SimPore – Al_2O_3 Coated Nanoporous SiN_x

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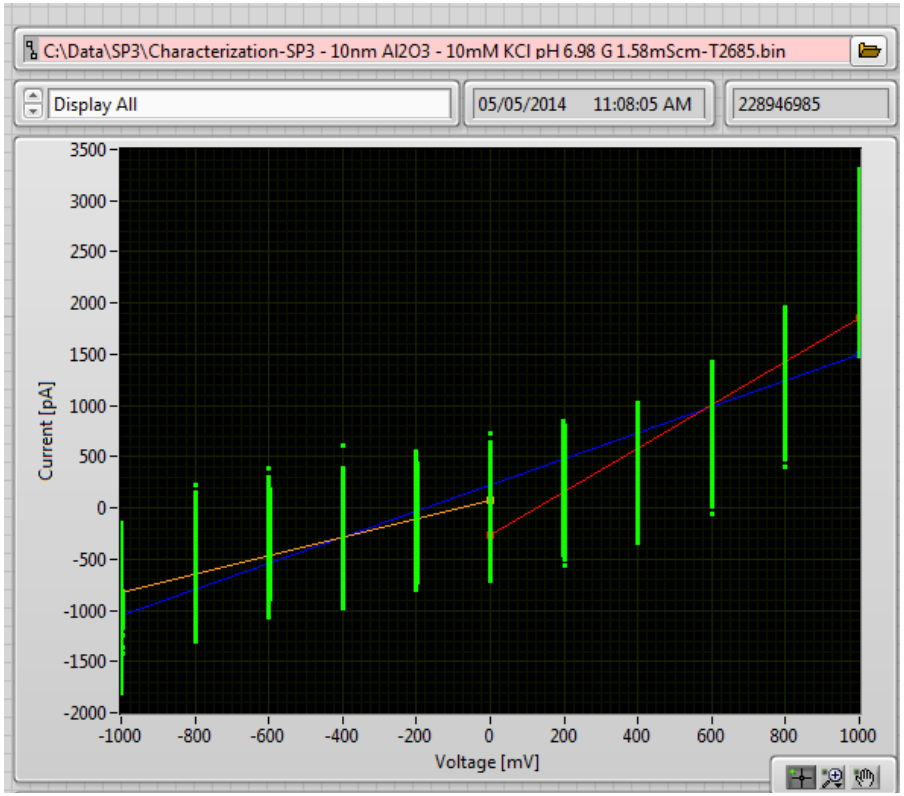
Experiment 1.1 Conditions

- 10mM KCl +5mM HEPES
- pH 6.98
- σ=1.58mS/cm
- 10nm Al_2O_3 coating (both sides)
- Guessed 40nm for membrane thickness (20nm SiN_x+20nm Al_2O_3)

IV Curve

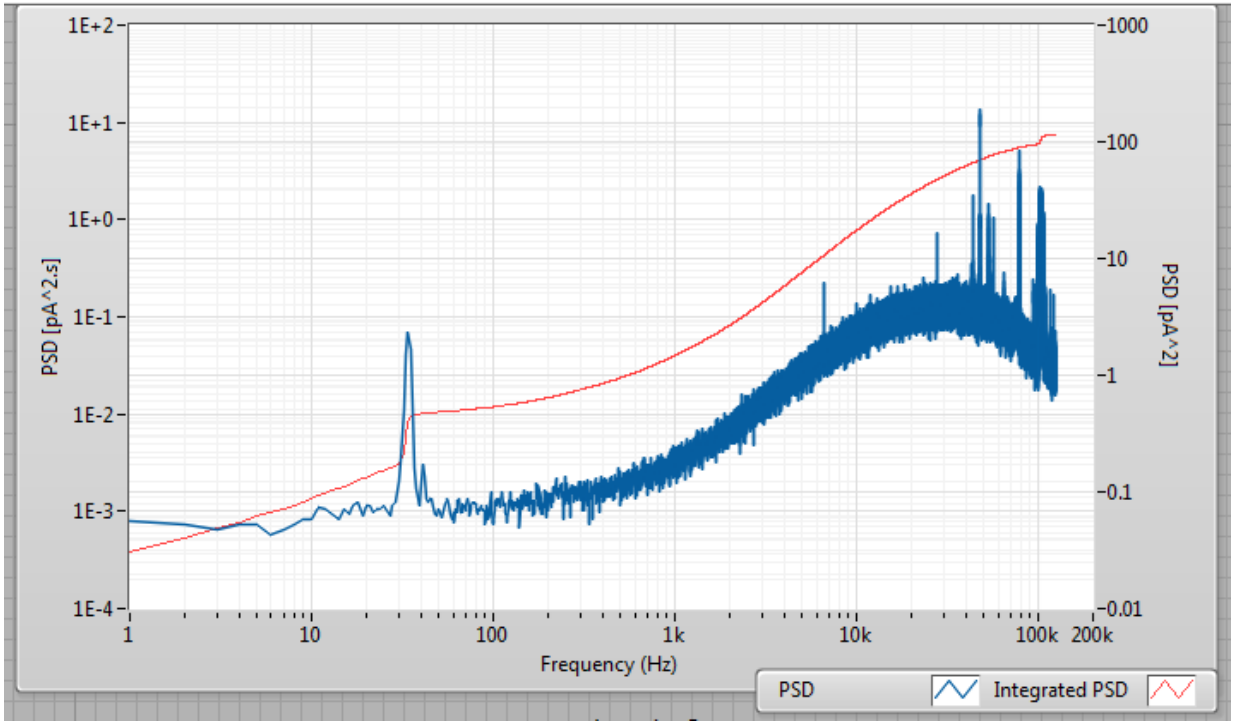
Conductance (+) = 2.13 nS
Conductance (-) = 0.90 nS

