DC Spark Setup

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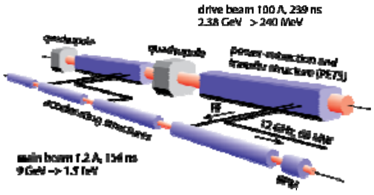
BREAKDOWNS IN CLIC

The design of the Compact Linear Collider (CLIC) is calling for a high accelerating gradient of 100 MV/m, raising the problem of RF vacuum breakdowns. For feasibility, the required breakdown probability is 10^{-7} 1/m.



CLIC is a study for a future electron-positron room temperature linear collider. Its unique feature is its two-beam acceleration method.

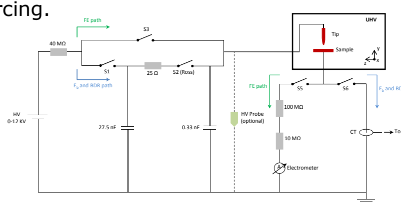
COMPARING RF AND DC

Supporting RF tests, two DC spark setups at CERN provide a cheap and effective alternative for breakdown studies. It allows the testing of several materials, surface treatments, and breakdown conditions (field, energy, temperature etc.).

Insight into the vacuum chamber of the DC setup: Cathode (planar, left) and anode (cylindrical with spherical tip, right).

DC SPARK SETUP

The typical operation voltage ranges from 2 to 12 kV. In order to reach electric fields in the range from 100 to 800 MV/m, the discharge gap is limited to around 20 μm. By switching between two different modes, we can measure field emission currents in the pA-range and discharge currents of 100 A during arcing.



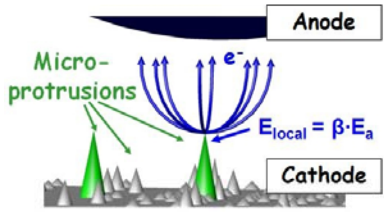
Schematic drawing of the electric circuit. In field emission mode, S1 is closed, while in discharge mode first S2, then S3 are closed.

IN-SITU MEASUREMENTS

1. From the **field emission mode** we can extract the so-called field enhancement factor β, defined by the Fowler-Nordheim eq.

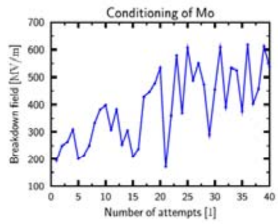
$$j_{FE} = \frac{1.54\cdot 10^{6}(\beta\cdot E)^{2}}{\phi}\exp(10.41\cdot\phi^{-1/2})\exp\left(\frac{-6.53\cdot 10^{3}\phi^{3/2}}{\beta E}\right)$$

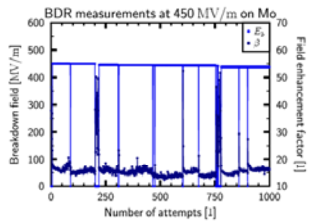
Here [j] = A/m², [E] = MV/m and [ϕ] = eV. The fit of β is performed in a linear regime between $2\cdot 10^{-11}$ and 10^{-9} A.



Through β, the applied electric field is locally enhanced to the order of 10 GV/m. The origin of this field enhancement is still not fully understood. In some models, it is attributed to a geometrical feature, however, chemical or crystallographic effects could play a role.

2. In **discharge mode** two types of information can be extracted: (i) breakdown probability in *breakdown rate mode* and (ii) saturated field in *conditioning mode*.



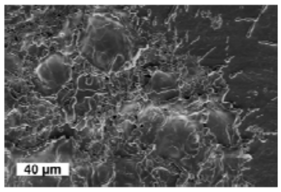


Most of the materials exhibit conditioning (left): After consecutive sparks, a given saturated field is reached. By applying a fixed field, breakdown probability (right) is determined.

3. To monitor plasma properties, **optical spectroscopy** can be performed. This gives information on the species present in the plasma, as well as a rough estimate of number densities and temperatures.

POST-BREAKDOWN ANALYSIS

Once taken out of the chamber, samples can be characterised with respect to (i) surface state (Scanning Electron Microscope), (ii) species content, e.g. Oxygen (X-ray Photoelectron Spectroscopy) (iii) surface profile (Atomic Force Microscopy), and (iv) crystallographic orientation (Electron Back-Scatter Diffraction).



Craters after several sparks on a Mo sample. [Courtesy of P. Alknes]

GENERALISING TO RF

Although both in DC and RF cases materials show conditioning, the DC and RF processes are slightly different. In RF, the complete cavity is probed, while in DC a spot of ~ Ø 0.5 mm is consecutively sparked.

In RF, the breakdown rate (BDR) will depend not just on the material but also on repetition rate, pulse length etc.

All these should be taken into account when generalising DC results to RF.

FUTURE PLANS

A temperature-controlled sample holder is currently under way in one of the setups to allow measurements ranging from elevated (up to ~1000 °C) down to cryogenic (-200 °C) temperatures.

Also an upgrade of the electronics that controls the system is planned, enabling us to go to even higher repetition rates. This will permit measurements of a BDR ~10^{-7} and below, which is currently not possible in RF, but is a feasibility requirement of CLIC.

REFERENCES

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