TiN METALIZING AND COATING FOR MULTI-MEGAWATT RF VACUUM WINDOWS

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ABSTRACT

Coatings on microwave windows and high-voltage ceramics are required to eliminate secondary electron emission (SEE), which initiates multipactoring discharge causing local heating and ceramic failures due to cracking and loss of vacuum. The region surrounding the triple junction (ceramic+metal+vacuum) is the primary source of free electrons and in microwave windows and high-voltage ceramics. This region is located at the metalizing and braze joint of the ceramic support structure making the vacuum seal. On very large microwave windows typically at low frequencies, this critical region is difficult to coat by the traditional techniques of sputter coating anti-multipactoring titanium nitride or other materials. The novel processes proposed here include a means for applying and controlling the thickness of titanium nitride both in the metallizing (controlling the source) and on the surface of the window, eliminating SEE and the multipactoring discharge

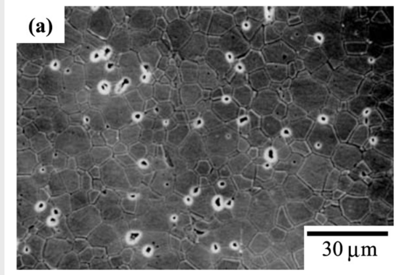

Figure 2. This example of alumina (Al_2O_3) porosity is Figure 1.4a from “Sintering: Densification, Grain Growth, and Microstructure” Kang, S., Elsevier Butterworth-Heinemann, 2005

Open pores are on the surface of the ceramic and closed pores are in the bulk of the ceramic (see Figure 2). Because ceramics are sintered and not melted, porosity is dependent on the ceramic manufacturer’s processes. As a result, every ceramic metalizing chemistry is fine tuned to a particular manufacturer’s ceramic, and manufacturers of ceramic assemblies have a favorite ceramic that works well with their metalizing process

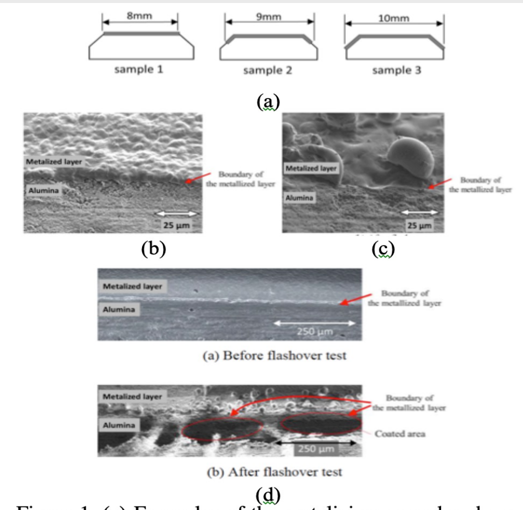

Figure 1. (a) Examples of the metalizing around a chamfer (Figure 2 Reference [1]) (b) before processing, (c) changes to the triple junction region after high voltage processing (Figure 9 Reference [1]), (d) Figure 10 Reference [1], identifying the coated area which “eliminated” the triple junction region.

DESIGN OF EXPERIMENTS (DOE)

The DOE uses a matrix of variables to efficiently determine the optimum values of those variables. Those variables and the measurements required to control the results are described with the ranges used in the DOE:

1. Ceramic type will be 96-97% purity from different manufacturers, a variable.
2. The %TiN is by weight of TiN nanoparticles in the Mo-Mn base metalizing by INTA and ball milled, a variable.
3. Firing temperature ramp time and hold time is a constant
4. Firing atmosphere is a constant
5. Surface finishing grinding tool is changed for different surface roughness, a variable
6. Surface Resistivity measurements of are made during the grinding process. Removal of material is completed based upon the measurements of surface resistivity in various ranges 10^{10}-10^{15}, 10-1^3, and 0
7. SEM photos of the surface verifying charge depletion (measured)
8. Peel Test of copper brazed to coupon, ksi ((measured)

The Design of Experiments are crucial to controlling processes in industry. The techniques have been used for many years and have proven invaluable to maximizing results with a minimum of cost and effort.

Table 2. An L9 array with 4 parameters at 3 levels.

Run #	Surface finish	Surface Resistivity	%TiN in Metalizing	Ceramic Supplier
1	16	0	25%	1
2	16	10^1-10^3	50%	2
3	16	10^{10}-10^{15}	75%	3
4	32	0	50%	3
5	32	10^1-10^3	75%	1
6	32	10^{10}-10^{15}	25%	2
7	64	0	75%	2
8	64	10^1-10^3	25%	3
9	64	10^{10}-10^{15}	50%	1

Modeling the Triple Junction

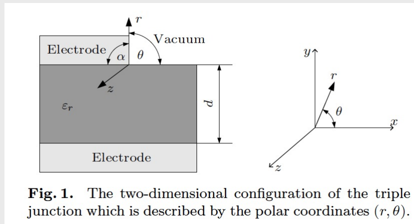

Figure 3. Modeling the triple junction with dielectric constant of the ceramic and angle of the electrode [9].

Most recent examples of modeling the triple junction have pointed to the ways in which the electric field could be modified to reduce field emission [9]. In this work, the angle of the electrode and the dielectric constant of the surface of the ceramic in vacuum are considered. Their results map with some elements of the findings in Reference [1], namely in how increasing the angle α and the surface characteristics next to it, θ, described in this model by the dielectric constant, impacts the contours of the electric field in the region and changes the enhancement factor. The modeling is far from perfect and needs modi-fications we intend to implement. In particular, pre-breakdown current from the region of the triple junction, which is well documented, and how that current impacts the voltage at the triple junction will be included.

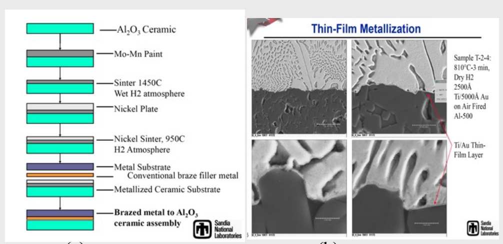

Figure 4. (a) The standard Mo-Mn process and (b) A thin film process using Ti and Au on AL500 Alumina achieving 12-14ksi peel strength[7]

The standard Mo-Mn metallizing processes, and thin film processes using Ti and Au, are shown in Figure 3. In Figure 3(b), both the surface roughness and porosity of alumina is identified and it is this characteristic which we shall take advantage of in creating a novel coating for RF windows that is the solution to three issues: 1) multipactor, 2) surface charging, and 3) brazing in the region of the triple junction.

NOVEL COATING APPROACH

The goal is to eliminate the triple junction, secondary electron emission, and window charging by developing a novel coating technique that can be used for all three. The window charging will be eliminated by producing a surface with a resistivity of 5x1010 to 1015 W/sq. The secondary electron emission will be eliminated by the use of TiN in the coating. The triple junction will be eliminated by coating the surface of the ceramic about 1-2 mm from the triple junction with a surface resistivity in the range of 101 to 103 W/sq.

To understand how a coating eliminates the triple junction a simple model is proposed: pre-breakdown current from the triple junction along the coated surface creates a re-duction in the potential seen at the triple junction by sim-ple IR losses. This is typically the result of conditioning as seen in the SEM photos of the condition junction of reference [1], but in this project, the novel coating processes will create this “conditioned” appearance. During the project a more thorough model will also be developed of the conditioned triple junction. The RF and mechanical design of the 402.5 MHz window in WR2100 waveguide will also be documented.

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