**Response to reviewer’s comments:**

**Response to the editor’s comments,**

2. Please upload each Figure individually to your Editorial Manager account as a .png or a .tiff file. Please combine all panels of one figure into a single image file.  
🡪 We have changed as recommended.

3. All tables should be uploaded separately to your Editorial Manager account in the form of an .xls or .xlsx file.  
🡪 We have changed as recommended.

4. Formatting:  
-Please submit figures in an accepted format and not in a Word document. Each figure should be an individual file.  
🡪 We have changed as recommended.

-Step 4.1.3 should be before 4.1.2.  
🡪 We have revised the step 4.1.3 to be before 4.1.2.

5. Length exceeds 2.75 pg of highlighted material and must be reduced accordingly.  
🡪 We have revised the length of highlighted material to be less than 2.75 pages. To reduce the length, we used abbreviations “RP” and “Al” for “roughing pump” and “aluminum”, respectively.

6. Grammar:  
-Line 49 – “A variety of steels meets” – should be plural verb.  
🡪 We have revised “A variety of steels meets” to “A variety of steels meet”.

7. Additional detail is required:  
4.3.2 – “aluminum foils“  
🡪 We have revised “aluminum foils” to “Al foil” in 4.1.2.

4.5.3 – Please use imperative tense.  
-Line 463 – “recommended.; simply”  
🡪 We have changed as suggested.   
  
7. Additional detail is required:  
-1.3.4 – Please include a citation.  
🡪 We have included the citation as recommended. Please refer to the reference #15.

-4.1.1 – This diagram is not clear on the position. Please describe using text where it should be placed. It seems as though it was already assembled and placed in prior steps.  
🡪 We have changed in accord with the recommendation as described at Fig 3 and step 3.5.

-4.4.1 – Which components are wrapped? All of them?  
🡪 The vacuum components between the SRG flange assembly and the inlet flange of the TMP are wrapped. We have revised as 4.2.1.

-4.4.2 – How is this checked?  
🡪 We check by measuring the resistance between the chamber and the heater wire with the multimeter. If the resistance is infinite then there is no electrical short circuit. We have revised as 4.2.2.

-4.4.3 – Are the heaters wrapped? How many heaters are used?  
🡪 The number of heaters depends on the size of the sample chamber. We used 3~4 heaters for this experiment. The heaters wrapping the chamber are also wrapped by Al foil.

-4.4.6 – How is degassing performed?  
🡪 The degassing of the RGA ion source is performed by the electron bombardment (which is the default function of commercial RGAs) as described in 4.2.6.

-4.4.7, 4.4.9 – How is this scan performed?  
🡪 We have revised as “Measure the RGA spectrum from 1 to 50 m/e” in 4.2.7.

-4.4.10 – When was the AV closed?  
🡪 We obtain the residual gas spectrum of the sample by subtracting the spectrum of the vacuum components excluding the sample from the spectrum of the whole vacuum components (the sample + other vacuum components). The time of closing the AV is described in 4.2.9.

-4.5.2 – Wasn’t the SRG already placed on the flange assembly in Section 4.1? When was it removed?  
🡪 The SRG head should be removed before baking. We have added this step in 4.2.1.

-4.6.2 – Which heater controller? There were multiple ones in 4.4.3.  
🡪 The heater controller is used for both temperature controls during bake out and measurement. We have revised “Start the heater controller” to “Start the heater controller for the sample.” as noted in 4.4.2.

-4.7.3 – How is this checked? How does one remove mechanical vibration?  
🡪 The roughing (mechanical) pump is the most vibration inducing component in this experimental setup. The vibration is reduced by placing a rubber pad between the floor and the mechanical pump. This point is addressed in 4.5.3 in the revised manuscript.

8. Branding should be removed from 1.1.3, Figure legends - ConFlat should be removed, CF without being defined is fine on its own.  
🡪 We have revised as recommended.

9.  Results: Please show any data demonstrating that hydrogen was released. How was this determined?  
🡪 It is usually accepted that the major residual gas after bake out is hydrogen as described in ref. 7. This point can be also clearly recognized from the spectrum obtained in the step 4.2.9.