in 10mM KCl



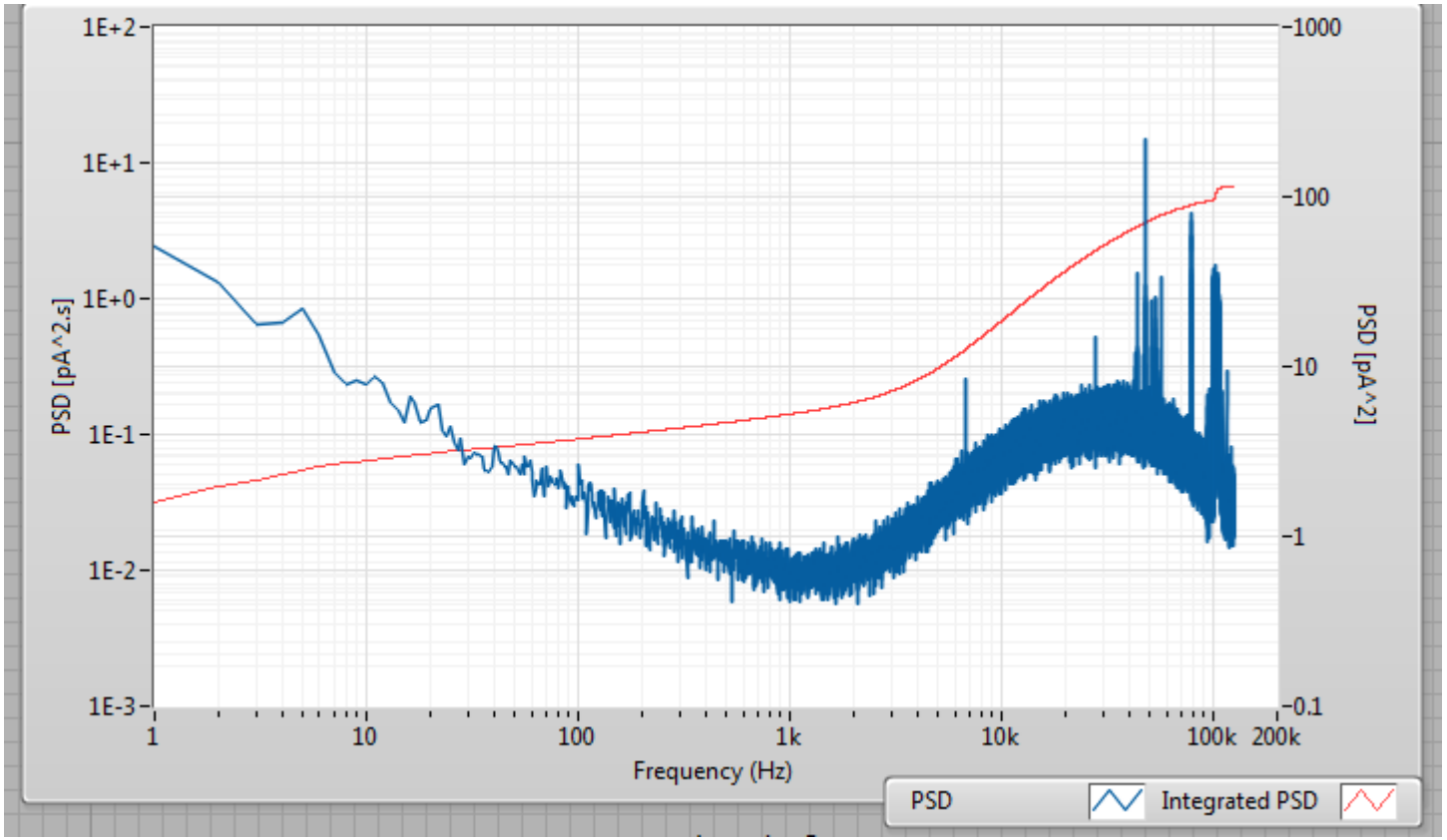
The IV curve looks exponential rather than linear and shows some rectification - this is indicative of lots of extremely small openings and could be due to the low salt and overlapping ELDs.

0mV Noise Baseline



Excellent thermal noise performance due to the very large R, though capacitive noise is a little higher than usual, even with the SiO2 coating, probably because of the low salt used. Ignore the 30Hz peak, this is electrode vibration and is not due to the nanopore system.

200mV Noise Baseline



Good noise performance at low voltage. At high voltage, there are significant current fluctuations and lots of 1/f noise (see last experiment with 11nm coating for examples), but here everything is fine. Peak to peak noise is ~0.5-1nA at 200mV with 100kHz LPF. The RMS current noise is shown in red of the figure (~integral of the PSD in blue).

Experiment 1.2 Conditions

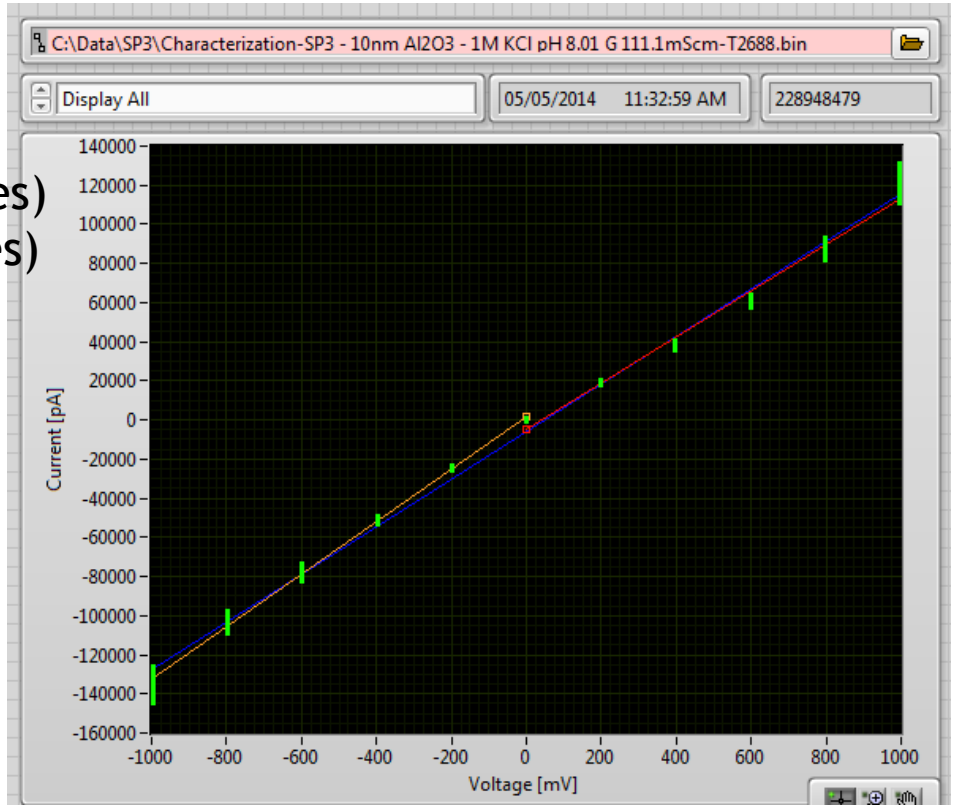
- **1M KCl +10mM HEPES**
- **pH 8.01**
- **σ=111.1mS/cm**
- 10nm Al_2O_3 coating
- Guessed 40nm for thickness (20nm SiN_x +20nm Al_2O_3)
- Same pore as previous experiments, just higher molarity.

