PLASMA CLEANING

A new method of ultra-cleaning detector cryostats

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Abstract: First results are reported from the application of a plasma-based method to ultra-clean detector cryostats. The device used is a LFG40 Controller from Diener electronic (http://www.dienerelectronic.de/en) in connection with a Kendro VT6060M vacuum oven. This technology considerably extends and enhances the cleaning methods used by ESO as described at SDW2002[1]. It cannot replace them but actually requires their previous application. Its virtues are the speed and ease of application. Particularly attractive is the possibility to treat a previously cleaned or lightly contaminated cryostat without prior disassembly (but with detectors removed), e.g., after it has been re-opened for corrective action.
The paper describes the principles of plasma cleaning, its general technical realization, the practical application, and possibilities for adaptation to specific needs. Various qualitative and quantitative measures of the efficiency of plasma cleaning are presented and as an example of successful plasma-cleaning: the very large OmegaCAM cryostat [2].

Key words: Cleaning, contamination, CCD cryostat, plasma, UV sensitivity

1. INTRODUCTION

Detector cryostats are very often affected by contamination, which can decrease especially the blue and ultra-violet sensitivity of CCD detectors. Infrared detectors seem to be less sensitive to contamination, but there is no alternative to an ultra clean detector cryostat.

Conventional cleaning methods like mechanical and chemical cleaning followed by a baking procedure give already good results [1]. However, investigating processes followed in industry, we found that ultra-cleaning can only be obtained by a final cleaning step of plasma cleaning.

Plasma cleaning is an easy cheap method requiring simple installations. It is low risk and excellent cleaning results can be obtained within a few hours of receiving the necessary equipment.

2. CONVENTIONAL CLEANING

As described in “CCD contamination can be kept under control” [1] conventional cleaning of detector cryostats consists of mechanical rough cleaning by tissues or other tools followed by ultrasonic cleaning with special detergents. The parts are then rinsed in de-mineralized water or bathed in acetone and/or alcohol, dried and then baked to their individual maximum temperature up to 160 centigrade in a vacuum oven.
Experience shows that residuals and traces of organic contaminations remain even after this rigorous process on surfaces and in cavities. These can affect the detector performance after left cold for several months of operation at the telescope site.

3. PLASMA CLEANING PROCESS

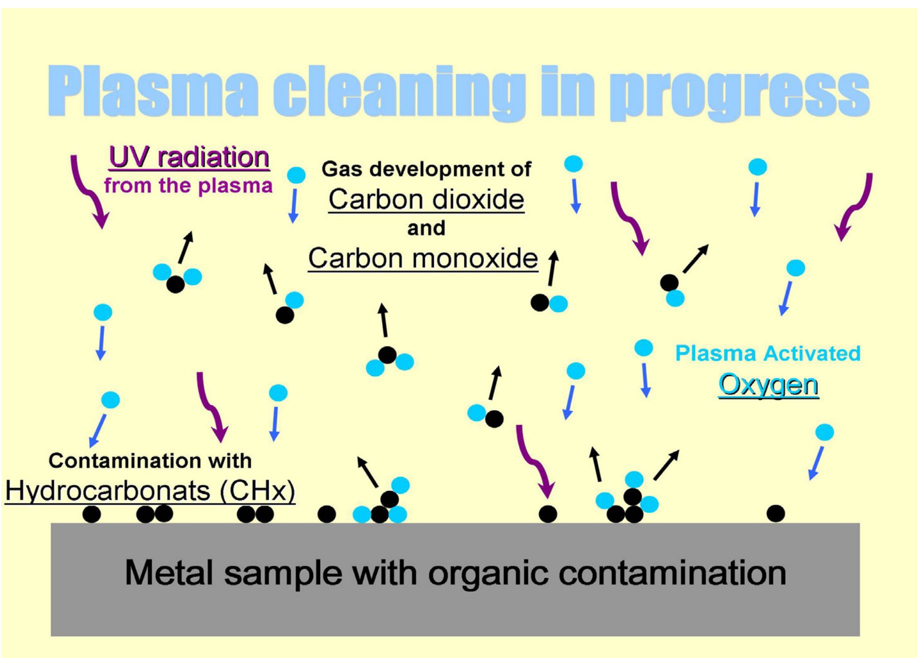

Figure 1. Oxygen ions of the plasma react with hydrocarbon contaminants to produce carbon monoxide and carbon dioxide, which can be pumped away

Plasma cleaning is suitable for removing very thin films, especially hydrocarbonats and oxides, which remain after conventional cleaning.
It is important to choose the correct plasma gas as gases react and work in different ways at removing contaminants. Oxygen removes contaminants by oxidation and reduction (see Fig. 1). Other neutral gases like Argon clean by sand-blasting surfaces.