**Response to comments of reviewer #1:**

*Manuscript Summary:*  
The authors technique is common in vacuum science but is not described or shown in detail in many places. This should be useful to those wanting to make outgassing measurements in the high vacuum, but are not familiar with spinning rotor gauges. However, there are several significant flaws that must be fixed.  
🡪 We thank to the reviewer for many detailed suggestions which are helpful to improve our manuscript. We have revised the manuscript in accord with the suggestions.

*Major Concerns:*  
General/overall:  
1) The authors discuss historical aspects of outgassing measurements and rate-of-rise measurements in several places, but this discussion is inaccurate and not relevant to the paper.  
🡪 We have removed the ambiguous parts of the manuscript as recommended.

2)I think the authors contextual discussions are a little weak and should be revised. The advantages/disadvantages are not clearly or precisely laid out. In the reviewer's opinion: The throughput method is more complicated, not practical in all situations, and requires a known pumping speed or conductance. The rate-of-rise method does not work well with gases that adsorb or condense. Other gauges can be used for rate of rise, but for high vacuum and ultra-high vacuum pressures, ion gauges and SRGs are pretty much all you have. Ion gauges generally have HIGHER outgassing rates than SRGS (this is incorrectly stated as having NO outgassing rate in several places) and can cause a temperature rise. SRGs are very linear (this is never mentioned) in the high vacuum, which makes them ideal for outgassing rate measurements. Etc. etc. etc.  
🡪 We have revised the manuscript (INTRODUCTION and DISCUSSION sections) as recommended by the reviewer.

3)The authors do not discuss the accuracy of the SRG (which is necessary for the slope and the absolute outgassing rates they quote).  
🡪 We have included the statement about the accuracy of the SRG in the line 88 of the manuscript.

4)They also do not discuss the frequency dependence of the residual drag (RD). This can cause a potential error. Perhaps the authors SRG had no appreciable slope on the RD, but this is not generally true. Someone following this procedure may get erroneous results if this is not correctly taken into account. This must be included in the protocol and the analysis.  
Detailed comments:  
🡪 We appreciate the reviewer that he/she reminded us that the frequency dependence of the RD. When we check the change of RD from our measured data during 24 h, we find that the change of RD is ranging from low 10-10 Pa/s to middle 10-9 Pa/s depending on the condition of the rotor. 1x10-9 Pa/s corresponds to 10% error of the minimum meaningful value (1 × 10−3 Pa/day; in line 431) with this experimental setup. We set this value as the criterion for acceptance to proceed to the next step. In this regards, we have revised the protocol as 4.5.

5)Line 86  
The spinning rotor gauge dates back to well before the 1990's. This statement needs to be deleted or changed. See "The spinning rotor Gauge" J.K. Fremerey, JVSTA 1715 (1985) for the modern version of the SRG. Experimental versions exist much earlier. Fremerey Rev. Sci. Inst. 44, 1396 (1973) is but one example.  
🡪 We agree with the reviewer’s comment. We have revised the manuscript.

6)Line 88  
This is a false statement and needs to be changed or deleted. The SRG certainly can and will outgas. Its absorption rate for H2 may be negligible at vacuum pressures, but surface absorption of water is still an issue.  
🡪 We revised the false statement. Please refer to the revised manuscript.

7)Line 3.6 and other places:  
1 degree seems a little tight and unnecessary. Two degrees is a more common rule-of-thumb. See "Recommended practices for the use of spinning rotor gauges in inter-laboratory comparisons" Measurement 66 (2015) 176-183. If this is your procedure, then I'm ok with leaving it, but you should be aware that this is probably not necessary.  
🡪 We agree the reviewer’s comments and revised the protocol.

8) 4.4.7 and 4.4.6 All of the RGS's I've ever seen cannot be operated at 150 C. If this is a special RGA, or has special bake-out cables, please state. Otherwise, change your protocol as the levels cannot be checked and the filaments cannot be degassed at this temperature.  
🡪 The electronics of the RGA is cooled by the external air fan during the experiment. We revised the protocol as 4.2.5.

