Recent Experiments on Vacuum Breakdown of Oxygen-free Copper Electrodes

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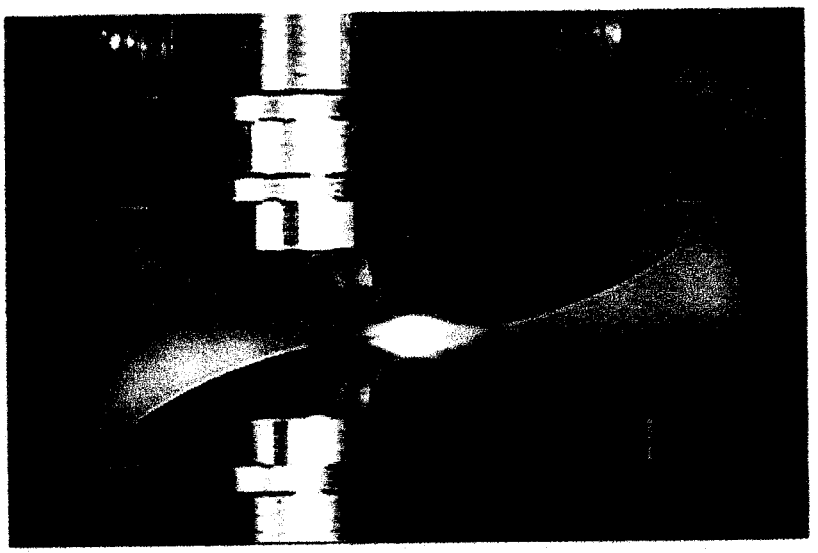
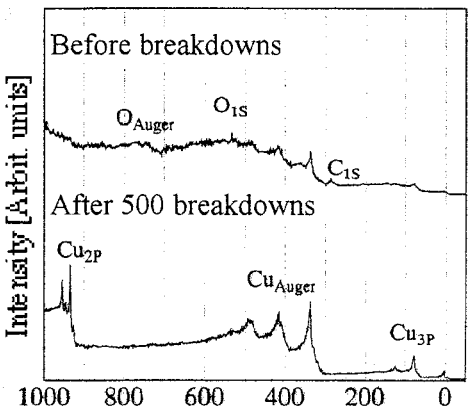
Summary

- Low gas content copper, that is, vacuum-degassed Class 1 copper has a high hold-off voltage capability.
- To obtain a better breakdown strength, *in situ* surface cleaning is necessary.
- The annealing is effective in improving the breakdown strength.
- A mirror finish by the electrochemical buffing or diamond turning reduces the required number off breakdowns to achieve a higher breakdown field.
- The combination of annealing and diamond turning is effective to obtain a high breakdown field ; the field reaches about 250 MV/m.
- The effect of diamond turning was discussed on the basis of the residual stresses on the electrode surfaces.

