

photon at this energy is converted into an excited pair consisting of an electron and a hole. The electron and the hole do not drift apart but stay bound to each other. They are not, however, too tightly bound to the parent atom. They represent packets of energy which can, in theory, drift through the network of atoms by means of a very efficient quantum mechanical transfer or "resonant transfer" of energy (Dexter and Knox, *Excitons*, Wiley; 1969). The importance of the exciton configuration is the high level of stored energy (say 6 eV for an alkali halide) and the theoretically long time before recombination.

Although the lifetime of an exciton is expected to be long in an ideal solid lattice, it may be limited to a few nanoseconds in a typical real solid by surfaces and lattice defects; a typical diffusion range is much less than a millimetre. It is, however, difficult to find where an exciton started its life and where it was annihilated. No current flows and no track is left. One is obliged to try to observe the effects of the energy released at annihilation and to eliminate the possibility of other forms of energy transport from the region where the light was absorbed. Several attempts have been made to measure the exciton diffusion length in cadmium sulphide. For example, Broser and Balkanski (*Z. Elektrochem.*, **61**, 715; 1957) illuminated a crystal with a fine spot of light and found that this could produce an electric current between two electrodes in a different region. The migration of energy could, however, possibly be accounted for by absorption and re-emission of light. Another important energy transfer process involving excitons was proposed in a satisfying new model for the formation of F-centres in alkali halides (Pooley, *Proc. Phys. Soc.*, **87**, 245, 257; 1966; Hersh, *Phys. Rev.*, **148**, 928; 1966). In this model, kinetic energy from an exciton annihilation is used to start a focused collision sequence in a crystal which ends with the expulsion of a halogen atom into an interstitial site. Townsend (*Phys. Lett.*, **28A**, 587; 1969) elegantly confirmed that ion motion is indeed involved when he showed that illuminating a very clean crystal of potassium iodide with light in the first-exciton band could produce efficient sputtering. An elaboration of these experiments has now unexpectedly produced an observa-

tion which could be interpreted as exciton motion; the method has more elegance and is probably less ambiguous than earlier experiments.

Al-Jammal, Pooley and Townsend (*J. Phys. C.*, **6**, 247; 1973) recently found that an electron beam of energy of several hundred electron volts gave a surprisingly high sputtering yield in potassium iodide, with an unexpected maximum in the curve of efficiency against energy occurring at 400 eV. This result implies that energy is being transported efficiently to the surface through 25 nm of crystal (the stopping range for 400 eV electrons). Most probably the transport is excitonic. The efficiency is so high that fluorescence and reabsorption are unlikely. Focused collision sequences are again known to be much too inefficient; for example, if 5 eV of kinetic energy is imparted to one atom, at least 1 eV is lost in transferring that energy to the next atom and so on down a chain of atoms. Five stages of transfer would be completed within only 5 nm. Alternatively, interstitial atom diffusion is possible but the effects of thallium ion doping are stronger than would be expected according to this explanation. Thus one is left with exciton diffusion as the most likely mechanism.

Using some approximations to esti-

mate the profile of electron energy deposition, Al-Jammal *et al.* estimate the exciton diffusion length to be about 20 nm. Probabilities of resonant transfer in KI are such that an exciton should jump once every  $10^{-12}$  s on average. For three-dimensional diffusion, the estimated typical range, 20 nm, will be achieved if the exciton lifetime is  $2 \times 10^{-8}$  s. This is of the same order of magnitude as the lifetime estimated by Collins (*J. Appl. Phys.*, **30**, 1135; 1959) and Bleil and Broser (*J. Phys. Chem. Solids*, **25**, 11; 1964) for excitons in cadmium sulphide. Thus a fairly consistent picture emerges. It has been shown that defects serve as traps and recombination centres for excitons in many materials. Thallium in potassium iodide acts in this way and was used in this experiment to check the consistency of the exciton diffusion model. Measurements on a crystal doped with thallium showed a reduced diffusion length of only 13 nm. This result gives a trapping cross-section for the thallium ion which fits well with its ionic radius.

The novelty of the approach derives from the use of a surface phenomenon, namely sputtering, to measure energy release in the lattice, rather than fluorescence, which was used in most of the previous experiments.

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## Transfer RNAs and Tumour Viruses

RNA tumour virus particles, in addition to containing 60–70S RNA which is presumably the viral genome, contain 4S RNA molecules that have been shown to be transfer RNAs specified by the host cell in which the virus particles matured. Furthermore, it is known that the relative amounts of various species of tRNAs in the virus particles and in the host cells differ, which suggests that the tRNAs in the virions are not simply a representative sample of the tRNAs in the host cell. It is not known why RNA tumour virus particles carry tRNAs, or how they get into the virions during maturation, but in *Nature New Biology* next Wednesday (April 4) Wang *et al.* describe some experiments which indicate that the viral genome may somehow control which species of tRNAs are incorporated.

Wang *et al.* compared the tRNA populations in non-defective avian sarcoma virus particles, SR.RSV, in avian leucosis virus particles, RAV.1, and in Bryan high titre Rous sarcoma virus particles grown in the presence of

RAV.1, which acts as a helper for the replication of the defective Bryan virus to yield phenotypically mixed BH.RSV (RAV.1) particles. They found that the relative amounts and number of species of tRNAs in RAV.1 and BH.RSV (RAV.1) particles differ and that the tRNAs in SR.RSV particles resemble those in BH.RSV (RAV.1) particles. The RAV.1 particles contain not only absolutely more chargeable tRNA molecules than either sarcoma virus but also more species of tRNAs. The pattern of tRNAs in transformed and untransformed chick cells was, however, very similar.

It seems, therefore, that leucosis viruses and sarcoma viruses propagated in the same cells pick up different populations of tRNAs and therefore that the viral genome may exert some control over this incorporation. What part if any the tRNAs play in the life cycle of the viruses still remains to be elucidated, but these experiments do suggest the incorporation of tRNAs is more than a chance event.