IV Curve

Conductance (+) = 118.2 nS (37-141 pores)
Conductance (-) = 134.2 nS (41-160 pores)

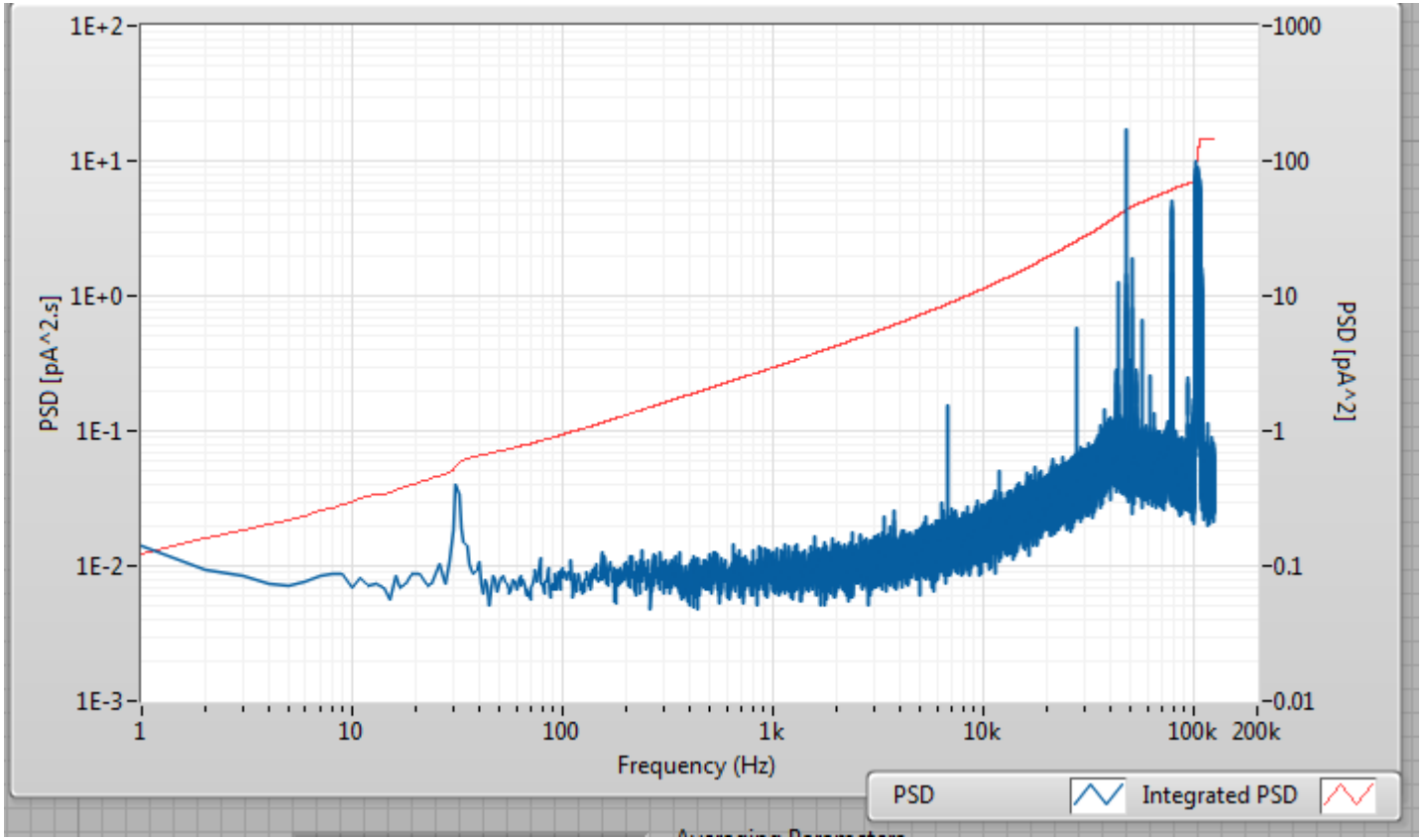
in 1M KCl

Limits of pore numbers calculated assuming all 4nm pores (low end) and all 2nm pores (high end)



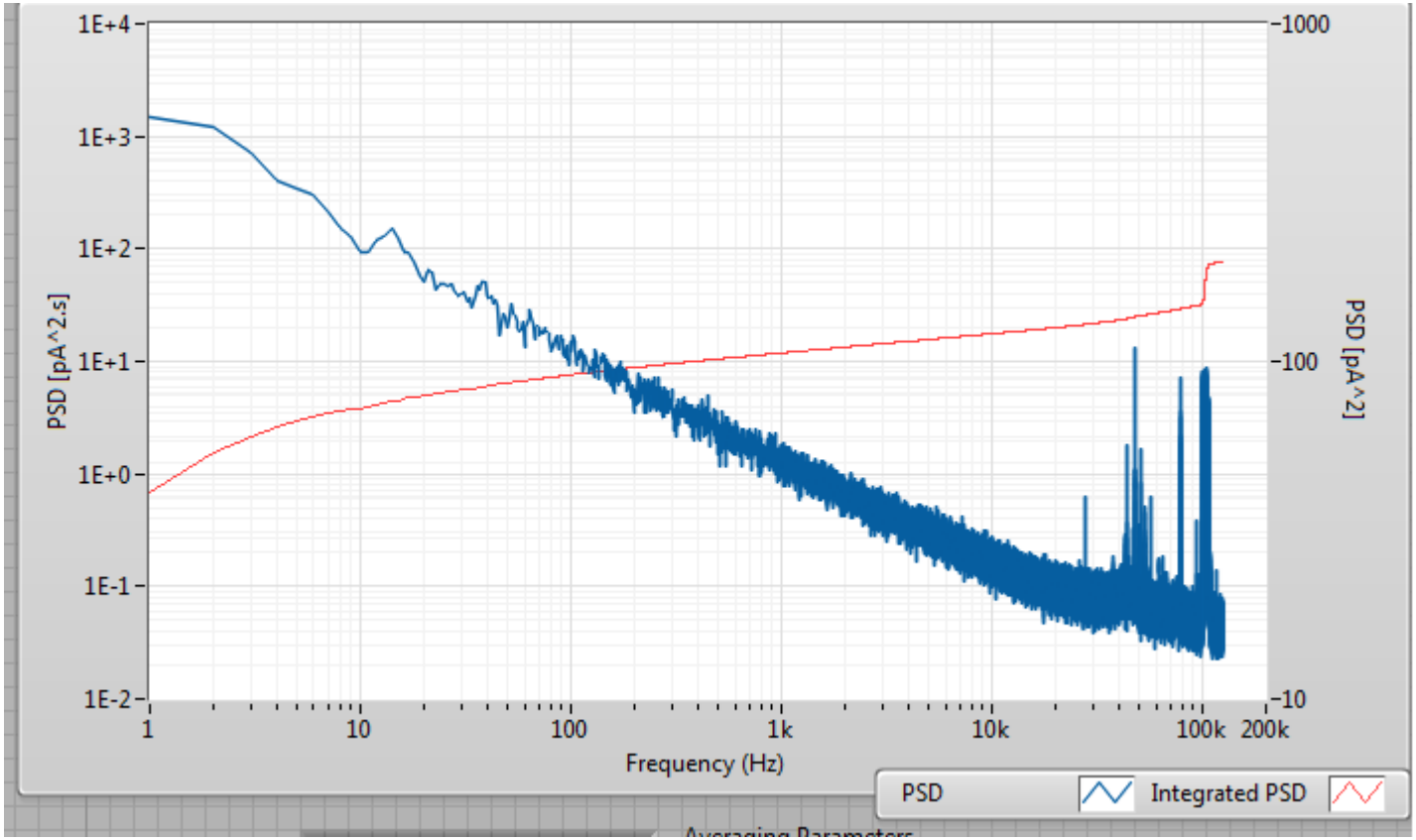
The system was unstable at -1V: the it initially conducted 64nA at 1V and jumped to 90nA quickly, then 100nA. And then it closed up again to 80nA, from which it grew again. This IV curve was after all that occurred, after it had grown to 135nA at -1V and was temporarily stable.

