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Simple Ion Beam Solutions

A solution to arcing caused by graphite grids in IBD process

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For some ion beam deposition (IBD) processes that involve dielectric coatings, graphite grids may develop periodic arcing. This arcing can be mitigated by a metallization process where there is no oxygen introduced to the chamber. It is thought that the positive charge buildup at the surface of the coated oxide on the accelerator grid is the cause of arcing. In order to mitigate the charge buildup, a periodic metallization step is proposed where a conductive layer is coated on the top of the oxide to prevent charge buildup.

Introduction

Ion Beam Deposition (IBD) is widely used for the deposition of optical coatings and other materials. Even though the ion beam parameters are optimized and the erosion of source grids is minimized, there is still some level of metal contamination incorporated into the deposited coating which originates in the grid materials such as Molybdenum or Titanium. Graphite grids are attractive for a process which requires low metal contamination, however they do require special attention. For example, graphite is a fragile material that can easily be damaged by dropping and other mechanical impacts.

Furthermore, the graphite grids may tend to develop more arcing when metal oxide or silicon dioxide is deposited in oxygen gas environment. The DC voltages applied to the screen and the accelerator grids collapse at the moment of arcing due to electrical short. As the arcing becomes more frequent and more severe, the power supply will not be able to properly regulate the grid voltages and the operation of the ion source will become impossible.

In general terms, grid arcing occurs for various reasons. These include but are not limited to (i) improper grid-to-grid spacing, (ii) local high pressure due to outgassing from the graphite grids, (iii) dielectric deposition on grids. All are potential causes of arcing, however the first two possibilities can be eliminated by proper assembling of grids and sufficient source warm up. The dielectric deposition on the grids might be the most difficult issue to deal with since the grids continuously receive the sputtered material from the target and the deposited film on the grids keeps growing during the deposition runs.

Problem description

Even if the ion beam is well focused with no direct impingement of high energy ions on the downstream grids, some ions still impinge on these grids. Early investigations showed these ions are mostly created by charge exchange collisions between the high energy ions extracted from the discharge chamber and neutrals (gas atoms or molecules) around the grid region [1]. These charge exchange ions do not have high kinetic energy and are easily attracted to the negatively biased accelerator grid (some ions are attracted to the decelerator grid, too). When the accelerator grid is electrically conductive, it does not cause charge buildup. However, most of metal oxides and silicon dioxide deposited on the accelerator grid are dielectric, so ion impingement on these oxides causes charge buildup.

It is thought that the arcing occurs in two steps. The first step is that the excessive charge buildup eventually causes break down and its energy evaporates the material nearby. The second step is that the evaporated material causes the momentary increase in the local pressure which ignites arcing between the positively biased screen grid and the negatively biased accelerator grid. In fact, it is observed that both the screen and the accelerator voltages collapse to create a short circuit between the two when arcing is observed.

This type of arcing does not occur when the grids are new and clean. As the deposited oxide thickness increases, the arcing begins to occur and the frequency of arcing keeps increasing.

For testing, several different graphite grid configurations were examined (e.g. clean and coated). The graphite grids investigated were for a 16 cm RF ion beam source mounted in a Techne IBD system. Target materials investigated were SiO_2 from SiO_2, TiO_2 from Ti, both with an oxygen background partial pressure.

In one case study, testing was performed on a grid set assembled with a clean screen grid, an oxide-coated accelerator grid and a clean decelerator grid as depicted in Figure 1. The typical arcing trends were observed in the sputter deposition process run with oxygen gas.

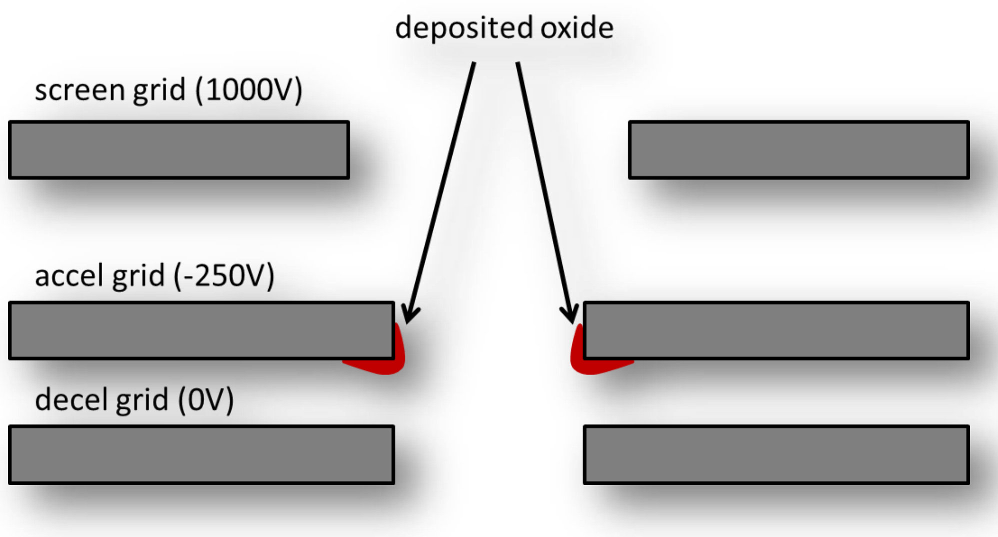

Figure 1. Grid assembly beamlet (one hole) diagram with a clean screen and decelerator grids, oxide coated accelerator grid.

