even as well as odd rotational lines are present in the $^3\Pi_g$—$^3\Sigma_u^+$ transition.

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## Precursor Shock produced by 0·25-g Chemical Explosions

J. M. DEWEY, in a letter[1] written some months ago, described precursor shocks produced by a 500-ton hemispherical charge of 2,4,6-trinitrotoluene (TNT) fired on the ground. He suggested that the precursor shocks were probably formed by ground waves feeding energy into the air ahead of the air shock.

We have fired 0·25-g spherical charges of penta-erythritol tetranitrate (PETN) on a steel plate and photographed the air shock-pattern using the schlieren technique. These photographs have shown a precursor shock and in some firings a portion of the precursor was downward-facing (similar to Dewey's description). To investigate his explanation of precursor formation we positioned a soft plasticene wall close to the charge, the object of this being to separate the direct air shocks from any ground-induced waves on one side of the charge. A photograph of the wave pattern from one of the firings is shown in Fig. 1; before the final exposure was made, 60 μsec after charge detonation, two separate exposures were taken to superimpose (i) a 5-cm grid and (ii) the charge position on the photographic plate. The steel-driven air shocks are visible on the right of the picture, and are similar to those observed by Boys[2]. Waves transmitted through the plasticene wall are also visible. On the left-hand side the precursor is seen leading the main air shock. A series of photographs has shown that the precursor is eventually overtaken by the main air shock which it then lags behind, becoming progressively weaker. A firing on a wooden plate showed that the precursor was less advanced of the main air shock at 60 μsec, and its intersection with the main air shock occurred at a reduced height above the surface.

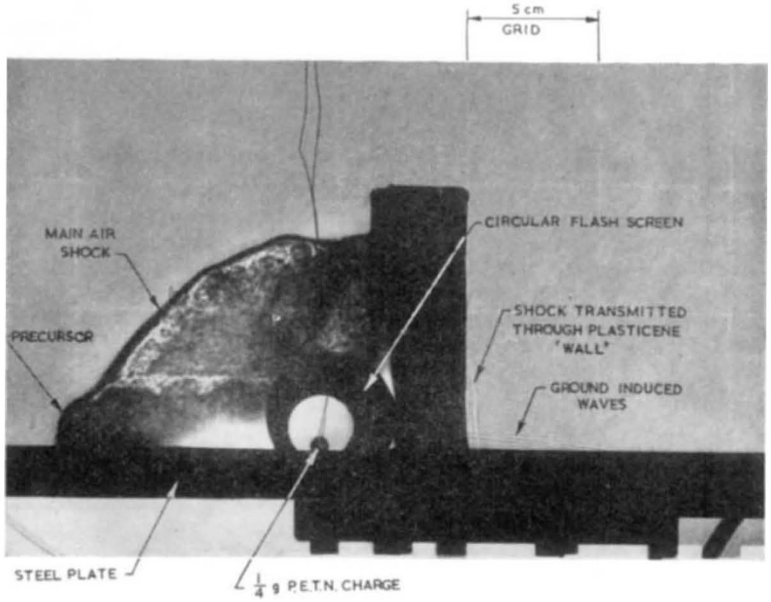


Fig. 1. Photograph of wave pattern from 0·25 g charge fired on a steel plate

These results suggest that, under certain conditions, precursors may be produced by the feedback of energy into the air from strong ground waves interacting with the main air shock.

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## Adsorption of Oxygen on Ultra-thin Titanium Films

A COMMON preparatory method used in the investigation of thin films is evaporation of a metal on to a non-metallic substrate. The actual formation of the film on the substrate is an intriguing process, for a collection of independently nucleated islands must grow together to form a continuous, two-dimensional body. This process has been examined with an electron microscope by Bassett *et al.*[1] and they have documented the case of gold on sodium chloride.

During the period in which the metal film is composed of discontinuous islands, electronic conduction through the film is difficult to explain by any mechanism other than tunnelling. Neugebauer and Webb[2,3] have considered this problem in association with the fact that such films have a negative temperature coefficient of resistance. Their conclusions are embodied in a conduction mechanism in which an electron must first be activated before it can tunnel across the gap separating the islands. The basic parameters which must be considered in this mechanism are related by the following equation*:

$$\sigma = \frac{A\,de^2}{rh^2}\sqrt{2m\varphi}\,\exp\left[-\frac{\varepsilon}{kT}\right]\exp\left[-\frac{4\pi d\sqrt{2m\varphi}}{h}\right] \qquad (1)$$

* Symbols are: $\sigma$, film conductivity; $A$, constant; $d$, inter-island distance; $r$, island radius; $e$, electronic charge; $m$, electronic mass; $\varepsilon$, activation energy; $T$, temperature; $\varphi$, metal work function; $h$, Planck's constant; $k$, Boltzman constant.

The dependence of equation (1) on the island radius, film temperature, and change in inter-island distance caused by thermal expansion of the substrate has been confirmed[2,3], but the tunnelling parameters, that is, metal work function and change in inter-island spacing caused by oxidation of the metal islands, have not been examined experimentally.

In the present investigation, the adsorption of oxygen on ultra-thin titanium films has been used to test the effect of a change in work function and inter-island distance on film conductivity. During the chemisorption of a monolayer of oxygen, the change in film conductivity caused by a change in work function can be determined. If the change in work function is known from other measurements, a value for the inter-island distance can be calculated from equation (1).

The reaction of oxygen with titanium does not stop with the adsorption of a monolayer of gas. Even at room temperature, an oxide layer continues to form. The oxide growth serves to increase the tunnelling distance between the metal islands if the assumption is made that tunnelling takes place from the surface of the metal and not from that of the oxide.

Equation (1) can be modified to include the empirical rate equation for the room-temperature oxidation of titanium[4].