0mV Noise Baseline



Still good noise performance higher thermal, but lower capacitive. Again, ignore the 30Hz peak.

200mV Noise Baseline



High 1/f noise, expected for such high current. Peak to peak noise is about ~1-2nA here. RMS current noise is shown in red.

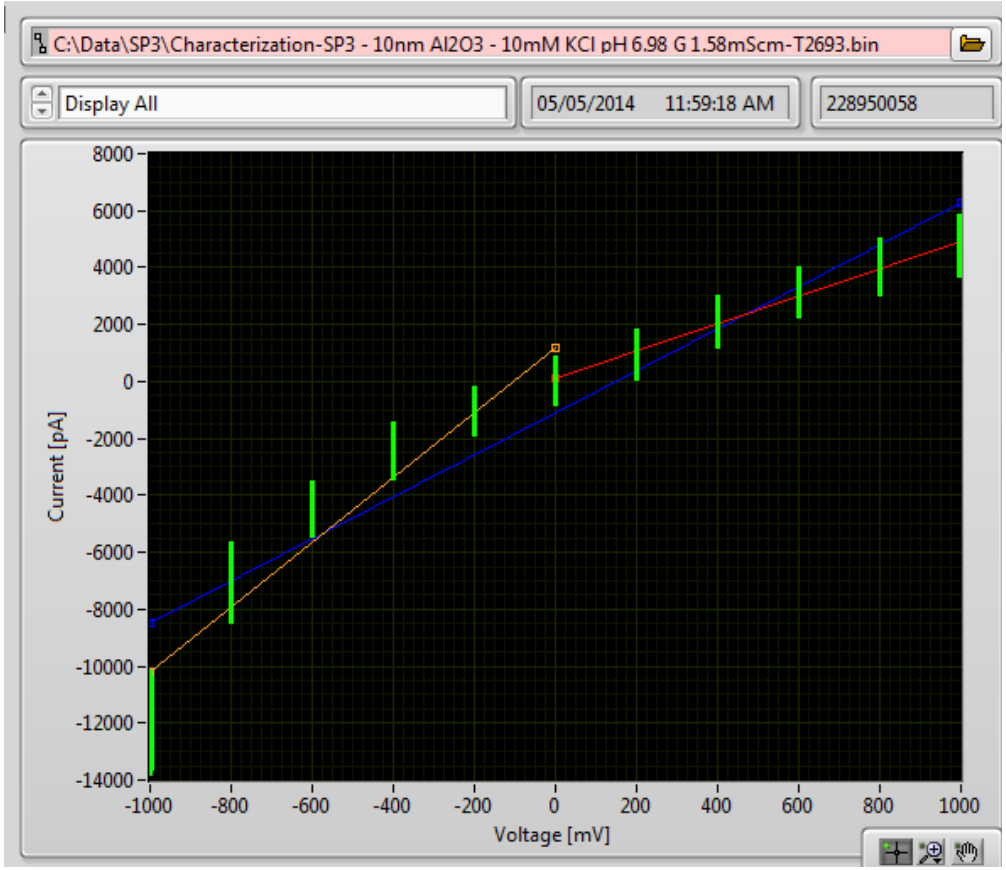
Experiment 1.3 Conditions

- **10mM KCl +5mM HEPES**
- **pH 6.98**
- **σ=1.58mS/cm**
- 10nm Al_2O_3 coating
- Guessed 40nm for thickness (20nm SiN_x+20nm Al_2O_3)
- Same pore as previous experiments, just lower molarity again, in order to quantify the increased size

IV Curve – after pore growth

Conductance (+) = 4.8 nS
Conductance (-) = 11.4 nS

in 10mM KCl



IV still looks exponential, but the pore has clearly grown. Conclusion: either alumina coating seems to be easily damaged at moderate voltages or more pores got wetted in the 1M KCl experiment. Interesting difference in behavior in + and - voltage directions: the negative direction is exponential and the positive direction is linear. The system also rectifies, consistent with lots of very small openings with overlapped EDLs.

Experiment 1 Conclusions

- The coating definitely worked, though from these results I can't estimate a size per nanopore since the thickness is unknown.
- The coating seems to either be slightly unstable at high voltages (~1V), or high voltages facilitates wetting of additional nanopores, leading to current fluctuations.

