EFFICIENCY DROP IN SEMICONDUCTOR RADON MONITORS DUE TO RADON ADSORPTION ON CHAMBER WALLS

- Deviating results in some semiconductor CRMs
- A method to check if radon could be adsorbed on chamber walls
- Results and impact on efficiency for semiconductor CRMs
- QA/QC Measurements – A help to identify and handle problems

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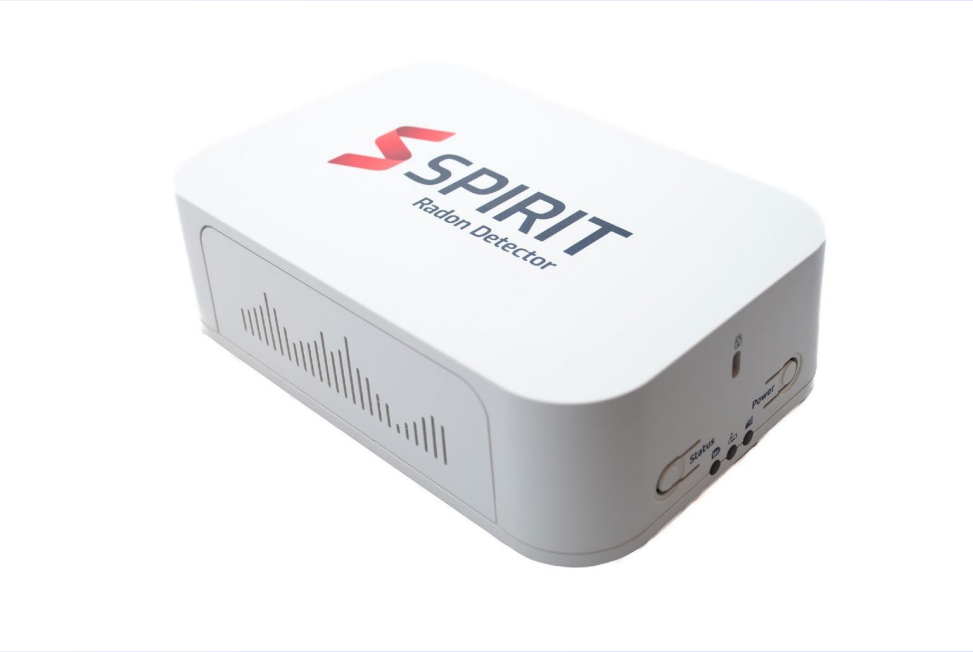
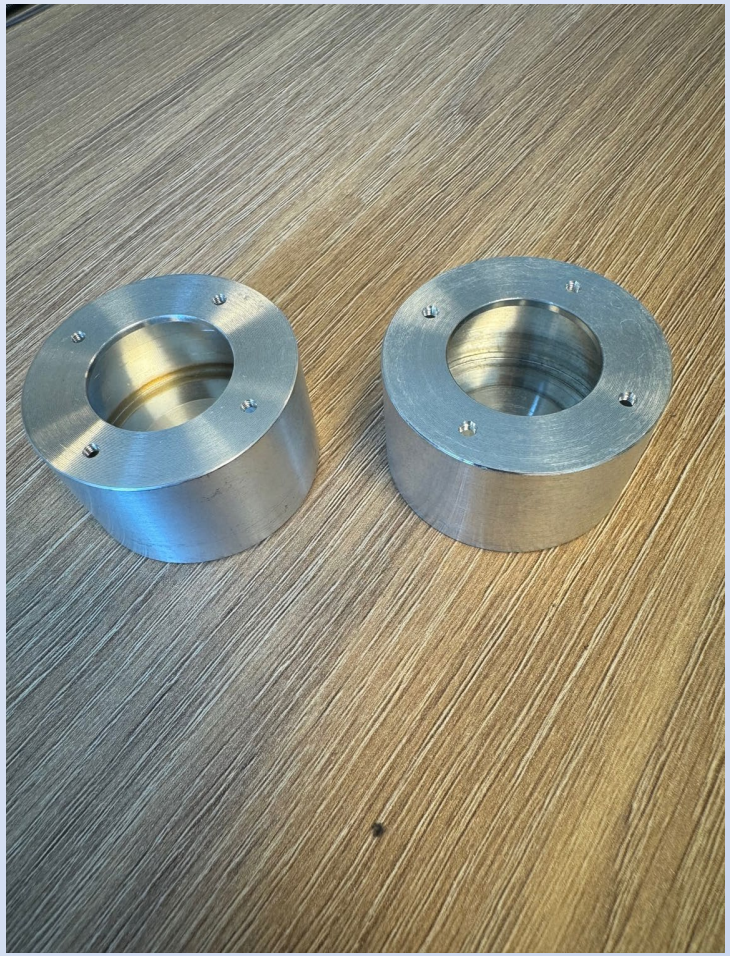
What is the difference between these two chambers to the semiconductor CRM?





