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The Study of Silicon Deposit and Cleaning Gas

(Phase III)

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In a previous report, we discussed the effectiveness of the cleaning gas (with 8% CF_4) in removing the silicon deposit from the wire surface. Although it is difficult to make an accurate estimation of necessary C/cm to restore gain to the original values, our data indicates that in order to restore 10-20% gain reduction, ~0.005 C/cm would be enough (with moisture level of ~700ppm). This integrated charge can be obtained within one day of operation at the design LHC luminosity.

One of the previous aging tests indicated that the glass wire-joints could survive safely ~0.2 C/cm with the 8% mixture. In other words, the number of safe cleaning could be as many as 40 times.

One of the objectives of this aging test is to find a set of parameters which is most effective in removing silicon off the wire surface but least damaging to the glass wire-joints. One parameter is the CF4 fraction in the cleaning gas. Another parameter is the moisture content in the straws. We already know that these two are the critical parameters controlling the glass-joint life time. In this paper, we report on the effect of the moisture level in removing silicon deposit from wire surface.

Procedure for Silicon deposit and cleaning

First let me discuss the procedure for depositing silicon on the wire. This is based on the previous run experience.

1. The ionization gas (Ar-CO2 (70-30)) is passed through the tube with silicone oil.
2. After the straws are filled with the silicon contaminated gas mixture, the Sr^{90} sources are opened for 20 minutes. Normally, the current drops by ~15% during this time.
3. After forcing the silicon deposit on the wire, gas now bypasses the tube with silicone oil. Flush the straws with the gas enough for at least ~50 times of straw volume.
4. Remove residual oil by opening the sources for ~one hour (this forces residual silicon to deposit on the wire surface). This step can be used to control the total amount of the silicon deposit (or gain loss).
5. Purge the straws overnight to clean out residual silicone oil.
6. Remove any residual oil by opening the sources for ~a couple hours until there is no more gain drop.
7. Change the gas to a cleaning gas mixture to start the cleaning process.

The steps for the cleaning procedure are as follows

8. Open the sources for 40 minutes
9. Make the gain map of all the straws (takes 20 minutes)
10. Repeat 1 and 2 continuously.

Plots

There are 12 usual plots for each straw taken at different stages.

Plot 1: The original gain map
Plot 2: The ratio of the gain map just before procedure 2 to Plot 1
(This ratio is called Rg. The denominator is always Plot 1)
Plot 3: Rg distribution after procedure 2
Plot 4: Rg distribution after procedure 4
Plot 5: Rg distribution during purging (procedure 5)
Plot 6: Rg distribution after procedure 6
Plot 7: Rg distribution one hour after starting the cleaning
Plot 8: Rg distribution after five hours
Plot 9: Rg distribution after ten hours
Plot 10: Rg distribution after fifteen hours
Plot 11: Rg distribution after 25 hours
Plot 12: Rg distribution after 40 hours

The effect of the moisture level in cleaning - discussion

Previously, we reported on the cleaning effectiveness of the 8% mixture with moisture level of ~700ppm. In this report, we show the results from the same mixture but with lower moisture level. The lower moisture level was obtained during the procedure 5 above. The CO_2 flow rate to the volume enveloping the straws and the dry air flow rate to the radiation shield box was increased to reduce the moisture level to ~450 ppm from ~700 ppm.

The gain map plots (12 plots above) from this run are shown in the attached plots (Run9PlotV.pdf) for all straws. These are the similar plots as the ~700 ppm run distributed earlier. From the plots we can conclude that within 24 hours (16 hours of irradiation), gain is restored for most region of wires except near the upstream HV plates, where the speed of restoration process is much slower (more below).