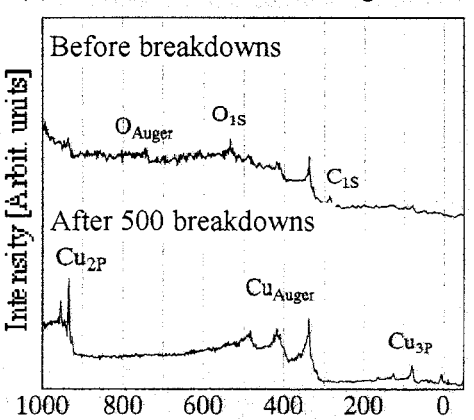


試料:無酸素銅

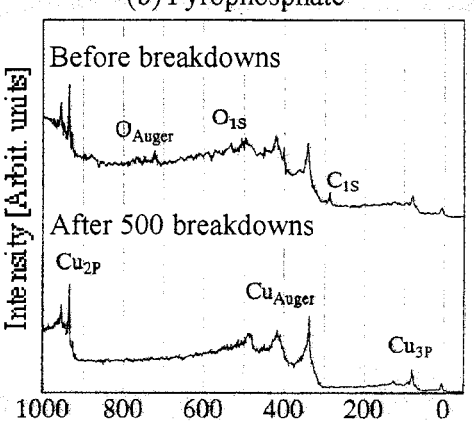
図3-5.絶縁破壊時の写真



(a) Acid sulfate bath with brighteners

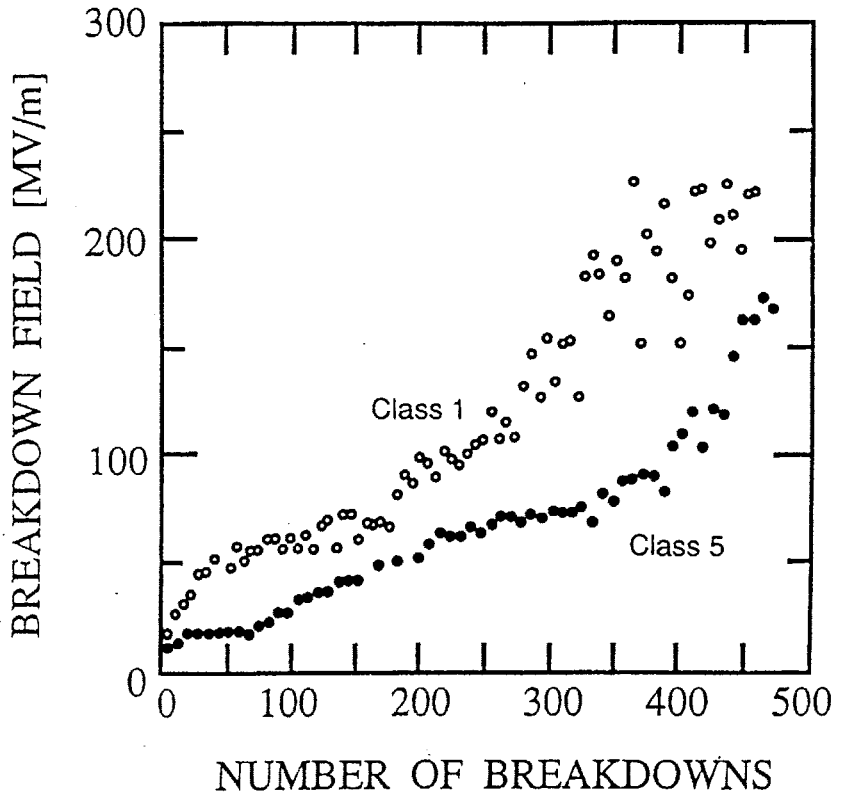


(b) Pyrophosphate

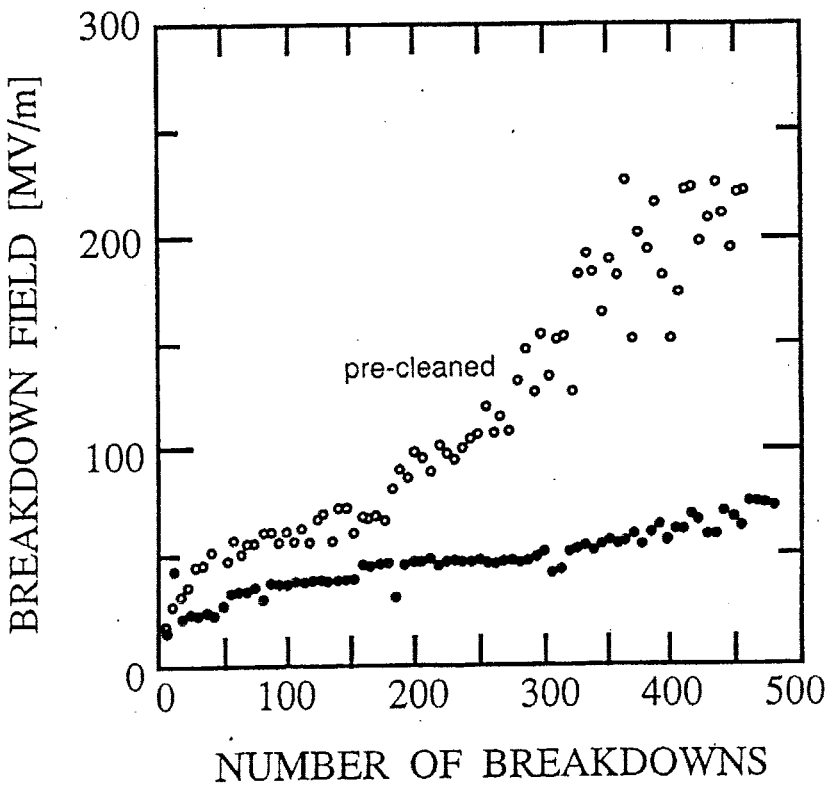


(c) Periodic reversing

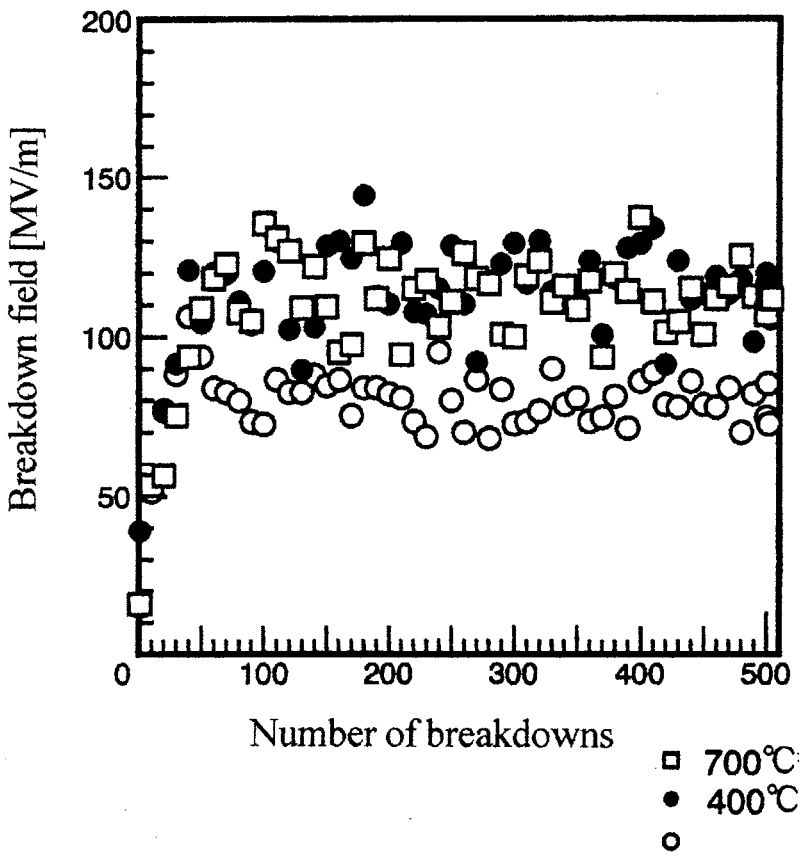