9)4.5.1 Give details on how the re-magnetization is done. I actually doubt this is generally necessary procedure as I've had experience baking SRGs many times and have never had a problem re-suspending the ball. In any case, because you cannot re-magnetize the rotor to its original moment, I'm not sure the statement is precisely correct. please re-write.  
🡪 We have removed the part describing the re-magnetization as recommended.

10)4.7.2 Please give details on how to check the signal level. Is this from the controller? The processed signal usually reads decrement, not dB. dB is a relative unit, do you mean dBm?  
🡪 The signal level is provided by the controller and the manual of SRG explains the unit as dB. If this is not appropriate, we have to change the unit.

11)Protocol section 4.9:  
The residual drag of the SRG is frequency dependent. This can have a positive, negative, or zero slope. It varies and is unpredictable. For the low-outgassing rates you are measuring, this frequency dependence can easily have an effect on the outgassing rate (in some cases in can be mistaken for a pressure rise due to outgassing). The authors must explain how to take this into account in the analysis and data acquisition.  
🡪 We have revised the protocol as shown in step 4.5. Please refer to the revised manuscript.

12) Discussion: The historical parts of the discussion about the throughput method and rate-of-rise method are neither true nor necessary for the paper. Please remove.  
🡪 We agree. We have removed as recommended in the DISCUSSION section.

13) Discussion: I would not necessarily characterize an extractor gauge as a "ion gauge with low outgassing". It is an ion gauge with a lower x-ray limit than traditional BA gauges.  
🡪 The filament current of BA gauge is 4 mA while that of extractor gauge is 1.6 mA, which results in the difference of the temperature of filament and the vacuum chamber surrounding the gauges. We believe that, from this difference, the outgassing from the BA gauge and its surrounding vacuum chamber is larger than those of the extractor gauge.

14) Line 435: "Although in principle the SRG has no outgassing" is a false statement and is unnecessary, please delete.  
🡪 We have deleted as recommended.

15) please state the pressure range that the measurement is taken over.  
🡪 The pressure range that the measurement is taken over is from 10−8 Pa to 10−3 Pa. This statement has been added in line 426.

*Minor Concerns:*  
16) Abstract  
Line two "steels meets" should be "steels meet"  
🡪 We have changed as recommended.

17) Line 49  
"steels meets" should be "steels meet"  
🡪 We have changed as recommended.

*Additional Comments to Authors:*  
N/A

**Response to comments of reviewer #2:**

*Manuscript Summary:*  
General comments:  
The authors should add, perhaps in the 'Introduction' section, the followings:  
-A comparison of measurement accuracy using cold cathode gauge vs. SRG. The CCG gauge does have small pumping effect and the measured outgassing rate needs to be corrected for it. However, the simplicity of using CCG as compared with the complexity of using SRG may warrant the substitution even the measurement error bars increase.  
🡪 We agree the reviewer’s recommendation of CCG for the simple outgassing measurement gauge. However, we considered that it is more appropriate to use the SRG for the measurement of very low outgassing rate in spite of the complexity of using SRG because of its negligible outgassing rate, excellent accuracy, good linearity and stability in high vacuum range.

-The needs to control temperature ramping during bakeout and cooldown to 1-2o C/hr, which seems to be extremely slow (#264 and #273).  
🡪 It was our mistake. We changed the unit from hour to minute.

Specific Comments:  
#71: XHV is commonly defined as P < 10-10 Pa  
🡪 We have changed as the reviewer’s comment.

#145, #147: lower case for liter, i.e. l/min  
🡪 We have changed as the reviewer’s comment in #146, #149 and #224.

#173: ….described in Temperature Control of List of ….  
🡪 We have changed as recommended.

#188: CF63 flanges and AV are not mentioned in any step, nor in the figures.  
🡪 We have deleted the CF63 flanges and the AV which are not mentioned in any step, nor in the figures.

#191, #294, #395: suggest to remove 'plumb line', since it is very difficult to align to 1o using plumb line.  
🡪 We have removed ‘plumb line’ as recommended by the reviewer.  
  
#212: Why will you want to pump down with HLD while connected to TMP exhaust end? Both TMP and HLD can be operated at the same time while by-passing scroll pump.  
🡪 We have revised the protocol as described in the revised figure 3. We added isolation valves (AVHLD and AVRo) for the HLD and the scroll pump. Accordingly, the protocol has been changed as described in 3.5.3, 3.6.6 and 4.1.1.