One good way to show the effectiveness of the cleaning power is to plot Rg as a function of time for a given straw and a location (along the straw). An example of this plot is shown in Figure 1. This is from straw #19, location 14. t=0 (the first point) is when the sources are opened for the first time with the cleaning gas in straws. The data is plotted every hour. When the gain is fully restored, the y value should be near 1. The wire-joint is located between location 14 and 15. The left plot is with ~450 ppm and right plot is with ~700 ppm. It is evident that the restoration slopeis faster with the higher moisture level. This is generally true near the high strength sources. For other locations, it is not obvious.

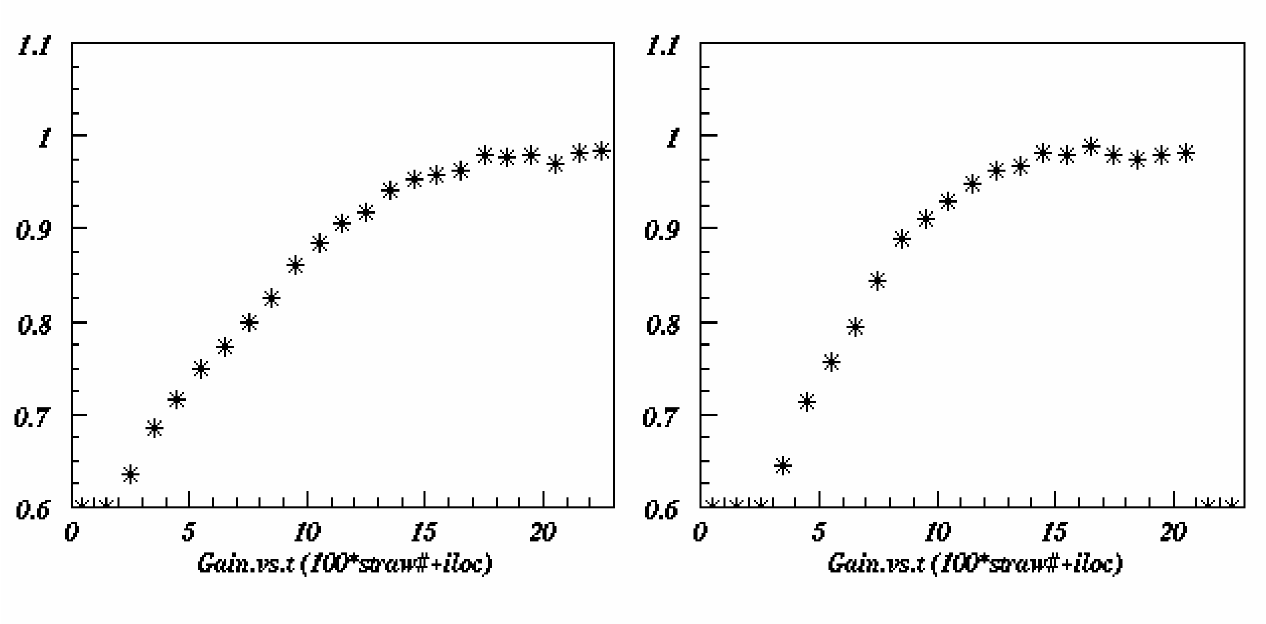

Figure 1. Rg distribution as a function of time from straw 19 and location 14. The left (right) plot is from the run with ~450 (700) ppm moisture level. The horizontal axis is time in hours. Rg is the ratio of the gain at t to the original un-aged gain. The restoration slope in the left plot is slower than the right plot.

Figure 2 shows the same but with straw 17 and location 4. This is one example that the gain at t=0 is different. Note that the smaller the location number, the closer to the gas inlet side. It is interesting that there is ~10% gain loss first before the cleaning happens. This behavior is generally true for the region near the gas inlet. This is not due to residual silicone oil in the ionization gas because during procedure 6 the gain in this region stayed constant. It seems that introducing CF_4 liberates some silicon.