The difference in efficiency differ with about a factor of 2 for the two different detector chambers. WHY ???

Background

Before launch of the new CRM monitor:

- **First manufactured devices showed an unexpected low efficiency, up to half of what was expected.**
- **After a lot of different tests, it seemed that this was related to the Al-chamber.**
- **Ultrasonic cleaning of the chambers in alcohol/water improved efficiency to what was expected.**
- **“Uncleaned chambers” showed a higher humidity dependence compared to cleaned chambers.**
- **Using cleaning routines, delivery of devices and measurement service starts.**
- **An approval limit on the efficiency (calibration factor) was set. Lower efficiency was regarded as an indicator that the cleaning had not been effective.**

Background cont.

After some months problems are discovered for some devices:

- **4-5 units sent to German customer divided a lot with comparison to other CRMs, as much as a 50 % deviation.**
- **From many recalled devices and measurement service devices, some devices showed significantly lower efficiency compared to calibration, although not as much as 50 %. However, most devices showed values close to concentrations in the control exposures.**
- **Problems seemed to be more frequent for different calibration batches of devices.**
- **Deviations were often low at low humidity.**

Consequences of the problems

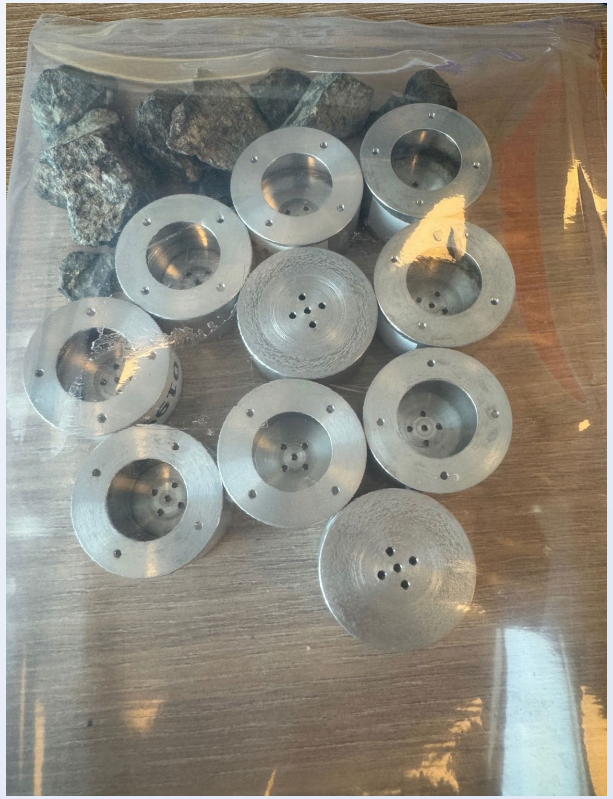
- Recalling a lot of devices from affected batches for control.
- Exposure tests of all devices used for measurement service and recalled devices.
- All results and reports are generated from the application server, giving a good possibility to identify possible incorrect reported results.
- About a hundred measurements were checked. Most deviations would affect results within uncertainty limits.
- Most measurements were follow-up measurements on workplaces where a small deviation in the response will not affect the calculated factor between radon levels during working hours and the whole measurement period.
- Two deviating standard short-term measurements were found but the deviation would not change conclusions (either very low values or very high).
- Stricter cleaning routines were implemented.

No major impact on reported customer measurements but a very large amount of work was needed to check this. Traceability through measurement data on the server was very valuable in this process.

What is causing the problems?