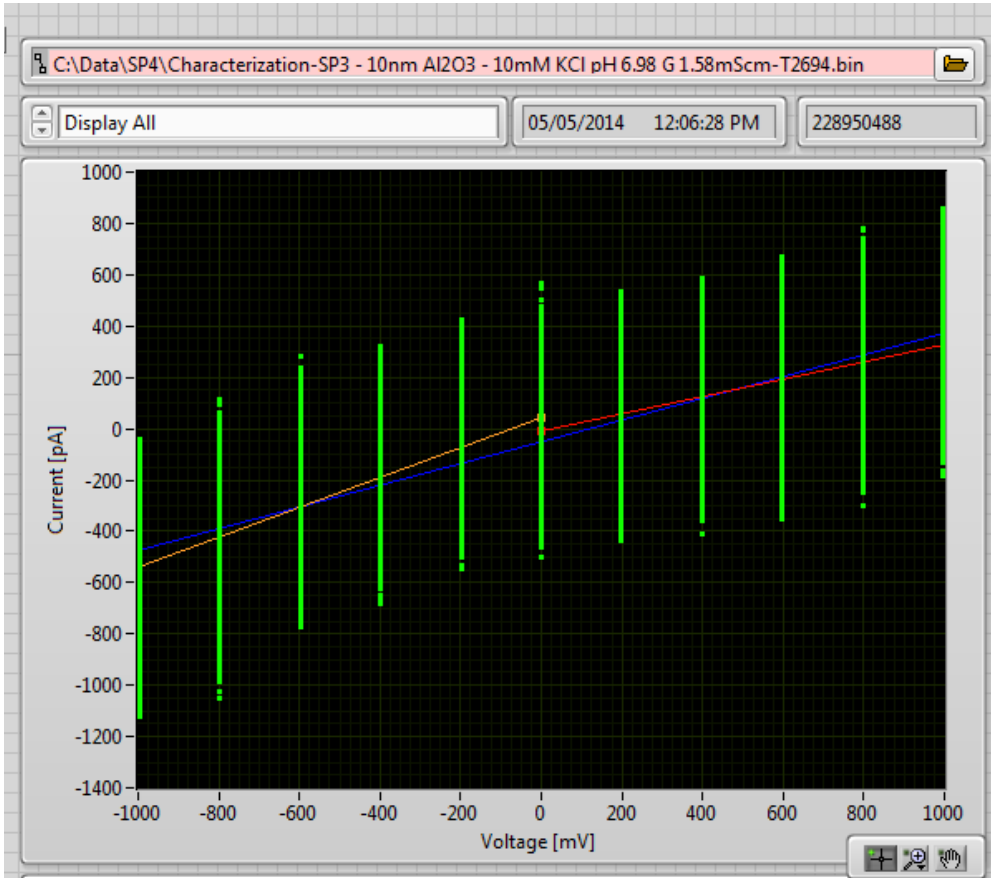
Experiment 2.1 Conditions

- 10mM KCl +5mM HEPES
- pH 6.98
- σ=1.58mS/cm
- **11nm Al_2O_3 coating**
- Guessed 42nm for thickness (20nm SiN_x +22nm Al_2O_3)

IV Curve

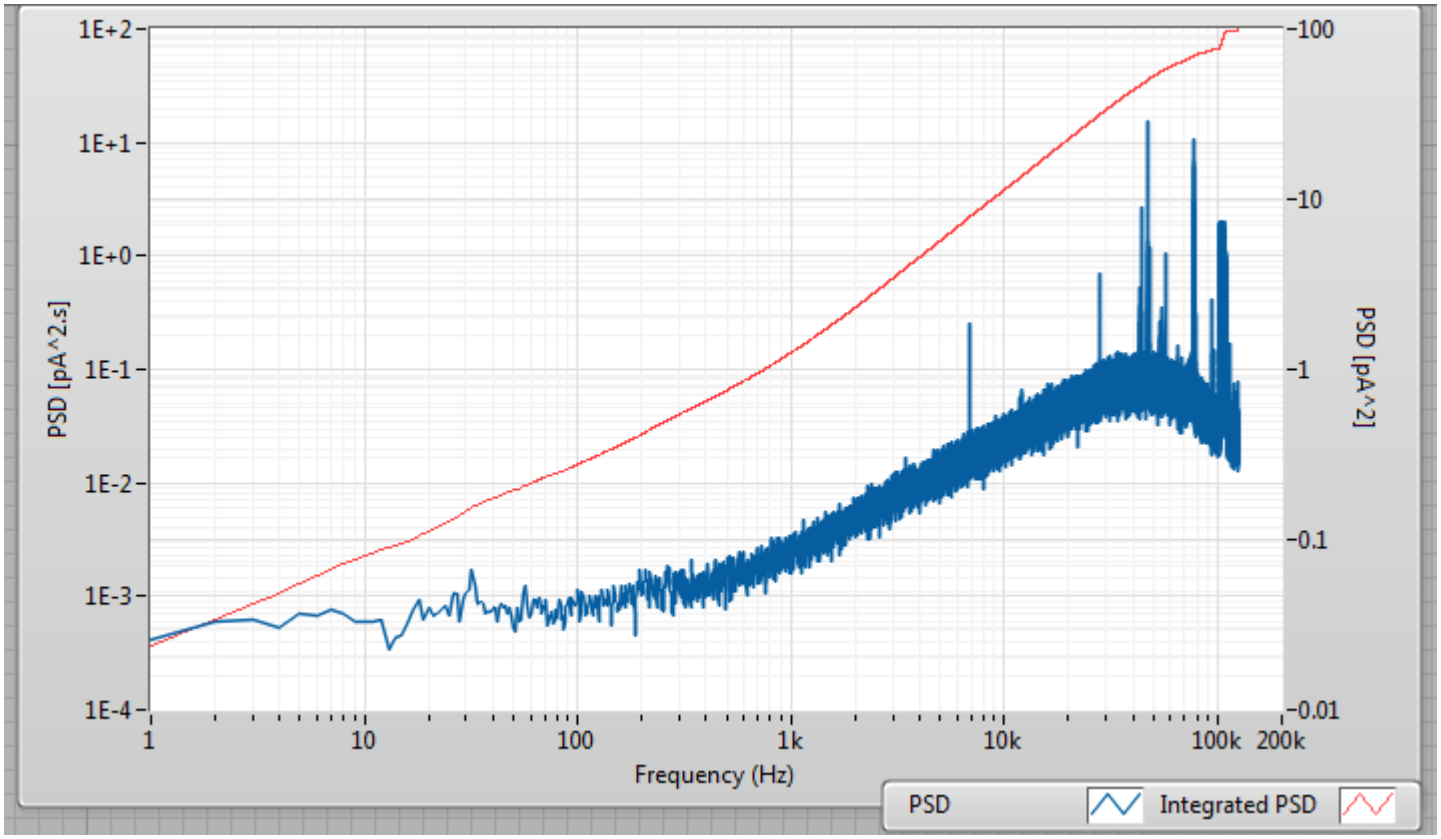
Conductance (+) = 0.34nS
Conductance (-) = 0.59 nS

