DIELECTRIC BREAKDOWN IN SOLIDS

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INTRODUCTION

This brief review of dielectric breakdown processes in solids is written with particular reference to short-time breakdown under impulse conditions and less emphasis will be placed on long-term degradation under high electric stress which is of more direct interest in electrical power industry. Nonetheless, the background discussion will be cast in fairly general terms, since the same principles apply to all types of breakdown once it ensues.

Breakdown in solids is not a simple phenomenon - it involves a range of processes which vary according to the particular material and the stressing conditions, with the influence of the electrodes a very important parameter. The basic understanding of the various elementary physico-chemical phenomena involved in breakdown is not well advanced, with the result that there exist many theories of which every one may be faulted on one ground or another.

Breakdown has to be taken as the resultant of these different elementary processes but it is very difficult to analyze it in terms of separate treatments of the various components which could then be re-assembled to form the complete picture. Such processes as carrier injection, their movement in the electric field, the resulting heating effects, defect formation in the material, avalanching, and other non-linear phenomena may be defined and analyzed individually, but their interpretation is too complex to enable a complete picture to be obtained from them.

A serious complication arises from the fact that the available experimental evidence on which to build theoretical models is gen-
 fatally very incomplete because of the need to collect considerable
statistical information on any one of the many aspects of break­
down. Thus the requirement for a data base is formidable and there
is little hope that an adequate experimental program can be mounted
and the results be made available in suitable form for evaluation.

The approach adopted in the present review is, therefore, to
attempt to present a balanced overview of the factors which in the
Author's opinion are important in influencing the breakdown process
and to indicate, where appropriate, the complications arising from
the interactions between them. In this approach the emphasis is
placed on outlining the broad trends, even at the expense of some
inevitable oversimplification.

GENERAL FEATURES OF BREAKDOWN IN SOLIDS

An examination of the available experimental evidence enables
certain general features of solid dielectric breakdown to be dis­
cerned and they may be summarized as follows.

a) Breakdown has an essentially statistical nature and
usually follows the Weibull distribution involving a
field-time action integral which implies a "memory" of
past history of stressing of the material.\textsuperscript{1-3}

b) The ultimate result of breakdown is the thermal formation
of a narrow channel of destruction joining the electrodes
across the dielectric material.

c) Breakdown may be preceded and accompanied by certain
visible irreversible signs such as the various forms of
"trees".\textsuperscript{4,5}

d) Under the combined action of electric field, temperature
and possibly other factors like chemical attack, the
material undergoes an aging process which is sometimes
divided into "long" and "short" term aging and which
leads to progressive reduction of the ability to with­
stand high electric stress.

e) Electronic or ionic charge carriers appear to be essen­
tial to bring about electrical aging.

f) The often invoked distributed processes of carrier gener­
ation, such as avalanching by impact ionization and the
Poole-Frenkel effect\textsuperscript{6} are unlikely to be the dominant
causes of breakdown in the majority of technically impor­
tant cases and other phenomena have to be invoked.