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Streckgrenze un
bei Raumtemperatur

About Temperature and Light Emission at the Fast Crack Propagation

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The very high energy consumption during crack propagation is mainly due to irreversible deformations around the crack tip. By this the local temperature is encreased, sometimes it can rise up to 10^3 K. The amount of encrease depends upon the material, the crack velocity and the size of the plastically deformed volume. For this reason the specimen temperature before fracturing may not govern alone the material behaviour around the crack tip.

The creation of heat by a propagating crack has been measured with thermocouples (1, 2, 3). Normally the thermocouple is located about one millimeter from the crack patte (1, 3) and the temperature encrease measured these is very small. In (2) very thin platinum wires of a diameter of 15 μm were used with a distance from the crack down to about 30 μm. The temperature encrease there was measured up to 130 degree. Rumpf (4) published a calculated temperature distribution before a running crack, assuming the crack as a moving point source of heat. This calculation shows how the crack velocity influences strongly the temperature level; at high velocities it will be higher than 10^3 K in glass or steel.

If the temperature will encrease so much, lightening can be expected. To prove this idea an experimental investigation as described in the following has been carried out. Further the temperature distribution was calculated considering the crack tip as a moving circular heat source with different diameters and a constant heat production density in this circular area. For this the analytical solution of the moving point source (5) is taken and integrated about the area. This must be done numerically because the solution consists in Bessel functions, which have to be expanded in rows for integrating.

In the experiments notched flat specimens of glass, PMMA and steel were stressed by tension in a high vacuum vessel. The lightening could be detected by a photomultiplier mounted outside of the vessel.

To measure the crack velocity in glass and PMMA several small metal strips were evaporated perpendicular to the crack path. The electrical signals caused by the crack when it cuts the strips are used to measure the average velocity between two strips. In the case of steel strain ganges were glued on the specimen to serve as signal generators. Beside of the light emission and the crack velocity the heat production was measured with thermocouples.

With all materials light emission correlated to the crack propagation could be detected if the crack velocity is great enough. The figure shows a typical oscillogram of a experiment with a glass specimen. The oscilloscope was triggered from the first strip and the courve gives the photomultiplier output. The needellike peaks indicate the cutting of the last four strips. The crack velocity is about 1300 m/s. The lightening occures during fracturing and lasts on after it during a period more than 50 μs. To prove that the light emission is not created by a gas discharge as it occures in triboluminescence with sugar, the vessel was evacuated down to 10^{-5} Torr. But the result did not change. Therefore the light emission can be considered as a heat lightening of the crack tip.

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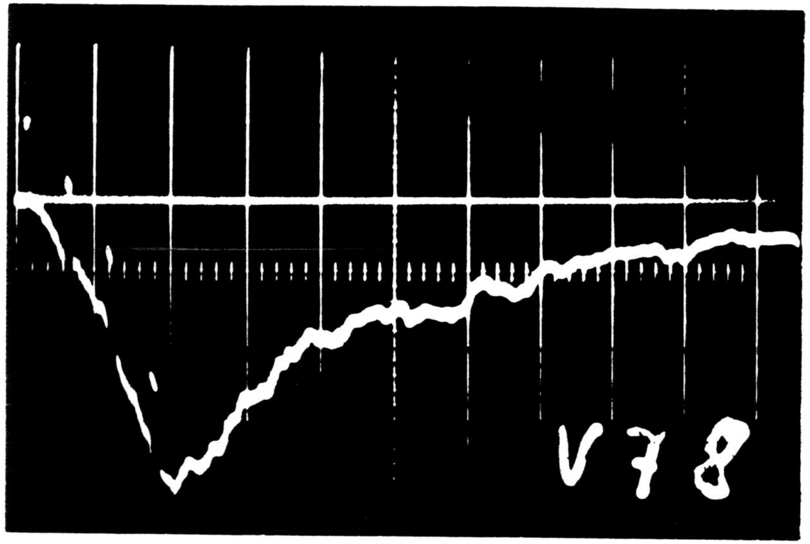

Light emission during fast crack propagation in glass

Vertical: relative light intensity measured with a S 11 photocathode multiplier

Horizontal: time, 5 μs/div. The 4 peaks indicate the rupture of the 4 evaporated metal strips on the sample

Crack velocity is about 1300 m/s