DC Breakdown Measurements

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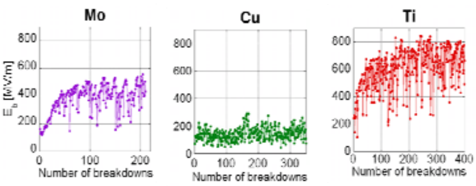
DC SETUP

The DC setup allows us to test different materials, surface treatments etc. in a fast and cost-saving way. The first setup was built in 2000 and activites are since ongoing on two setups at CERN.

CONDITIONING MATERIALS

Materials can exhibit either conditioning or de-conditioning. Copper, the material of main interest for CLIC, is special since it has a very short conditioning phase (0-10 sparks) and typically de-conditions rather than conditions.

After conditioning, a given saturated field (E_{sat}) is reached. Depending on the material, E_{sat} covers a wide range (see below).

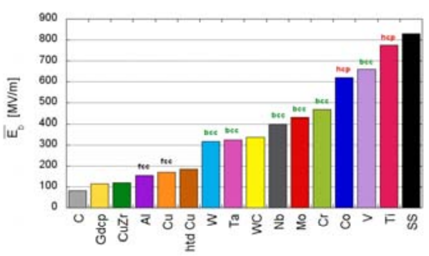


Typical conditioning curves of Mo, Cu, and Ti. Plotted is the breakdown field (E_b) as a function of the number of breakdowns.

RANKING OF MATERIALS

Different materials can be ranked according to their E_{sat}. This ranking gives an idea of how "resistant" the material is against break-downs. The range of E_{sat} for what has been tested is from 100 to 800 MV/m.

It has been suggested by F. Djurabekova et al., that this ranking can be linked to the lattice structure of materials. For this reason also Co has been tested and reached, as predicted, a high E_{sat}.

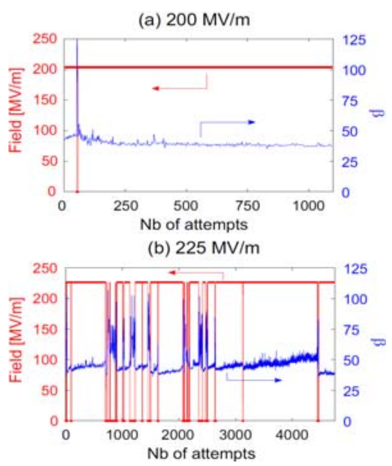


Ranking of DC tested materials. The main CLIC candidate, Cu, has E_{sat} ~ 200 MV/m.

AN EVOLVING BETA?

The nature of the field enhancement factor β is not fully understood yet and can be of geometrical or structural origin. A question often posed in RF is whether breakdown rate (BDR) is a purely statistical phenomenon or whether there is an evolution, a "memory" of the previous pulses.

This has been tested for Cu in the DC setup at different BDR's. In "quiet periods", where no breakdowns occur, we have observed a slight increase in β prior to breakdown. It turns out that a condition for having a breakdown is to reach a local field (β·E) of ~10 GV/m for Cu.

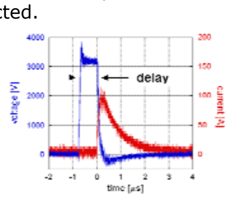


Evolution of β in BDR measurements on Cu, at a breakdown field of 200 MV/m (upper) and 225 MV/m (lower). Prior to breakdown, β grows until a local field of ~10 GV/m is reached. At low fields, a relaxation of β can be seen too.

Note that our measurements do not allow us to conclude what causes the evolution of β. A local measurement combined with imaging would be needed to determine the cause.

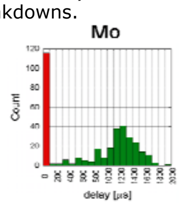
DELAYS BEFORE BREAKDOWN

By measuring in parallel the voltage and the current signal over the discharge gap, statistics on the delay before breakdown has been collected.



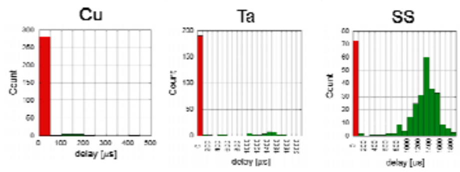
Typical discharge characteristics in the DC setup.

Results show two breakdown populations with different delays: One population with immediate (~100 ns) and one with delayed (~1 ms) breakdowns.



Distribution of breakdown delays in Mo. Immediate breakdowns (red) dominate during the conditioning phase, while delayed breakdowns dominate after conditioning (green).

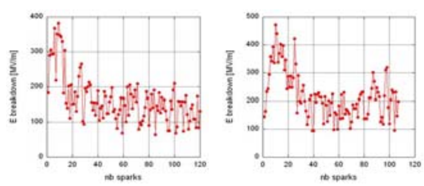
For materials with a short conditioning phase, less delayed breakdowns on the ms range can be observed.



Delay distribution for different materials.

OXIDISED COPPER

Experiments on oxidised Cu showed the increase of the conditioning phase with the thickness of the oxide layer. An estimated thickness of 15 nm (see left fig.) lengthens the conditioning phase from 0-10 to 15-20 sparks, while with an even thicker oxide a layer lasting up to 20-40 sparks was achieved.



De-conditioning of oxidised Cu. Heat treat-ments performed prior to measurement: 48 h at 125 °C (left) and 72 h at 200 °C (right).

REFERENCES

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