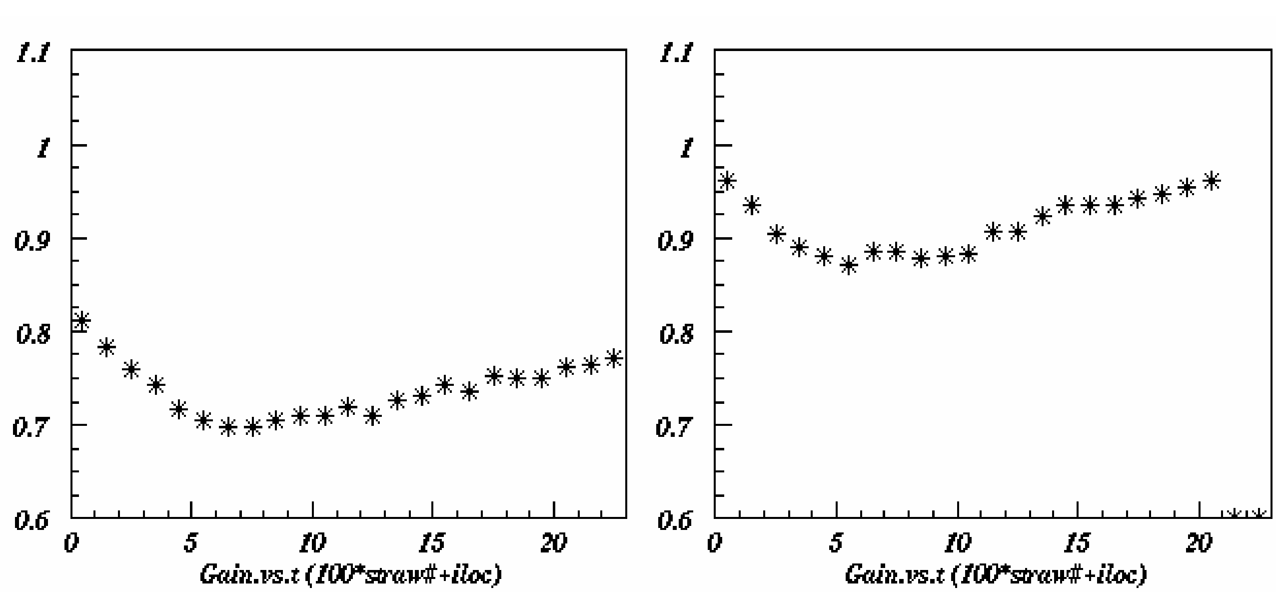

Figure 2. Rg distribution as a function of time from straw 17 and location 4. The left (right) plot is from the run with ~450 (700) ppm moisture level. Both plots have not reached the full restoration and have the similar restoration slope.

Figure 3 below is from the same straw but the location is 20. In both plots, the rate of the restoration is much faster compared to Figure 2. In general, the gain restoration of the downstream section happens at much faster rate than the upstream section.

