Alumina ceramics with charge dissipation properties

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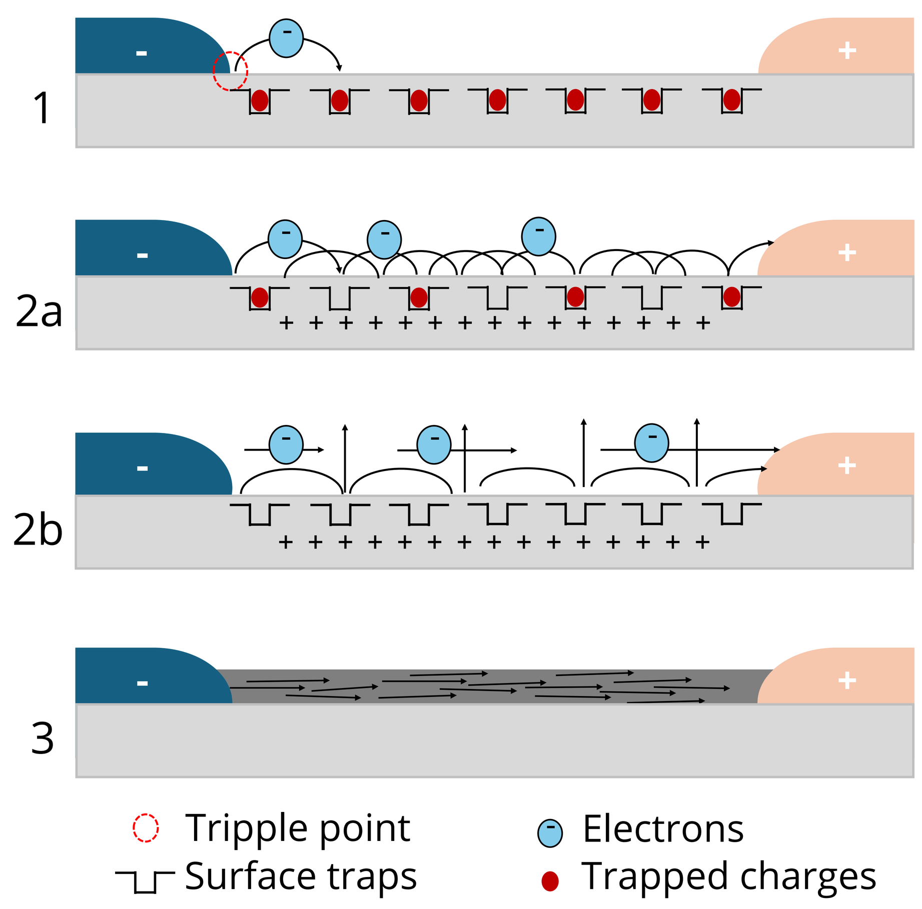
Motivation

- **Introduction:** Alumina insulators are reaching their performance limit in high-power X-ray tubes due to surface charging and accumulation of surface charge followed by a surface flashover [1].
- **State of the art:** Volume and surface doping are the current development trends to increase the surface withstanding voltage of the alumina insulators in vacuum [2, 3].
- **Aim:** To investigate the effect of dopants and processing parameters on the electrical properties and charge dissipation of doped alumina ceramics.

Surface flashover phenomenon in vacuum



Physics of the surface flashover in vacuum [1]

1. field emission from the triple point
2a. secondary electron emission avalanche
2b. electron induced outgassing
3. electrical flashover in the desorbed gas

Materials and methods

Volume doping: Commercial alumina powders were doped with transition metal oxides by wet milling and spray-dried into pressable granules. Test samples were prepared by die-pressing and sintering in different atmospheres.

