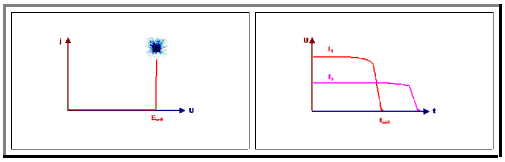
3.5.3 Summary to: Electrical Breakdown and Failure

- 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!

Example 1: TV set, **20 kV** cable, thickness of insulation = **2 mm.** ⇒ ***E* = 100 kV/cm**
Example 2: Gate dielectric in transistor, **3.3 nm** thick, **3.3 V** operating voltage. ⇒ ***E* = 10 MV/cm**

- 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.

Questionaire

Multiple Choice questions to all of 3.5