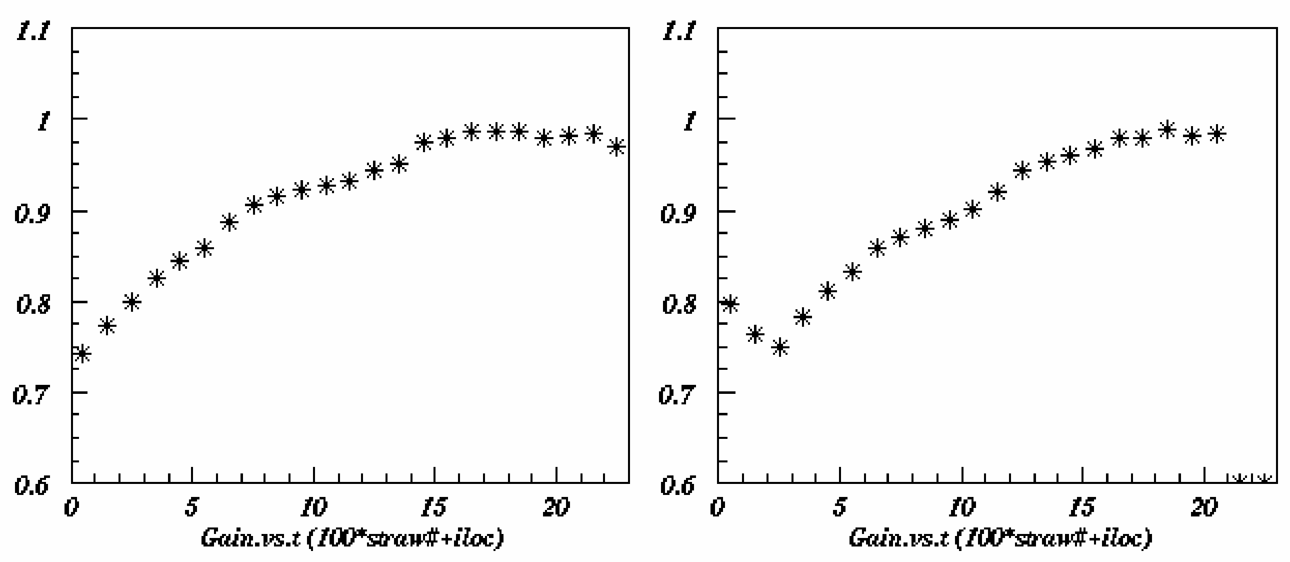

Figure 3. Rg distribution as a function of time from straw 17 and location 20. Both have similar restoration slope. The left (right) plot is from the run with moisture level ~450 (700) ppm.

This may indicate some type of accumulation effect of chemicals which remove silicon deposit. As ionization gas travels along the straw, these chemical are produced (and also used up). The data seems to indicate that it takes some time for the chemicals to reach high enough concentration to remove silicon deposit effectively. This may also explain why the first location (seen in both ~700 and ~450 ppm run) failed to be restored.

One consequence of the chemical build up is the cleaning speed may depend on the flow rate. To test this, the flow rate was reduced by ~1/2 after 18 hours into the run. Figure 4 shows the result of the gas flow rate change. Figure 4a is from straw 17 (location 4, the same as Figure 2a except the time is extended) and there is nothing noticeable around t~20. Figure 4b is from straw 18 (also location 4) and the conclusion is similar. The figures seem to contradict the accumulation hypothesis.