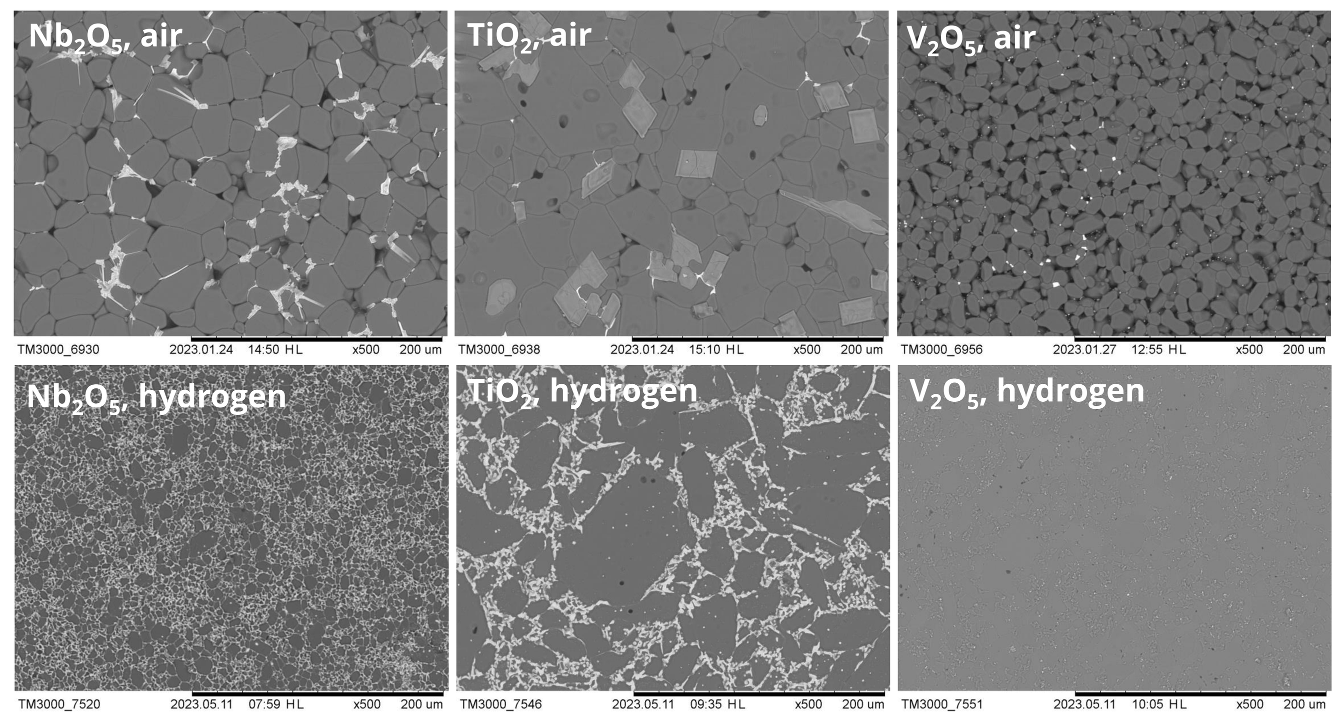
Surface doping: Dense alumina substrates were spray-coated with transition metal oxides and fired in different atmospheres.

All samples were reduction fired in wet hydrogen.

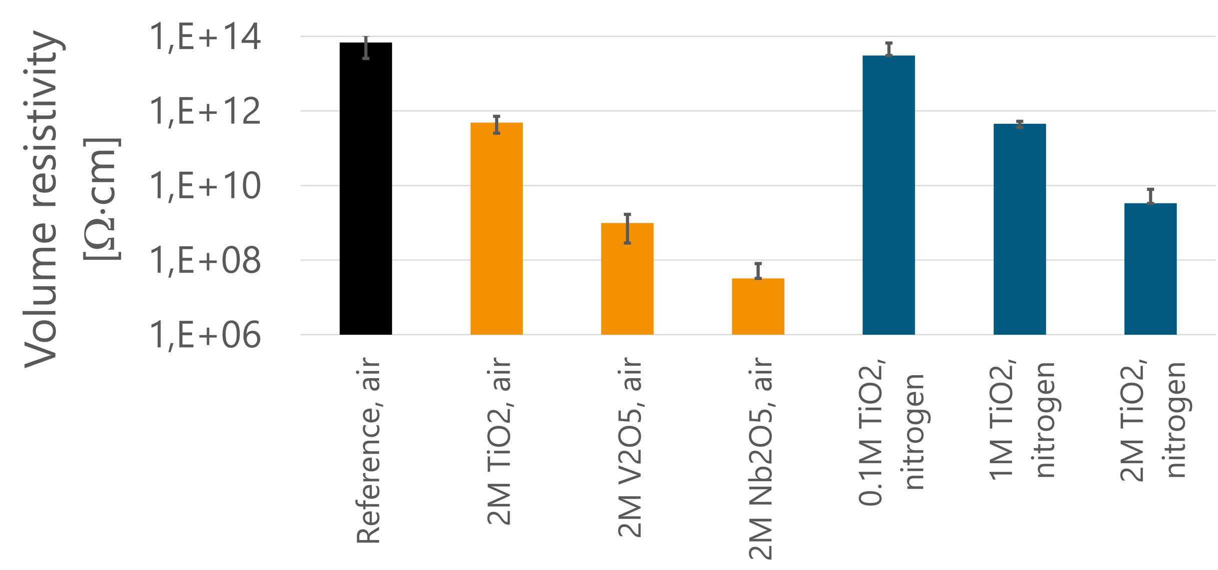
The microstructure was investigated by SEM, and the electrical resistivity was measured with a ring electrode at 500 V_{DC} in air.