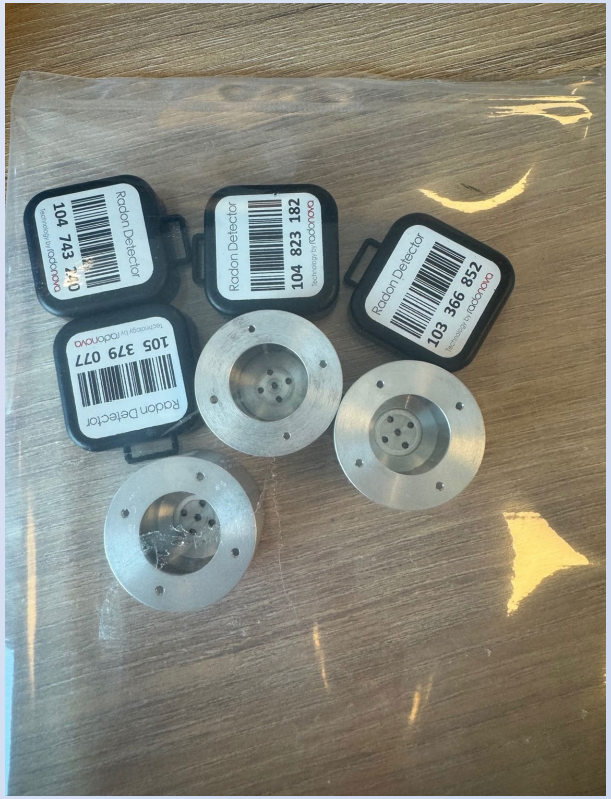
- If the air is very humid, the radon daughters may need to travel a longer distance, which increases the chance that they will lose their charge before reaching the semiconductor detector in the chamber. This would result in the detector being much less efficient in high humidity conditions.
- Something on the Al-surface affect the response a lot.
- Could radon be adsorbed in the surface? Tests of chambers exposed in very high radon atmosphere with airing them for one hour didn't give any identification at all of adsorbed radon (no such "memory" effect in the time response of the instrument is seen either).
- If the time constant for possible radon adsorption is very short compared to the diffusion time into the chamber, you might have the observed effect.
- One test of chambers exposed in very high radon atmosphere with airing for two minutes, and after that putting them in sealed bags together with passive radon detectors , gave indication of trapped radon gas. A question is if this was due to some remaining air with high radon levels or if it was due to radon adsorbed on the chamber walls? Relative comparisons between different set of chambers must be performed.

Method to check for radon absorption on chamber walls



Put chambers in a sealed bag together with U-stones for a couple of days to get a very high radon exposure.

Remove the chambers and air them under rapid movement for about 2 minutes.



Put chambers groupwise together with passive radon detectors in sealed bags for about 2 weeks.

Results

3 sets of chambers with 4 chambers in each set

- **Newly cleaned according to latest cleaning routines**
- **Old not cleaned chambers, about one year old**
- **Badly cleaned chambers from CRMs delivered to Germany**

5 alpha-track detectors were put in the bags together with chambers for each set for 10 days

Set of chambers	Measured radon concentration
Newly cleaned	0.3 ± 0.5 pCi/L
Old not cleaned	2.8 ± 0.7 pCi/L
Badly cleaned	14.8 ± 1.0 pCi/L

The absolute values of the measured radon concentrations can't be used for any conclusions, only the relative differences are of importance.

The results clearly show that a significant amount of radon is adsorbed on the chamber walls for chambers on CRMs with unexpected low efficiency.

Comments to the results

- **It had been observed that the efficiency with one-year old devices without cleaned chambers had increased significantly. Therefore, the relative differences between the different set of chamber is in accordance with the observed calibration factors.**
- **More tests after about one year with the same chambers could give information whether the differences between the sets are kept over time.**
- **SPIKE tests indicate that CRMs with assumed well cleaned chambers lose efficiency after cleaning and then stabilize. This is a small efficiency drop at low humidity but could be up to 15-20% in higher humidity.**

New routines

- **Two factory calibrations are performed before devices are approved for shipment.**
  - **One exposure at least one month after chamber cleaning and the second exposure at least two months after the first calibration exposure.**
  - **Second calibration is used, and it should not differ too much compared to the first calibration.**

- **New humidity response functions will be implemented.**
  - **A slightly higher humidity dependence is expected for devices stored some months compared to the devices with newly cleaned chambers.**

QA/QC Measurements for CRMs

ANSI/AARST MS-QA-2023, Radon Measurements Quality Assurance

- **Annual calibrations (CRM)**
- **Comparison checks every tenth measurement (CRM)**
- **20 of each type of QC check to monitor system performance**
- **SPIKE tests, at least three per every 100 devices, or a maximum necessary of six per month**

For the SPIRIT CRMs, Radonova is making quarterly SPIKE exposures of at least 20 devices. Since humidity and temperature could influence, the set of at least 20 devices should be exposed at the same time.

Conclusions

Expect that unexpected things could happen!!

QA/QC measurements are a valuable tool for discovering and understanding unexpected problem.

THANK YOU !!

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