4. REALIZATION OF PLASMA CLEANING

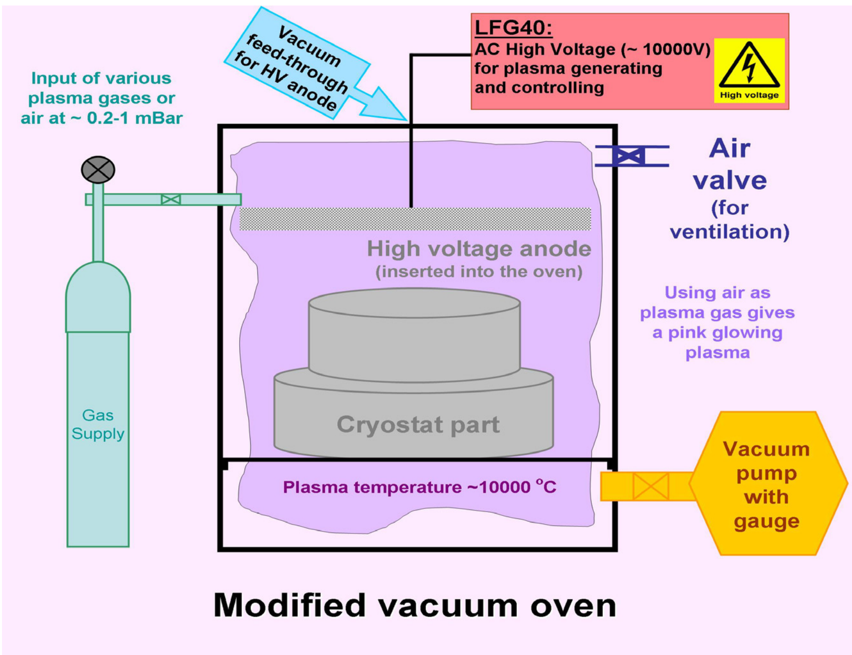

Figure 2. Plasma cleaning using a modified vacuum oven

An existing vacuum oven (Kendro VT6060M) was modified by introducing a high voltage anode through a vacuum feed-through at the backside (see Fig. 2). A strong dry vacuum pump (Alcatel ACP28) was used to quickly pump down the insides of the oven to approx. 0.1mBar. Ambient air or gas from a bottle (we tried synthetic air, oxygen or Argon) produces a constant gas stream regulated by the oven gas valve through the oven giving a pressure of 0.1 – 1 mBar. This is the optimum pressure to ignite the plasma with the connected LFG40 plasma controller from Diener Electronic[3]. Oxygen is the best cleaning gas for aluminium and stainless steel parts. Hydrogen is best for cleaning of noble metals. However, ambient air is sufficient for good cleaning of most materials. The normal cleaning time takes no longer than 10 minutes.