The charge dissipation properties were investigated by statically charging the ceramic surface and consequently measuring the residual surface charge.

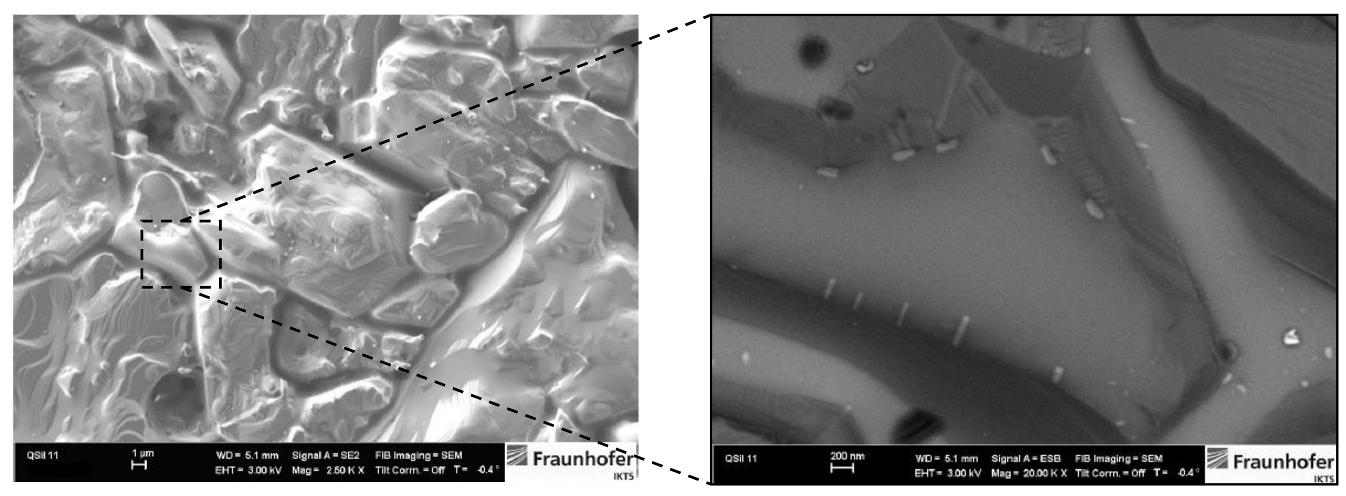
Doped alumina ceramics



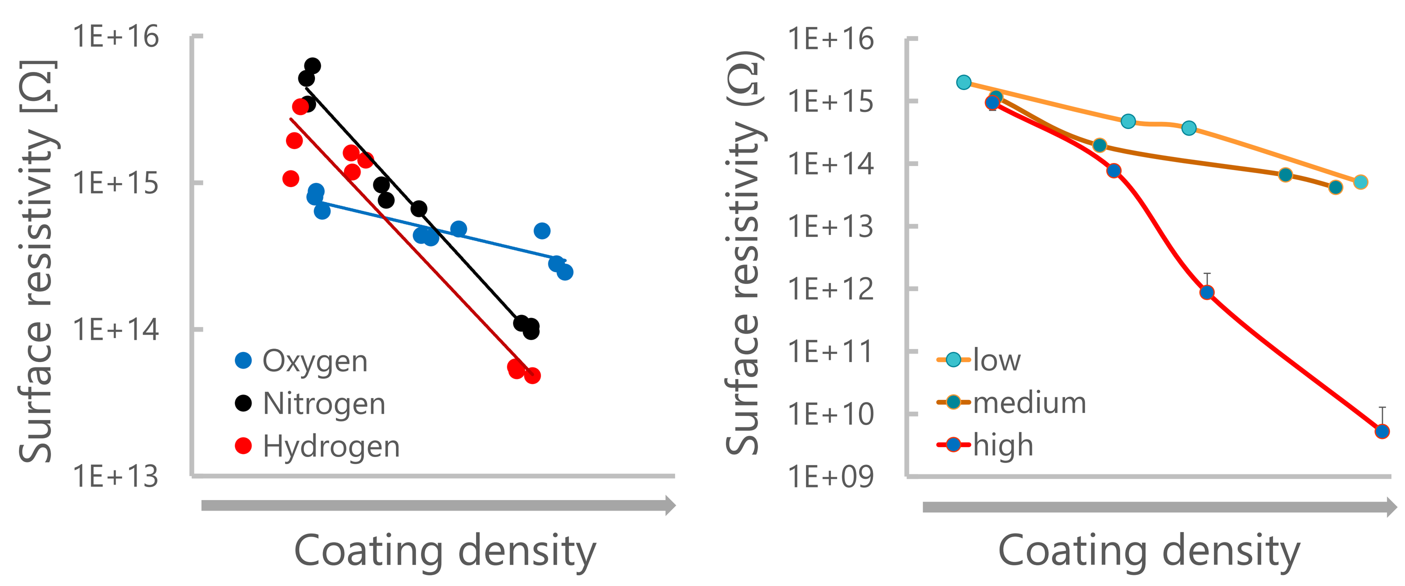
Microstructure of 99.5% Al_2O_3-ceramics volume-doped with 2 mol.% metal oxide after sintering in air or hydrogen



