from nuclear magnetic resonance, electron microscopy and other techniques was presented for the inhomogeneous incorporation of H. Previously, it had generally been believed that H was uniformly distributed throughout the bulk; Knights, however, showed that high H-containing samples were formed from clusters about 100 Å in diameter, with the H concentrated at the cluster boundaries in the form of SiH_2 configurations. Lower H-containing samples did not show this island morphology, but appeared homogeneous. Plasma chemistry seems to play a major part in the deposition process, as might be expected.

Chalcogenide glasses, the other main area of amorphous semiconductor research, also received much attention. The major breakthrough in this field in the past two or three years has been the realisation that intrinsic structural defects have a major role in determining many electronic properties of these materials. These point defects — dangling bonds — are believed to undergo reconstructions in which electron pairing at these sites occurs. Thus, considering a-Se as an example (in which normally bonded atoms are 2-fold coordinated, forming chains), a simple dangling bond is 1-fold coordinated and contains one electron in the orbital formerly used in bonding. Reconstruction occurs by the transfer of an electron between two such defects: addition of the electron to a centre results in a negatively charged 1-fold coordinated centre: removal of an electron results in an empty orbital capable of forming a dative bond with the full lone-pair orbital on a neighbouring Se chain, thereby forming a positively charged 3-fold coordinated centre. J. Joannopoulos (Massachusetts Institute of Technology) described some of the first self-consistent calculations on such defect configurations in an attempt to obtain total energies. However, it seems that, at least at present, the inability to model the atomic relaxations in a realistic manner leads to estimates accurate only perhaps to 0.5 eV, unfortunately not precise enough to determine the relative stability of various configurations.

B. Golding (Bell Laboratories) described some fascinating experiments probing low-lying excitations — so-called two-level systems — which seem to exist in chalcogenide glasses. These had been thought to be due to the tunnelling of atomic groups between two nearly equivalent configurations, and they dominate the thermal properties below 1 K. Stimulated emission (in the form of ultrasonic or electromagnetic echo radiation) from these two-level systems can be obtained, and it was shown that such electrical echoes could be altered in magnitude by annealing or by irradiation with light having the energy of the band-gap (or half-band-gap) of the material. The importance of this result lies in the fact that these changes are precisely in the same sense as those observed in photo-luminescence or electron spin resonance under the same conditions, properties which are believed to be due to the structural defects mentioned earlier. This is the first direct indication that a connection may exist between two-level systems and structural defects in chalcogenide glasses, an intriguing possibility.

G. Pfister (Xerox) reported on the incorporation of additives (such as transition and alkali metals) in chalcogenide glasses and the effect on properties such as drift mobility and photoluminescence. The discovery that, although the former is dramatically affected, the latter is relatively unaffected by doping means that the simple model for defects in chalcogenide glasses needs to be modified. On a more technological note, a novel method of high resolution image replication using amorphous Ge–Se films was described by K. Chopra *et al.* (Indian Institute of Technology, Delhi). This technique relies on the enormous thickness changes (about 12%) that occur when obliquely deposited films are illuminated with band-gap light; this method has the advantage of being conducted under dry conditions, unlike conventional photolithography.

Finally, the prize for the most unusual and esoteric method of glass production must surely go to a joint Czech and Russian group (L. Stourac *et al.* Czech Academy of Sciences, Prague & Institute of Space Research, Moscow). The experimental environment they used was the weightless condition aboard the Salyut 6 spacecraft, and glass formation and the influence of zero gravity on the structure and opto-electronic properties of Ge-Sb-S glasses were studied. I fear that it will be a little time yet before British researchers have an opportunity to conduct similar experiments! □

*The Eighth International Conference on Amorphous and Liquid Semiconductors was held on 27-31 August, at Harvard University. The Proceedings are being published as a separate volume of the *Journal of Non-crystalline Solids*.

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