ELECTRICAL BREAKDOWN IN POLYCRYSTALLINE SODIUM CHLORIDE AT 350°C*

By L. A. BUTLER† and J. R. HANSCOMB†

Previous work (cf. Hanscomb 1962) provided strong evidence that in single crystals of sodium chloride, the mechanism of electrical breakdown is "thermal" at 350°C under conditions in which the specimens were subjected to linearly rising fields resulting in breakdown in the time range $3 \cdot 5$ ms -10 s. The thermal mechanism invoked in that study attributed breakdown to Joule heating from ionic current. No evidence of an electronic contribution to the pre-breakdown current with a consequent "intrinsic" type mechanism of breakdown was found.

As further evidence of the thermal mechanism resulting from ionic conductivity, it was decided to experiment with polycrystalline specimens of sodium chloride. The abundance of grain boundaries and the random orientation of individual crystallites in such specimens would, it was expected, influence the breakdown strength if intrinsic, but should not lead to a significant departure from single-crystal measurements if thermal theory were involved. This paper reports the results of measurements carried out with such polycrystalline samples and leads to the conclusion that, as with single-crystal specimens, the thermal theory is involved in breakdown at 350°C.

The specimens were of the recessed cavity type and of the same geometry as used in the previous investigation with single crystals. Attempts were made to precast the specimens to the required shape but were not successful. Trial and error experiments finally led to the production of flat plates produced in graphite moulds of special design to ensure that crystallization commenced at the centre of the plate and radiated outwards. The salt was melted under partial vacuum and rapidly cooled. In this way no gas bubbles were trapped in the samples and cracking was minimized. The plates were, however, very brittle and difficulty was experienced in machining and polishing these to the required geometry. Visual examination of mechanically cracked specimens showed them to be made up of crystallites with dimensions of the order of $0 \cdot 1$ mm.

In order to compare breakdown data with previous single crystal results, the salt used was doped with approximately $1 \cdot 2 \times 10^{-5}$ mole fraction $MnCl_2$.

The impulse generator and the electrode arrangements employed were as described by Hanscomb (1962). The activation energy ϕ was obtained from a $\log R$ versus $1/T$ plot; the resistance R being determined from low-field measurements. The samples used and results obtained are shown in Table 1.

From thermal theory, $K = F^* t^{*\frac{1}{2}} \phi^{\frac{1}{2}} R^{-\frac{1}{2}}$ should be constant for a constant specimen geometry, material, and ambient temperature (cf. O'Dwyer 1960). The null hypothesis is adopted that these breakdowns are due to the impulse thermal mechanism and are from the same normally distributed population as the doped single-crystal results. The mean K for the single-crystal results is $1 \cdot 53$ with variance $0 \cdot 058$. Corresponding figures for the polycrystalline samples are $1 \cdot 44$ and $0 \cdot 070$. Statistical analysis provides no evidence to reject the null hypothesis.

TABLE 1

SODIUM CHLORIDE CRYSTALS WITH Mn^{++}

ϕ	R (MΩ)	t^* (ms)	F^* (MV/cm)	K
$1 \cdot 38$	$0 \cdot 185$	$9 \cdot 1$	$0 \cdot 165$	$1 \cdot 36$
$1 \cdot 41$	$0 \cdot 190$	$14 \cdot 1$	$0 \cdot 156$	$1 \cdot 59$
$1 \cdot 39$	$0 \cdot 190$	$8 \cdot 0$	$0 \cdot 150$	$1 \cdot 08$
$1 \cdot 43$	$0 \cdot 190$	$11 \cdot 0$	$0 \cdot 185$	$1 \cdot 62$
$1 \cdot 42$	$0 \cdot 190$	$11 \cdot 1$	$0 \cdot 190$	$1 \cdot 72$
$1 \cdot 38$	$0 \cdot 170$	$7 \cdot 2$	$0 \cdot 160$	$1 \cdot 22$
$1 \cdot 43$	$0 \cdot 180$	70	$0 \cdot 064$	$1 \cdot 53$
$1 \cdot 42$	$0 \cdot 185$	63	$0 \cdot 050$	$1 \cdot 10$
$1 \cdot 41$	$0 \cdot 180$	72	$0 \cdot 055$	$1 \cdot 31$
$1 \cdot 41$	$0 \cdot 200$	100	$0 \cdot 070$	$1 \cdot 86$

If we take the hypothesis that the variables are not related as required by thermal theory then there should be no correlation between F^* and $t^{*\frac{1}{2}}$. The regression coefficient r is found to be $-0 \cdot 72$, which gives a t value of $4 \cdot 23$ with 8 degrees of freedom and this is above the $0 \cdot 2\%$ level. Such good correlation could arise by chance in only 1 in 500 trials and is thus highly significant. The hypothesis that the variables are not related by impulse thermal theory must therefore be rejected.

From the above evidence it would appear that breakdown in polycrystalline specimens of NaCl at 350°C is thermal, providing further support for this mechanism under the experimental conditions stated.

References

HANSCOMB, J. R. (1962).—*Aust. J. Phys.* **15**: 504.
O'DWYER, J. J. (1960).—*Aust. J. Phys.* **13**: 270.