Resistivity of volume-doped Al_2O_3-ceramics sintered in air or nitrogen and a consequent reduction firing in hydrogen

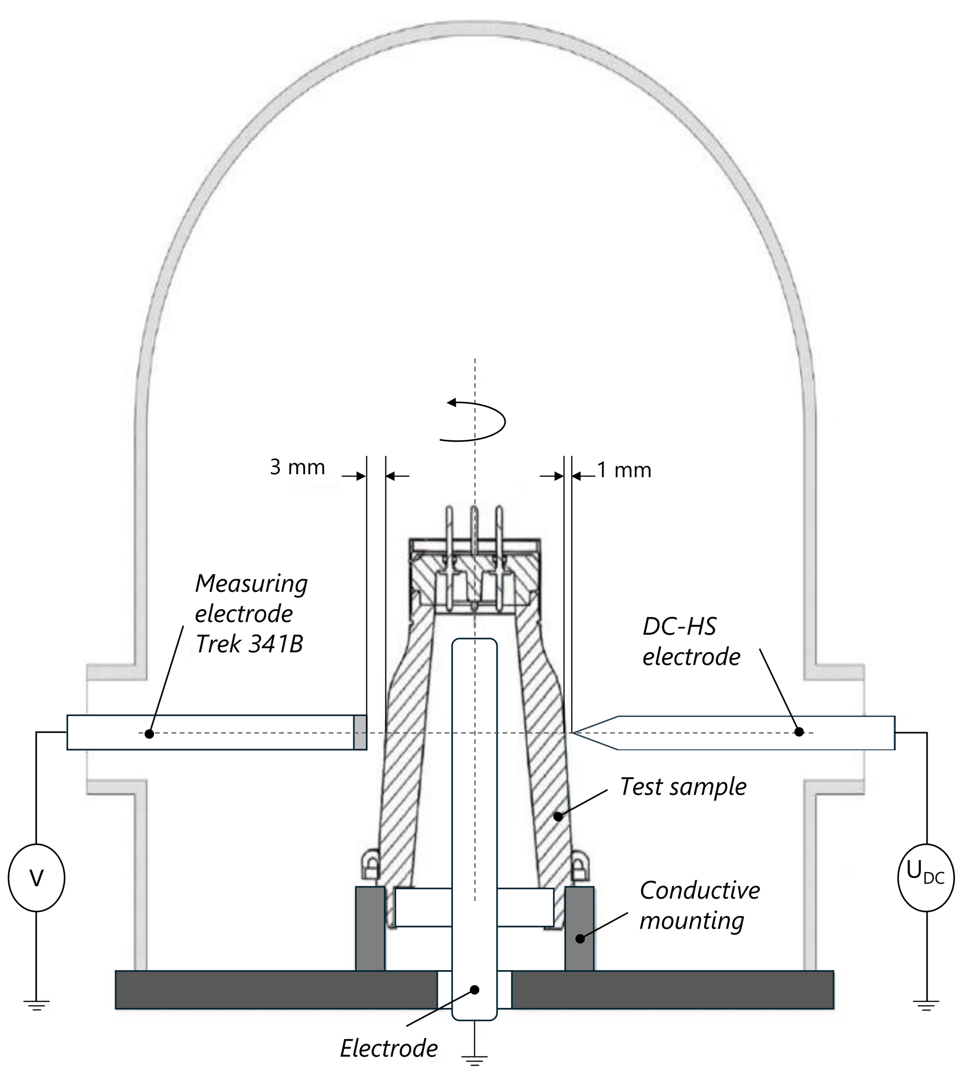


SEM micrographs of the surface of TiO_2-surface doped alumina sample

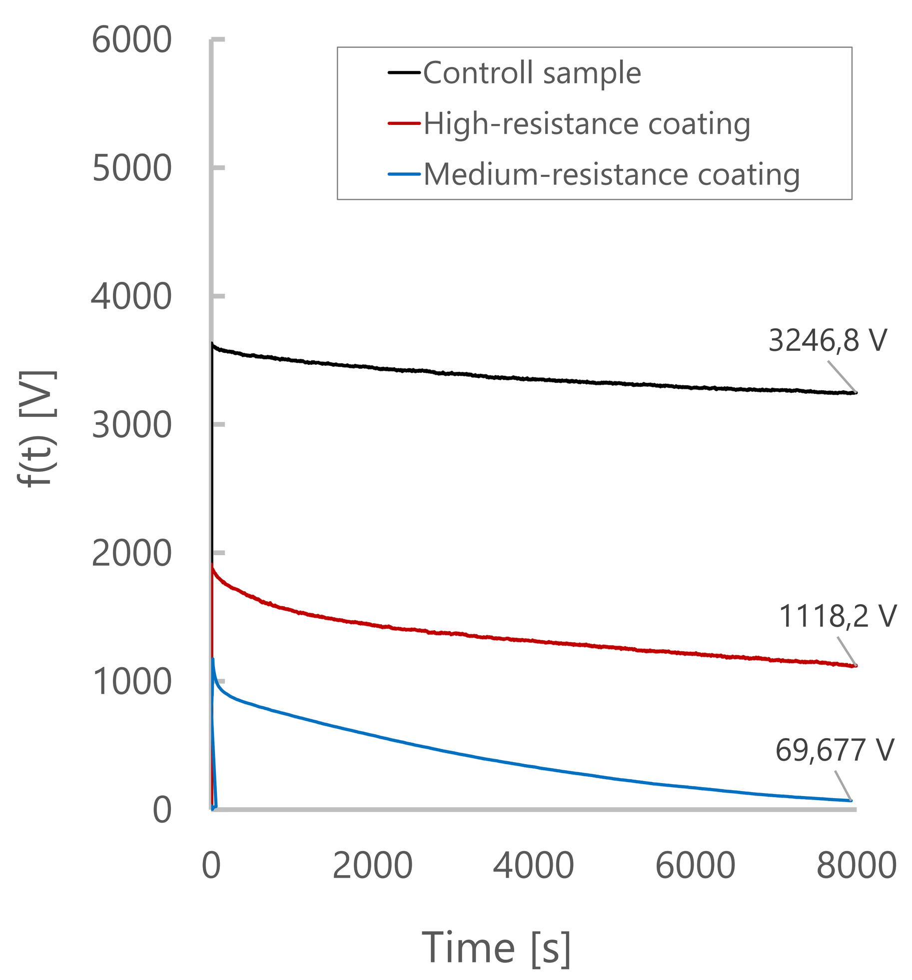


Effect of coating thickness, firing atmosphere, and temperature of reduction treatment on the surface resistivity of TiO_2-surface doped alumina ceramics

Charge dissipation properties



Schema of the test setup for measuring the surface potential



Temporal progression of the surface potential after lateral charging of the ceramic body

Conclusions and outlook

- Doping with transition metal oxides was applied in industrial conditions to modify the electrical conductivity of commercial alumina ceramics.
- The dopants contribute to the electrical conductivity by building a 3D-network of conductive suboxide phases among the alumina grains.
- The conductivity can be adjusted in a wide range by the selection of the dopant, the dopant concentration and the processing conditions.
- The doped ceramics dissipate the surface charge faster than the undoped ceramics. The rate of dissipation is proportional to the surface conductivity.
- Alumina ceramics with improved dissipation properties are promising materials for the next-generation high-power X-ray tubes.

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References:
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[2] US 6641939 B1, Transition metal oxide doped alumina and methods of making and using
[3] EP2857373, High-withstanding-voltage alumina sintered compact and high-withstanding-voltage member