in 10mM KCl



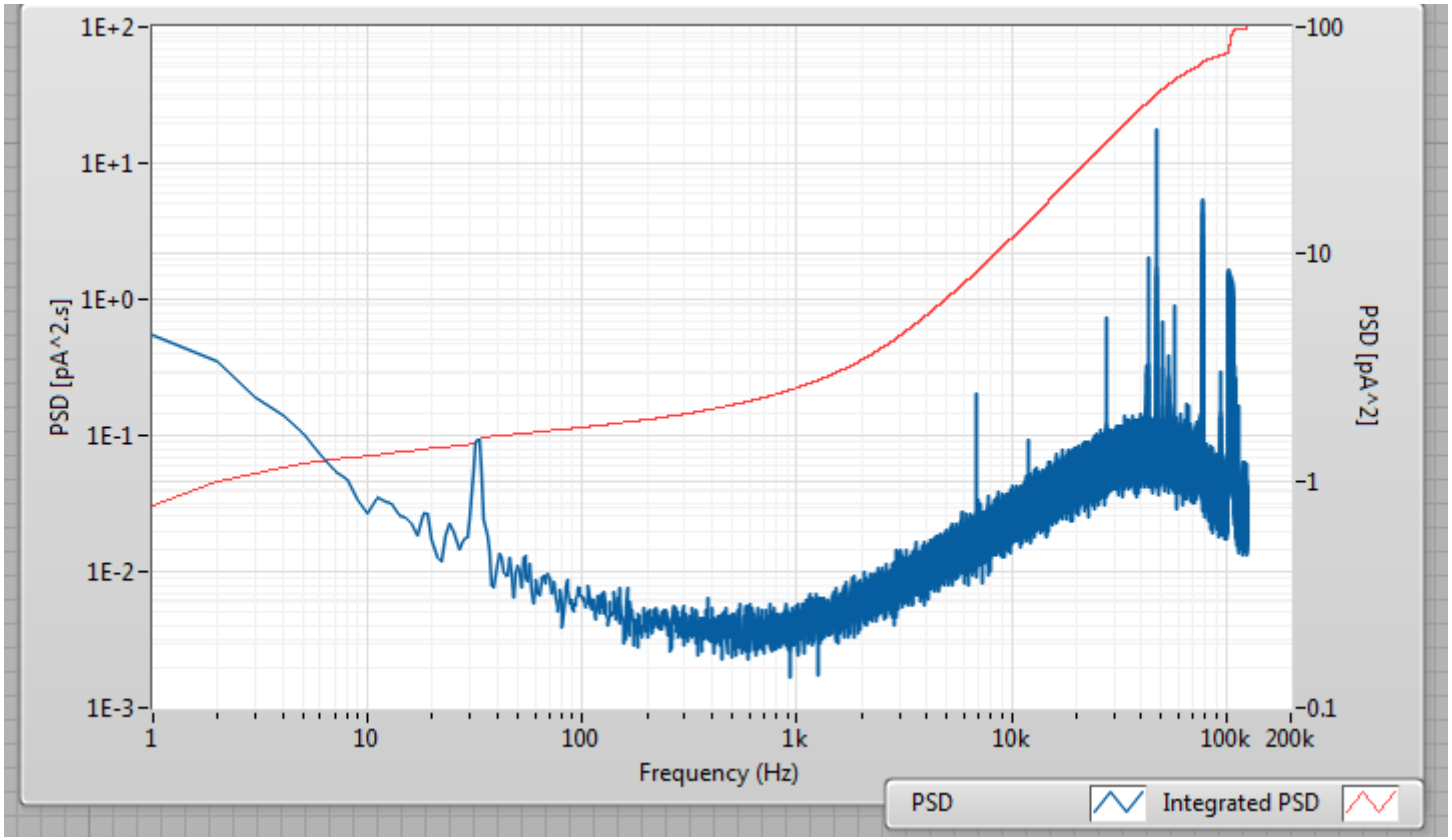
The system is definitely less conductive than the 10nm coating case (c.f. experiment 1.1). The pore is also more linear than exponential here, which is slightly surprising.

0mV Noise Baseline



Excellent noise performance.

200mV Noise Baseline



Experiment 2.2 Conditions

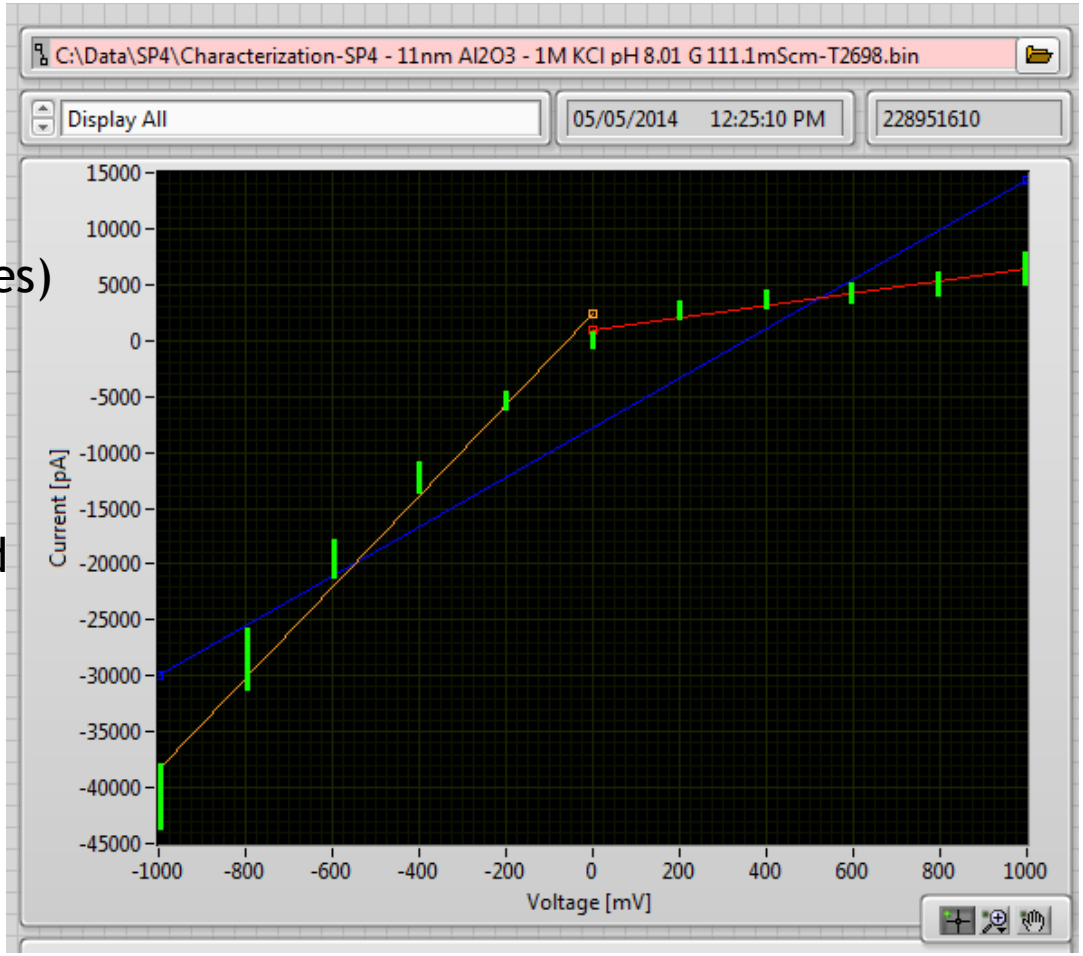
- **1M KCl +10mM HEPES**
- **pH 8.01**
- **σ=111.1mS/cm**
- 11nm Al_2O_3 coating
- Guessed 42nm for thickness (20nm SiN_x +22nm Al_2O_3)