For the next case study, a grid set was tested where the grid assembly consists of an oxide-coated screen grid, a clean accelerator grid and an oxide-coated decelerator grid. These grids did not arc for the first ~30 minutes in an oxygen gas environment.

These two case studies indicate that the oxide coating on the accelerator grid is a major contributor for the arcing, while coating on the other grids has little contribution.

The type of grid arcing observed with graphite grids does not occur with other grid materials such as Molybdenum or Titanium. The graphite has porous structure and its oxides (CO and CO_2) are gaseous. These unique features may create a more electrically insulating environment at the boundary between the graphite grid and the deposited oxide film causing charge to accumulate more significantly, and resulting in more susceptibility to arcing.

Proposed solution

A conceptual method to reduce the charge buildup on the accelerator grid is to metalize the surface of the oxide coating on the accelerator grid and release the charge through this electrically conducting layer. The background oxygen gas can be simply turned off in the middle of the reactive deposition run to achieve this.

We experimentally demonstrated the effectiveness of this metallization step. The first step is to create the situation where there is high arc count. This was done by running the deposition process with oxygen for a long time, forming a thick oxide coating on the accelerator grid. Arc counts exceeded 100 per minute.

The second step is to turn off the background oxygen in the process and deposit a metal coating on the grid assembly. As shown in Figure 2, the arc count decreased rapidly to less than 1 per minute within one minute, and eventually reached zero. When turning on the oxygen again, the arc count remained less than 1 per minute for 10-30 minutes depending on the length of the metallization step, and then gradually increased back to the original arc count level after a few hours. Unfortunately, the effectiveness of metallization step is not infinite, and users need to insert another metallization step before the arcing returns.

A proposed implementation of the metallization step is shown in Figure 3. In this example, the metallization step is inserted every 4 layers of the process step. The actual frequency and length of the metallization step largely depends on the process condition. Note that the metallization process typically requires a shutter between the target and the substrate to prevent the unwanted metallic material from depositing on the substrate during the metallization step.

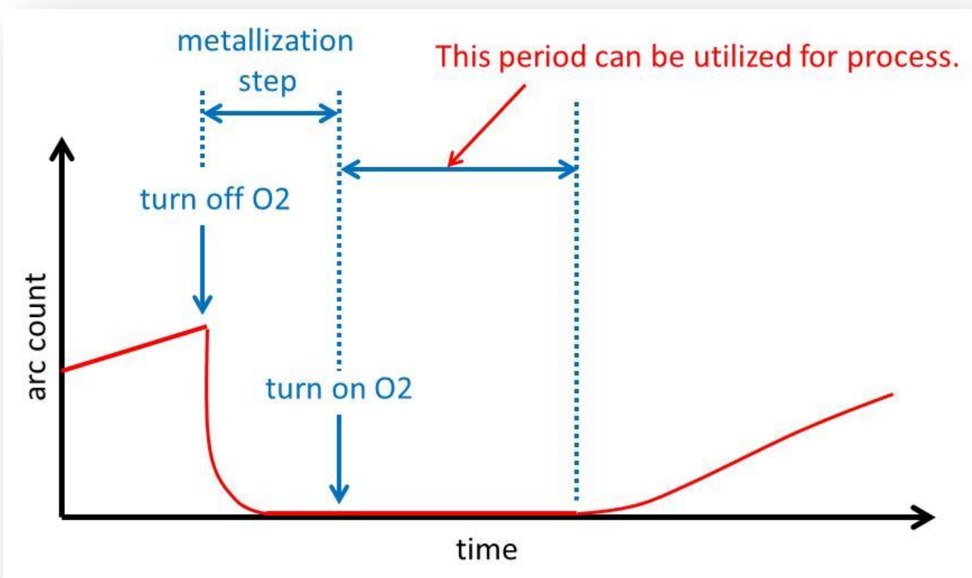

Figure 2. Effect of metallization step on arcing. As O_2 is turned off while there is high arc counting, arc count rapidly decreases to zero within a few min. Arc count starts to increase once O_2 is turned on again, but only after some arc-free process time.

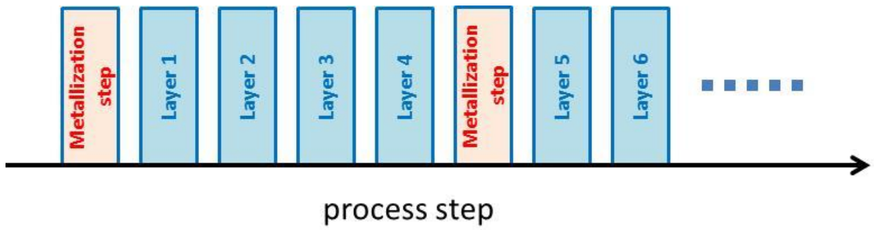

Figure 3. An example of the implementation of metallization step. Metallization step is inserted prior to the process run, and every 4 layers.

Conclusions

The mechanism of arcing with graphite grids in typical IBD process is investigated and a proposed solution is demonstrated. The arcing seems to occur due to the charge buildup on the accelerator grid when it is heavily coated with a dielectric material. Metallization steps inserted between process steps form conductive layers which avoid the charge buildup. Proper length and frequency of the metallization step eliminates the arcing.

References

[1] Monheiser J M, Wilbur P J "An experimental study of Impingment-Ion-Production Mechanisms" AIAA 92-3826, Joint Propulsion Conference (1992)