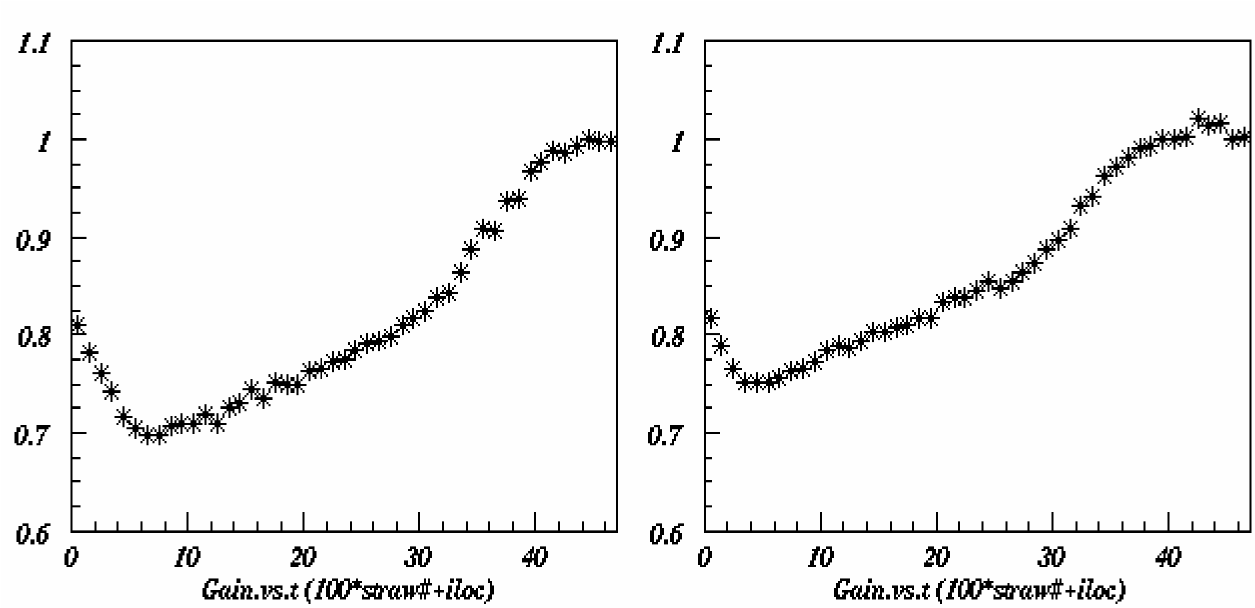

Figure 4. a) The same as Figure 2a except there is more data. b) The same as a) but it is from straw 18. The flow rate is changed at t~20, and there is no noticeable change in the restoration rate. Both are from ~450 ppm data.

Next Step

1. Reverse the gas flow direction.

We observe that it takes much longer for the section of wire close to the gas inlet to reach its original gain. Even after ~ 2 days of running, the gain at the first location is still well below its normal gain (this is similar to the ~700 ppm run) and the restoration at the second location is virtually halted *(see below) as shown in Figure 5. In the ~700 ppm run, the second locations were fully restored within 24 hours (Figure 6). Although Figure 4 may indicate otherwise, the cause may be due to low concentration of chemicals responsible for removing silicon deposit. One way to test this is to reverse the gas flow direction.

(* I should note that this could be due to some residual effect from the previous ~700 ppm run. In that run, the gain of the first location decreased during the cleaning process. By the time the cleaning process ended, the gain of location 1 decreased more than 30% in some straws. Since the gas multiplication is low (means little cleaning chemical production) around location 1, the cleaning process may not happen efficiently at the second location. This could indicate that the length of the wire cannot be cleaned would increase as the number of cleaning increases with reasonable radiation.)