XPS spectra of electroformed copper



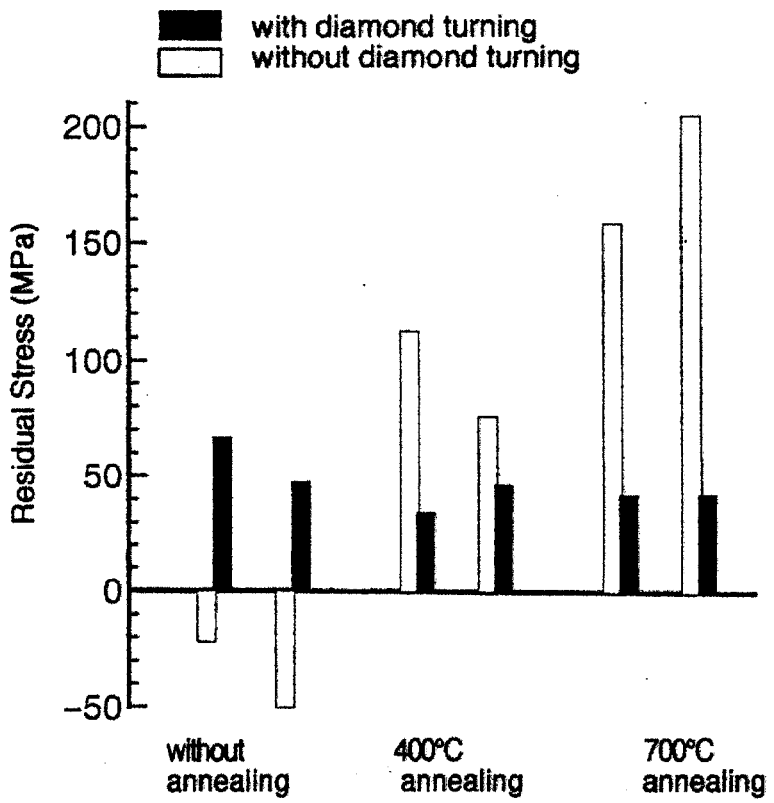
Difference of the breakdown fields between Class 1 and Class 5



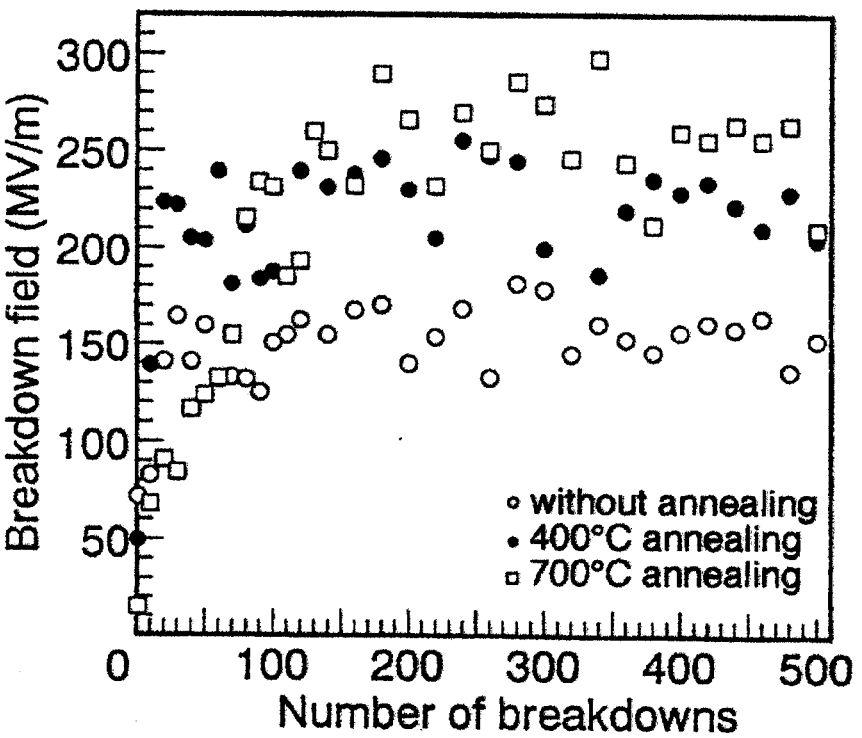
Effect of in situ pre-cleaning performed by Ar-ion sputtering on the breakdown fields. Class 1 copper was used.