IV Curve

Conductance (+) = 5.6nS (2-7 pores)
Conductance (-) = 40.8 nS (13-49 pores)

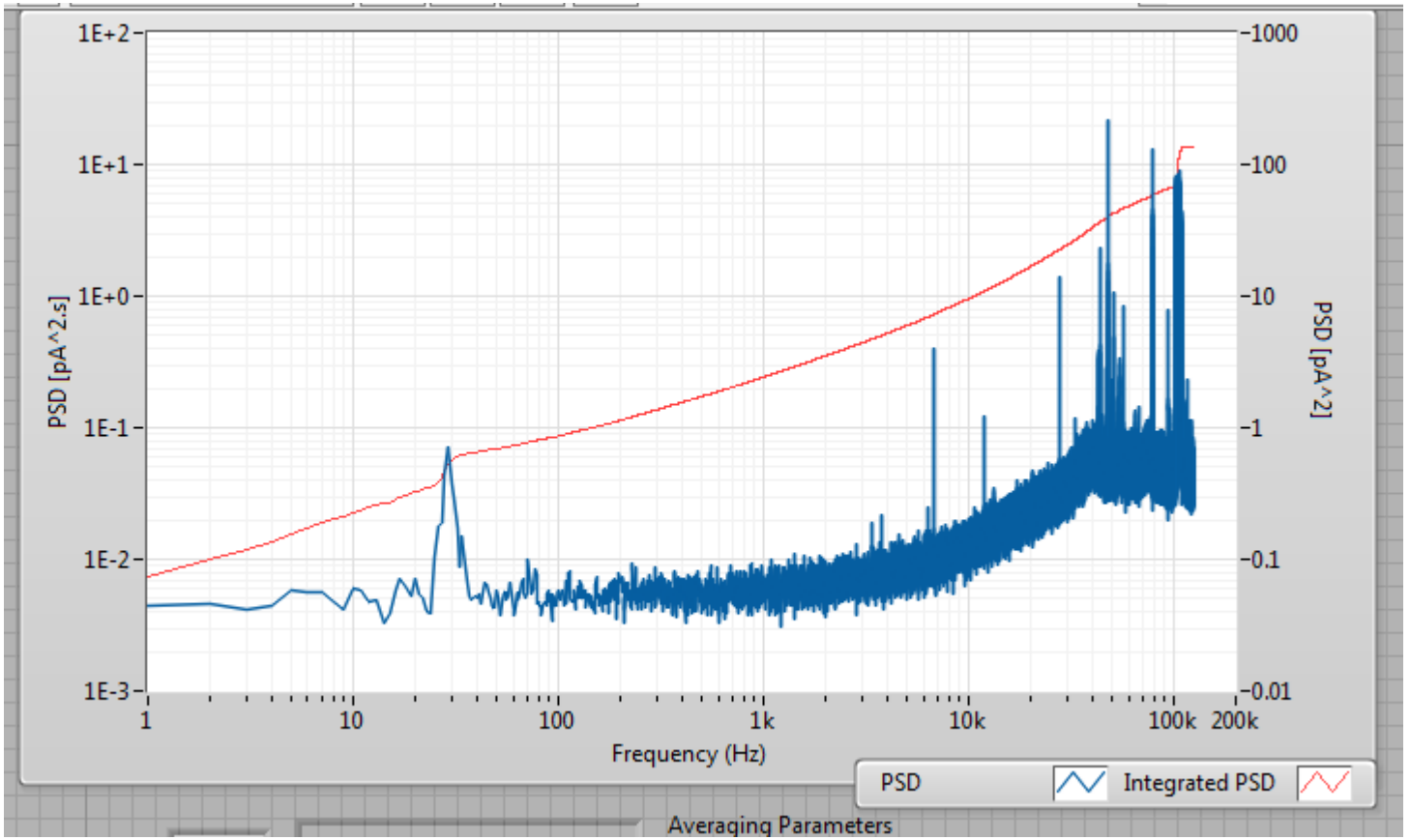
in 1M KCl

Limits of pore numbers calculated assuming all 4nm pores (low end) and all 2nm pores (high end)



