

### 3.5.3 Summary to: Electrical Breakdown and Failure

The first law of materials science obtains: At field strengths larger than some critical value, dielectrics will experience (destructive) electrical breakdown

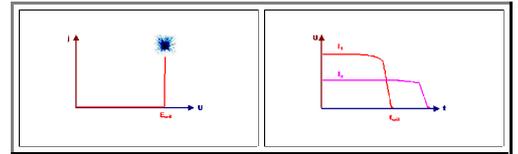
- This might happen suddenly (then calls break-down) , with a bang and smoke, or
- it may take time - months or years - then called failure.
- Critical field strength may vary from **< 100 kV/cm** to **> 10 MV / cm**.

Highest field strengths in practical applications do not necessarily occur at high voltages, but e.g. in integrated circuits for very thin (a few nm) dielectric layers

- Properties of thin films may be quite different (better!) than bulk properties!

Electrical breakdown is a major source for failure of electronic products (i.e. one of the reasons why things go "kaputt" (= broke)), but there is no simple mechanism following some straight-forward theory. We have:

- **Thermal breakdown**; due to small (field dependent) currents flowing through "weak" parts of the dielectric.
- **Avalanche breakdown** due to occasional free electrons being accelerated in the field; eventually gaining enough energy to ionize atoms, producing more free electrons in a runaway avalanche.
- **Local discharge** producing micro-plasmas in small cavities, leading to slow erosion of the material.
- **Electrolytic breakdown** due to some ionic micro conduction leading to structural changes by, e.g., metal deposition.



**Example 1:** TV set, 20 kV cable, thickness of insulation = 2 mm.  $\Rightarrow E = 100 \text{ kV/cm}$

**Example 2:** Gate dielectric in transistor, 3.3 nm thick, 3.3 V operating voltage.  $\Rightarrow E = 10 \text{ MV/cm}$

#### Questionnaire

Multiple Choice questions to all of 3.5