Effect of annealing on the breakdown fields. The electrode surfaces were finished by ECB.



Residual surface stresses of OFC electrodes measured by X-ray diffraction method. Surface stresses after diamond turning show an almost constant value. Annealing was pre-treated before diamond turning.

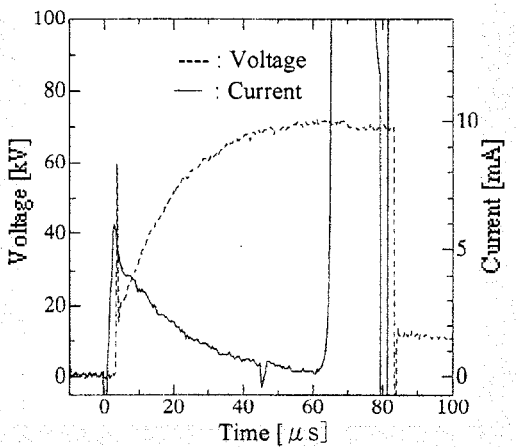


Effect of diamond turning and annealing on the breakdown field.

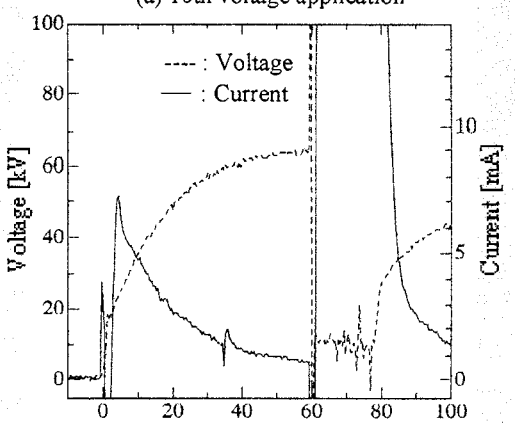
Table 3. First breakdown fields (E_1) of electrofromed and other finished electrodes. DC impulse (64/700 μs) testing.

copper electrode		Ra (μm)	E_1 (MV/m)
casted OFC (Class-1)	*turning*	----	20
	electrochemical buffing	0.03	16
	diamond turning	0.06*	71
electroformed	*Periodic Reversing*	0.40	41
	Acid sulfate (+ brightener)	0.84	13
	Pyrophosphate	----	10

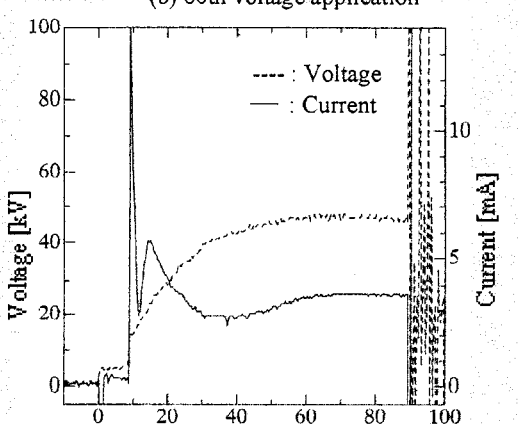
* Rmax



(a) 10th voltage application



(b) 80th voltage application



(c) 240th voltage application

Voltage-current wave forms

I - V characteristics during DC impulse voltage conditioning

a) initial stage; *non-metallic layer or inclusion*

*current increase without volatge drop, followed by breakdown

*hot electron emission through dielectric or oxide surface layer

b) initial and/or intermediate stage; *clump or microdust*

*current increases and voltage drops, simultaneously

*removal and evaporation of clump, causing charged particles

c) saturated and steady stage; *metallic field emission*

*increase of field emission current, followed by breakdown

*F-N type field emission from clean/metallic surface