placements are produced every 40 Å on the average. Occasionally the displacement produces a highly energetic (~ 10^5 eV) primary knock-on which proceeds to lose energy by hard-sphere collisions. In such cases a displacement spike can be formed. Atoms are driven into the surrounding lattice to occupy interstitial positions on a closed shell which surrounds a core of vacant lattice sites.

A number of electron microscopists have examined the tracks which fission fragments produce in crystalline matter, and it has generally been concluded that thermal spikes are responsible for the observed effects. Experimental evidence for the concept of the displacement spike has so far been equivocal. In crystals of molybdenum disulphide, however, the observation of intermittent dark contrast tracks suggests a discontinuous release of energy by the fission particle[4]. There can be no doubt that some of the intermittent contrast effects are due to dynamic diffraction effects at inclined continuous and linear regions of strain. Such phenomena are similar to those seen at inclined dislocation lines in metal foils and can be partially explained by an application of the kinematic theory of electron diffraction. In the majority of cases, however, the contrast effects survive a tilting of the specimen about an axis perpendicular to the electron beam and these are therefore real in nature. An example is given in Fig. 1*a*. It will be observed that the separation between the segments gradually decreases. In some of the tracks the segments are clearly resolvable as dark contrast loops (Fig. 1*b*) and there is evidence[4] that these are closed dislocation lines.

It is possible to explain these observations by adopting the ideas of Brinkman[3]. If it be assumed that the energy which is delivered to the electrons in molybdenum disulphide is spread throughout the lattice as heat (the electrons are highly mobile between molecular layers) then the damage-creating mechanism is that of displacement. As the particle loses energy the separation between successive displacement spikes decreases until a merging results in the formation of a continuous track. For isolated displacement spikes the configuration is unstable and collapse can result in the formation of a closed vacancy dislocation loop[5]. In the continuous region a dislocation dipole[6] or a long dislocation loop can be formed —there is basically no difference between these two types of extended defect.

It may be concluded that the concept of the displacement spike is useful for visualizing the dynamic processes which occur when displacement cascades are produced by heavy particles. The energy which is communicated to the electrons, however, may result in the initiation of a thermal spike, and this may be the dominant mechanism of damage creation in other types of crystal[6].

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LEWIS T. CHADDERTON

Physics and Chemistry of Solids,
Cavendish Laboratory,
Cambridge.

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ENGINEERING

A 5-Mc/s Klystron Amplifier using Positive Ions

AN experimental investigation of the principles of microwave klystrons is rendered difficult by the inherently high operating frequencies at which it is not feasible to measure such quantities as input and output voltages. An important parameter in the klystron is the length of the drift space. In the normal operating range this is usually less than 1 cm. It is therefore difficult to carry out quantitative experiments in which the drift-length is varied. The drift-length depends on the transit time of the electrons and its relation to the high-frequency period. Thus lowering the operating frequency gives longer drift-lengths. Cullen and Stephenson constructed a special demountable klystron to operate at a frequency of 300 Mc/s, in which the optimum drift-length was about 5 cm and it was fairly easy to investigate the effect on performance of varying this length. Voltage measurement at 300 Mc/s still presented some problems.

By using beams of positive ions instead of electrons, transit times are changed in the ratio $\sqrt{(m_i/m_e)}$ where m_i, m_e are the masses of the ion and the electron respectively. Thus it becomes possible to investigate velocity modulation effects at much lower frequencies. Using argon ions we have constructed a klystron amplifier to operate at a frequency of 5 Mc/s. Voltage gains up to five times have been obtained. The optimum drift-length is about 5 cm with currents of 3 mA and accelerating voltages of 2–4 kV. Preliminary investigations have shown that the performance gives good quantitative agreement with the small signal space-charge wave theory of Ramo and Hahn[2,3]. It appears therefore that the positive ion klystron is a good analogue of the microwave klystron and the possibility arises of investigating microwave electronic problems at low frequencies, where measuring techniques are relatively simple.

M. R. GAVIN
K. CHANDRA
L. J. LLOYD

Department of Electronic Engineering,
University College of North Wales,
Bangor.

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Thermocouple Electric Motors

FURTHER to the recent publications[1,2] on the subject of electrostatic motors running at high voltage and low current, I gave consideration to design possibilities of a thermocouple-driven motor operating at a few mV. but a heavy current.

A pilot model was made and ran satisfactorily; due to the voltage drop of normal brush gear being too high, mercury commutation was tried. This motor ran well, but considerable splashing of mercury occurred which was unsafe from the health angle. A totally enclosed design was adopted (Fig. 1). The motor was powered by a single massive thermocouple of iron-constantan.

The main particulars are (all resistances in μohms):