5. PLASMA CLEANING IN READY ASSEMBLED CRYOSTATS

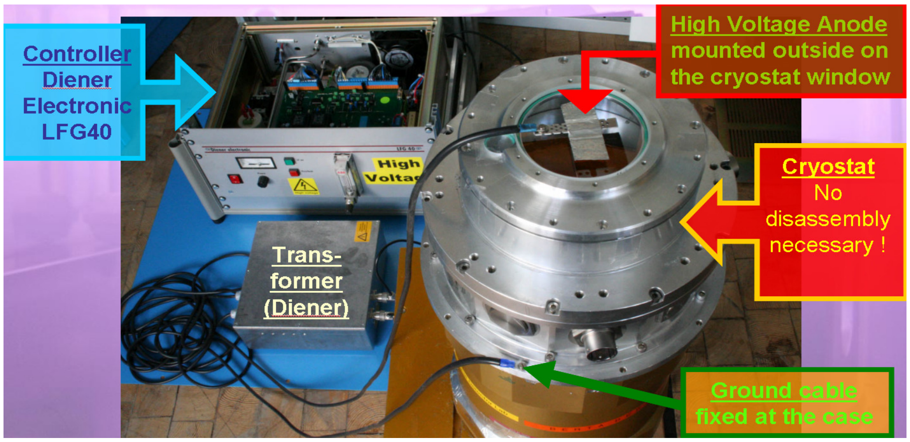

Figure 3. Special arrangement: Plasma ignition inside a ready assembled cryostat

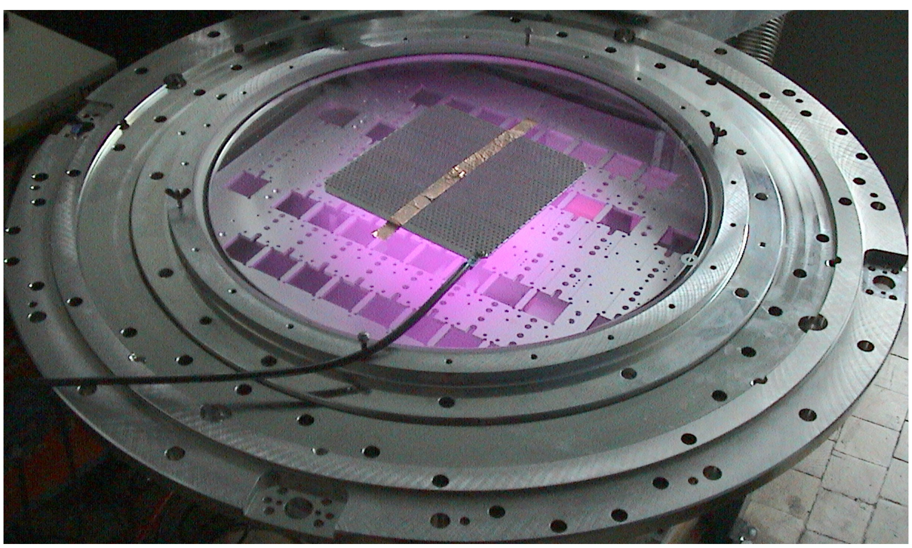

Figure 4. OmegaCAM Cryostat during plasma cleaning

Another very useful application is the possibility to ignite the plasma in a ready assembled detector cryostat. This is possible with only an additional transformer and high voltage anode simply glued to the entrance window of the cryostat (see Fig. 3). This technique is extremely useful to maintain optimum cleanliness after short opening of the cryostat for minor modifications. Without this special plasma cleaning technique it would not have been possible to clean the OmegaCAM cryostat due to its large volume (approx. 120l volume). There was no alternative to this internal plasma ignition technique. After some minutes of ignition, the whole OmegaCAM cryostat was filled with a violet colored magic glowing plasma (see Fig. 4).

6. TEST OF PLASMA CLEANING RESULTS

Water drop method:

A sample which is contaminated shows a round water drop on its surface (see Fig. 5 left side) due to surface tensions created in the water by the contaminates. After plasma cleaning there is little or no adhesion on the surface due to the lack of contaminates so no water drop develops and the water simply flows away (see Fig. 5 right side).

Figure 5. Demonstration of water drop method

End vacuum test:

A cryostat after plasma cleaning reaches a much better end-vacuum after 1 hour of pumping. In our tests, a much lower pressure of 5.0E-5mBar was obtained after plasma cleaning compared to 1.0E-3mBar before plasma cleaning.

Mass-spectrometer test:

A mass-spectrum was taken of a sample contaminated with a typical thin film of workshop oil before and after plasma-cleaning. The resulting two