#214: ….minimum detectable limit of the HLD.  
🡪 We have revised as recommended.

#218: ….is leak tight.  
🡪 We have revised as recommended.

#233 to #237: repeated statements, can you combine them?  
🡪 We have revised as recommended. Please refer to the revised step 3.5.

#244: Disconnect and remove…..  
🡪 We have revised the protocol as step 3.6.6.

#246: Scroll pump should be connected already, as a common practice or as part of a pump station shown in Figure 3.  
🡪 We agree. We have revised the protocol as described in the revised figure 3. We have added isolation valves (AVHLD and AVRo) for the HLD and the scroll pump and both are connected to the system together. Accordingly, the protocol has been changed as described in the revised step 3.6.6.

#262: ….wrap the chamber in aluminum foil.  
🡪 We have revised as 4.2.3 as recommended. We used abbreviation “Al” for “aluminum” to reduce the length of the highlighted materials.

#266: Hold….for 24-48 h using bakeout program controller.  
🡪 We have revised as 4.2.5 as recommended.

#333: What steps to take, if these criteria are not met?  
🡪 Because maximum 10% error due to the frequency dependence of the residual drag is already included in this protocol as described in the revised step 4.5.1, we set the criterion for linearity of the measured outgassing rate to be within 10% error. From our experiences, the outgassing rate data within 10% error is obtained routinely with this experimental setup. However, if this criterion is not met, we suggest to continue to measure the outgassing rate for another 16 h for more stabilization. In this regards, we have revised as “…the pressure rise is linear within 10% error. If these criteria are met, stop the measurement. Otherwise, continue to measure until the pressure rise becomes linear within 10% error for at least 16 h.” in the step 4.6.3.

#341: ….after the valve is closed.  
🡪 We have revised as 4.7.2 as recommended.

#358 and #364: Are both heat treatments done in vacuum furnace?  
🡪 Yes, both heat treatments are done in vacuum furnace. We have revised as #340 and #347.

#406: round up to 1 digit, i.e. 8.3±0.1, since the accuracy of these measurements can't be that great.  
🡪 We have revised as recommended.

#406 and #432: both SRG and extractor have similar contribution to outgassing? How is it compared with outgassing/pumping of CCG?  
🡪 The outgassing rate for the SRG described in the text is sum of the outgassing of the SRG and the isolation angle valve, whereas the outgassing rate of the extractor gauge is from its own as described in ref. 18. We believe that the outgassing rate of the SRG itself is much lower than the value in the text. We have not measured the outgassing or pumping effect of CCG which we consider as out of the scope of this work.

#463: define 'intensity'  
🡪 ‘intensity’ is defined in line 395.

Table of Materials/Equipment:  
Sputter Ion Pump, Cold Cathode Gauge, CF63 AV are not mentioned in the text.  
Copper gaskets and bolt/nut set can be left out in the table  
🡪 We have removed Sputter Ion Pump, Cold Cathode Gauge, CF63 AV which are not mentioned in the text as recommended by the reviewer.

*Major Concerns:*  
N/A  
  
*Minor Concerns:*  
N/A  
  
*Additional Comments to Authors:*  
N/A  
  
**Reviewer #3:**  
*Manuscript Summary:*  
Well written detailed description of the techniques used for outgassing rate measurements. This should enable others to reproduce results, and is a clear, concise explanation of the technique and results.  
🡪 We appreciate the reviewer for the positive comments.

*Major Concerns:*  
Well written overall.  
  
*Minor Concerns:*  
N/A  
  
*Additional Comments to Authors:*  
N/A

**Flaw corrections:**

- Mistakes in unit conversion:

#406: 8.34 (± 0.052) × 10−8 🡪 8.3 (± 0.1) × 10−12 (#389 in revised manuscript)

# 432: 9 × 10−8 🡪 1 × 10−11 (#410 in revised manuscript)

# 437: 7.5 × 10−8 🡪 7.5 × 10−12 (#415 in revised manuscript)

# 454: 1 × 10−5 🡪 1 × 10−3 (#432 in revised manuscript)