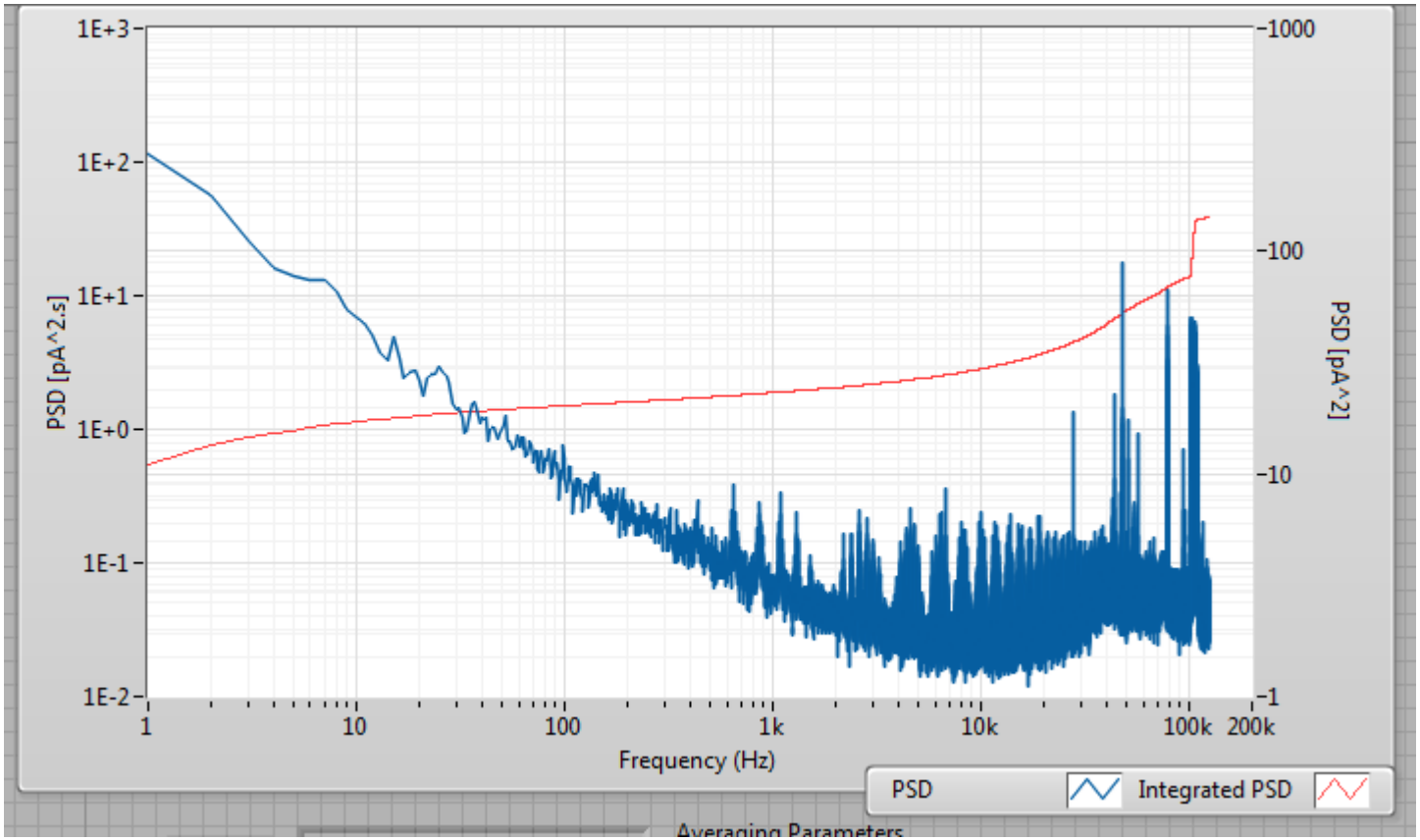
Very highly rectifying. Consistent with lots of very small openings. Note that it rectifies even more than the 10nm case, and has more conductance in one direction. Could be related to difference in wetting or to the number and size distribution of pores.

0mV Noise Baseline



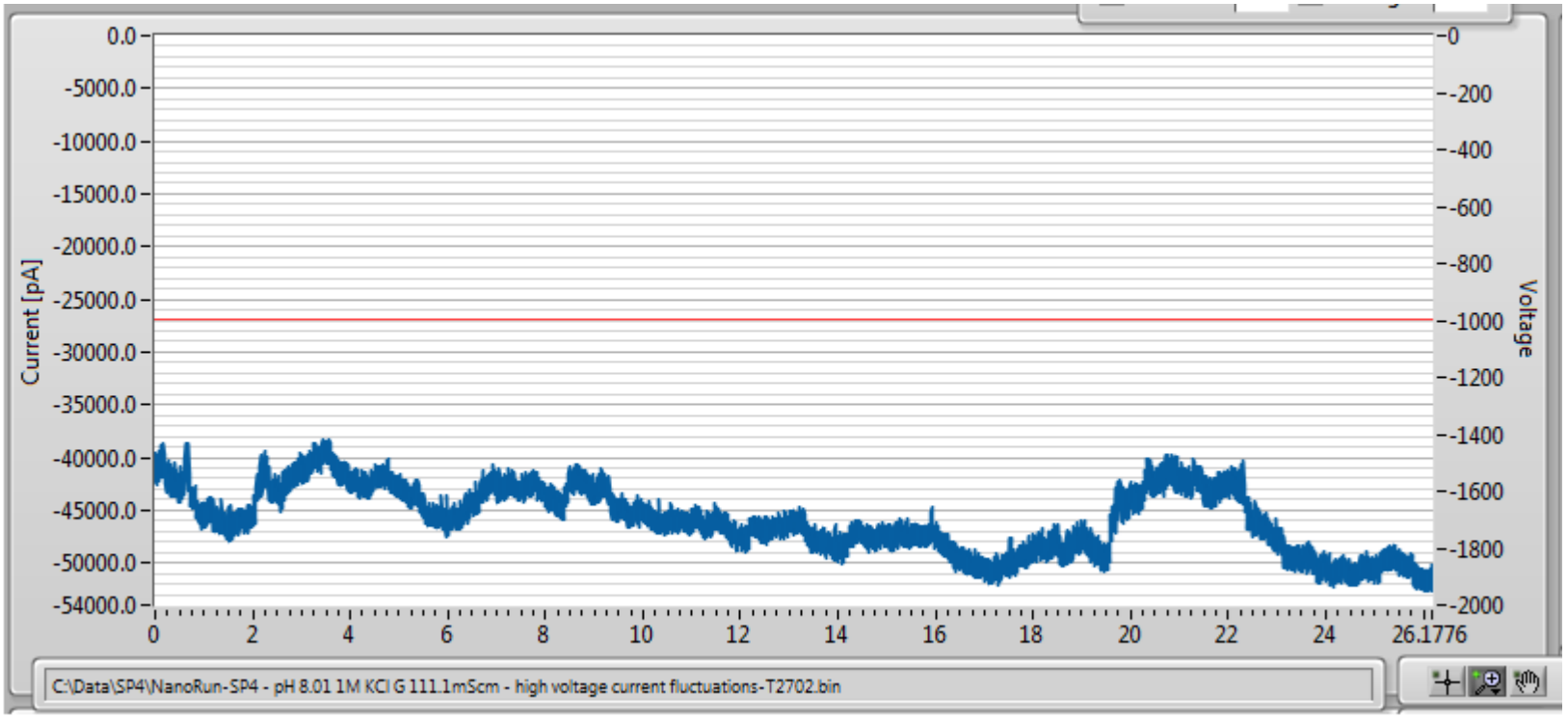
No surprises here…

200mV Noise Basline



High 1/f noise, slightly less than the 10nm case as would be expected since less current is passing.

1V Current Trace



At high voltage (1V here) there are wild current fluctuations in both 10nm and 11nm coatings. This chip is also unstable, growing slowly over time, though it is more stable than the 10nm coating case.

Experiment 2 Conclusions

- Higher degree of rectification than the 10nm coating case suggests smaller openings in general.
- 11nm coating was slightly more stable than 10nm coating.

Conclusions

- Instability could indicate that pores which are almost closed (or just barely closed) are easily opened or damaged by the application of voltage.
- The coated pores show clear differences from the uncoated case considered before.