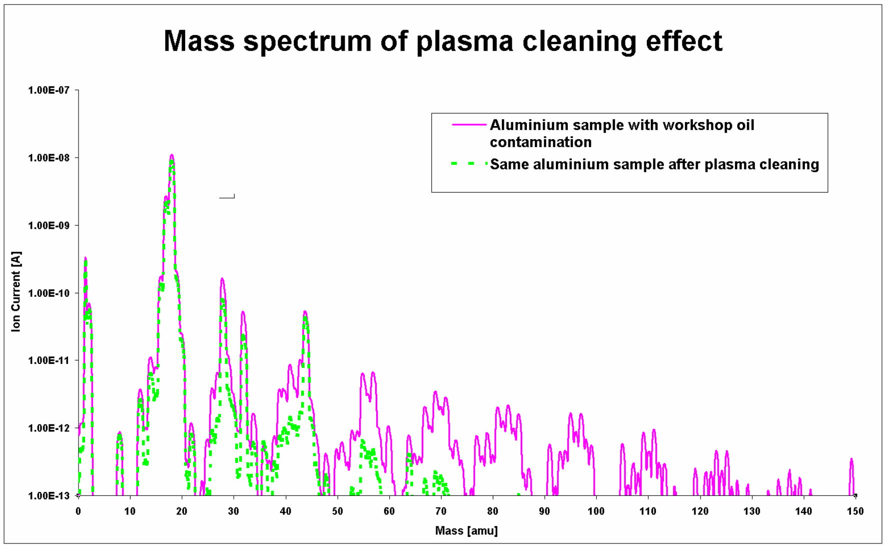

Figure 6. Mass-spectrum of sample before and after plasma-cleaning

spectrums (see Fig. 6) show that most of the lines above masses of 50 amu are reduced significantly. Previous experience shows that unwanted contaminants mainly consist of elements and molecules with masses above 50 amu.

7. COSTS AND CONSTRAINTS

The cost of plasma cleaning equipment is low especially if one can refurbish an existing laboratory vacuum oven and/or if one can use an existing vacuum pump. The annual maintenance costs are negligible.

Procurement costs:	
Vacuum oven	~8000 EUR
Diener Electronic	
LFG40 Plasma Controller	~5000 EUR
Diener Electronic Converter	1000 EUR
Vacuum pump Alcatel ACP28	7000 EUR
Maintenance:	
Electrical costs per cleaning process	0.20 EUR
Costs of special gases	~200 EUR per annum
Maintenance	>100 EUR per annum

Stainless steel and aluminum can be plasma cleaned for up to 1 hour duration, however, more than satisfactory cleaning results can be obtained within 10 minutes of cleaning.
Noble metals should not be cleaned longer than 10 minutes in ambient air and oxygen else they become black. Hydrogen gas is an alternative for longer cleaning of these materials.
Plastic materials and PCBs should not be plasma cleaned longer than 10 minutes or surface damage (melt) may result. The plasma cleaning process works by producing temperatures in excess of 10,000 °C in the first molecular layers of the sample to "burn" away contaminants. The sample remains hand-warm in its interior. This "burning" away could damage plastic materials when exposed too long to the plasma. Up to now no damage has been observed to electronic components on PCB boards, however, we are yet to clean highly static sensitive *active* components like operational amplifiers. Before assembled cryostats are cleaned, detectors are removed to reduce risk of damage or irreversibly degrading of their performance. The plasma treatment induces strong electrical field and high surface temperatures which could damage the fine surface structures of detectors. We would welcome for our future tests any working CCD sample from a manufacturer interested in tests with this cleaning procedure. Maybe with plasma cleaning the quantum efficiency of the detector could be improved.
All plasma cleaned pieces should be handled using standard clean room conditions, otherwise the plasma-cleaning will need to be repeated.

For safety reasons, personnel should not be exposed to the exhaust gas coming from the vacuum pump, plasma filled oven or cryostat. The UV radiation emitted from the plasma is harmless as it is fully absorbed by the oven window. The high voltage cables of the plasma devices should be handled following standard electrical safety procedures.

8. CONCLUSIONS

Plasma cleaning is shown to be an easy and effective method in achieving ultra high cleaning results for detector cryostat components and/or complete assembled cryostats when used in addition to conventional cleaning processes. It is a fast cleaning process and has even been applied successfully to the very large OmegaCAM cryostat.

ACKNOWLEDGEMENT

I want to thank Mark D. Downing for “polishing” my English in this paper.

REFERENCES

[1] Deiries, S. et al.: Ultra-clean CCD Cryostats – CCD contamination can be kept under control, Scientific Detectors for Astronomy, Kluwer Academic Publishers, 2004

[2] Iwert, O. et al.: The OmegaCAM 16k by 16k CCD detector system for the ESO VST, Talk at SDW2005 in Taormina

[3] More information about the Plasma cleaning process and about custom made and standard plasma cleaning devices are available from
Diener Electronic at http://www.dienerelectronic.de/en/index.html