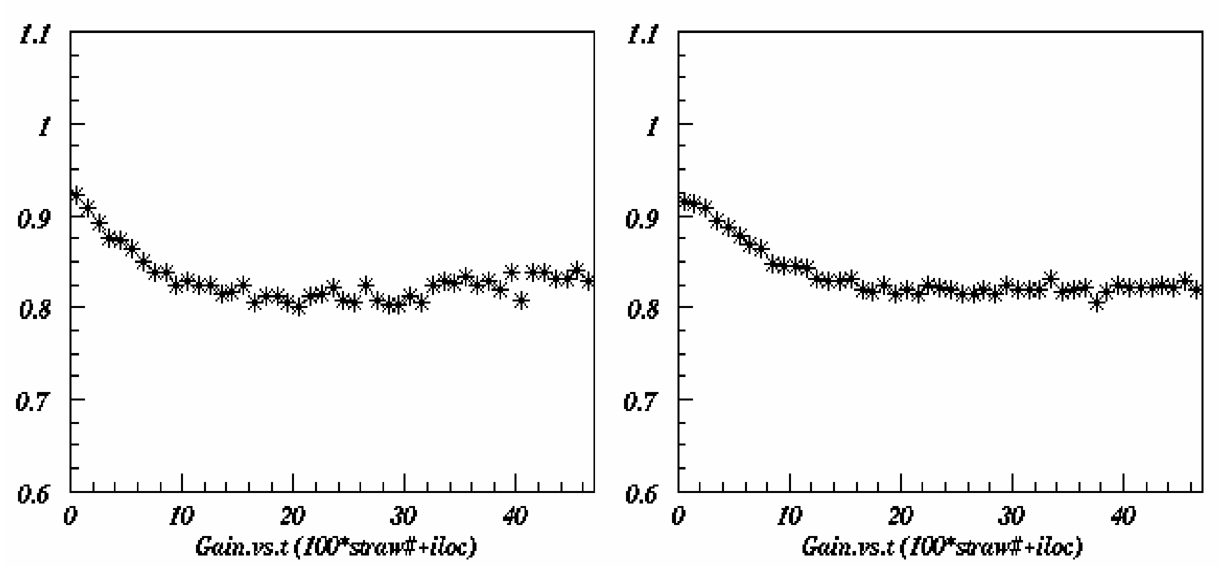

Figure 5. a). From straw 17, location 2. b) From straw 18, location 2. The gain restoration has halted. Both are from ~450 ppm run.

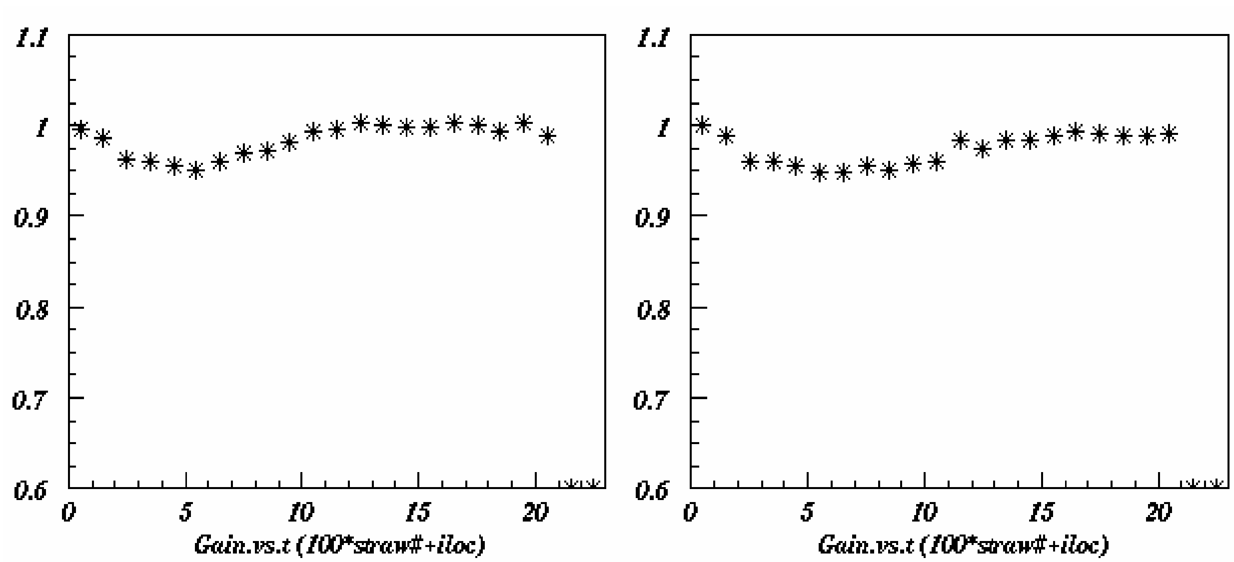

Figure 6. The same as Figure 5 but from ~700 ppm run. Note the different x scale compared to Figure 5.

2. 4% cleaning gas mixture

Another run is to test the 4% cleaning mixture (Ar-CO_2-CF_4 (70-26-4)). If the 4% mixture works as well as 8%, then 2% mixture should be also tried. The moisture level will be kept ~700 ppm.

Based on the ~700 and ~450 ppm data, it seems that when the radiation level is ‘low’, the amount of cleaning chemical production is only proportional to the radiation level (fairly independent of CF_4 fraction and the moisture level). If the radiation level is ‘high’, the amount of cleaning chemical production reaches a saturation point which depends on the CF_4 fraction and the moisture level. If this hypothesis is correct, then the rate of restoration around the region of wire-joints for this run would be similar to the 8% mixture with ~450 ppm moisture level and the rate of restoration of other region would be similar to either moisture content.