Investigating protection layers

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Nikhef/Bonn LepCol meeting
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Conductivity of 11 samples of different SixNy protection layers

- Received from IZM (Yevgen) via Uni Bonn on March 2020
- Layer thickness 2 µm
  - For GridPix we normally use 4 µm
- **Conductivity** calculated from IV measurements
- Process parameters varied
  - **SiH_4/N_2** concentration
  - Plasma **power**
  - Plasma **HF/LF**
- **N10** is the **reference,** same process as used for 2018 production

GelPak Nikhef	SiH4/N2 (%)	SiH4 (sccm)	N2 (sccm)	Plasma power (W)	Frequency (HF / LF)	Deposition time (s)
N10	2	50	2450	250	HF	263
N11	1	25	2475	250	HF	797
N12	4	100	2400	250	HF	578
N13	2	50	2450	450	HF	539
N14	1	25	2475	450	HF	662
N15	4	100	2400	450	HF	190
N16	2	50	2450	900	HF	369
N17	1	25	2475	900	HF	699
N18	4	100	2400	900	HF	269
N19	2	50	2450	250	LF	601
N21	4	100	2400	250	LF	428

Experimental setup

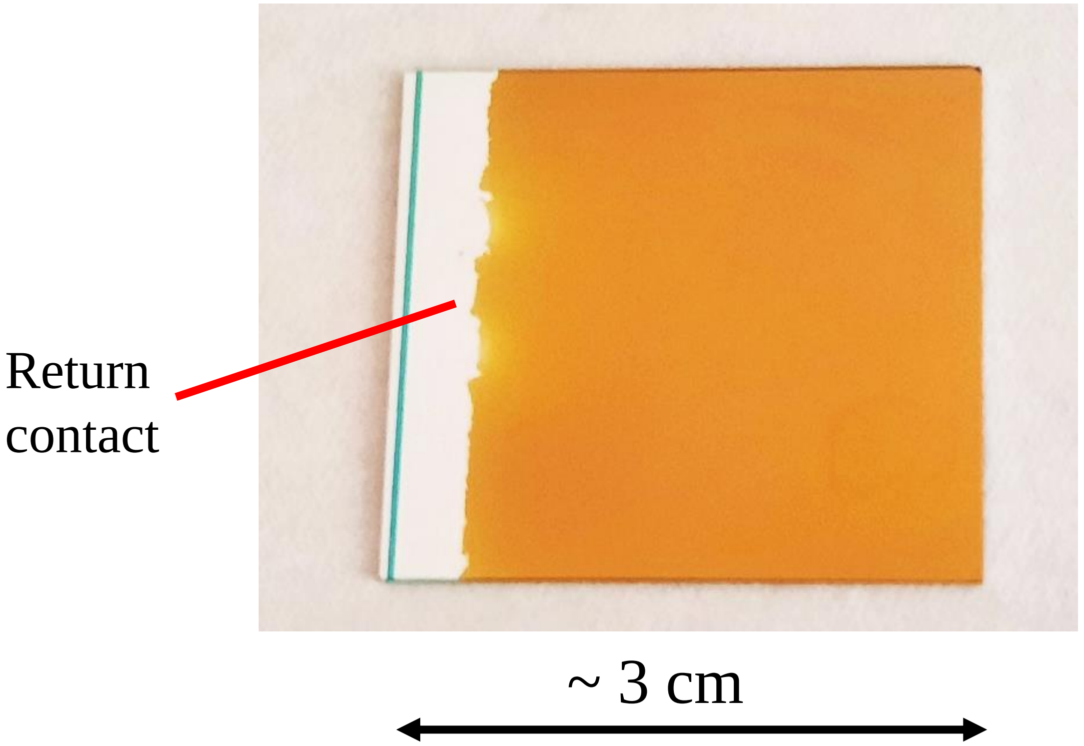
- HP 4140B pA meter
- Mercury probe MDC MP-811
- Soap probe
- Nikhef MiniHV unit, tripping at 5000 nA
- HV control and current RO by PC with LabVIEW program
- Measurements due to **corona regulations** done at my **home**

Mercury probe

The samples

- Silicon substrate
- Metal layer
- Si_xN_y layer of 2 μm
- Back side insulated

- The samples were covered by a wax like layer often preventing good electrical contact
- Cleaned using alcohol



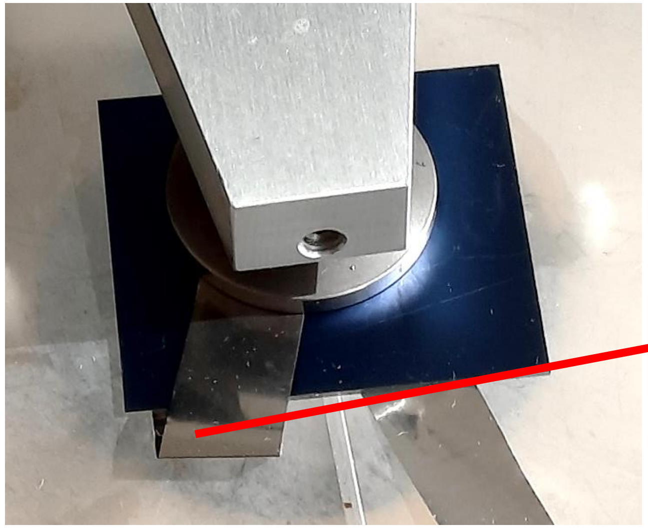
The probes

- Hg probe
  - Mercury suck by vacuum to make contact under the sample
  - Contact surface 18.9 mm^2
  - 10 µm SS contact foil needed
    - Sample is insulated at bottom side

Mercury contact

(Top view, seen through a glass plate)

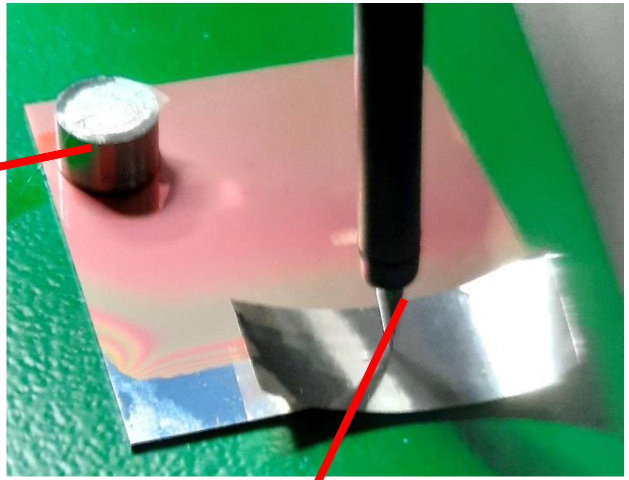
Sample under Hg probe



Contact strip

- Soap water probe
  - 8 mm SS disk as HV electrode
  - 80 µm wire to miniHV
  - A drop of soap water under it
  - => contact surface 50.3 mm^2

Sample with soap probe

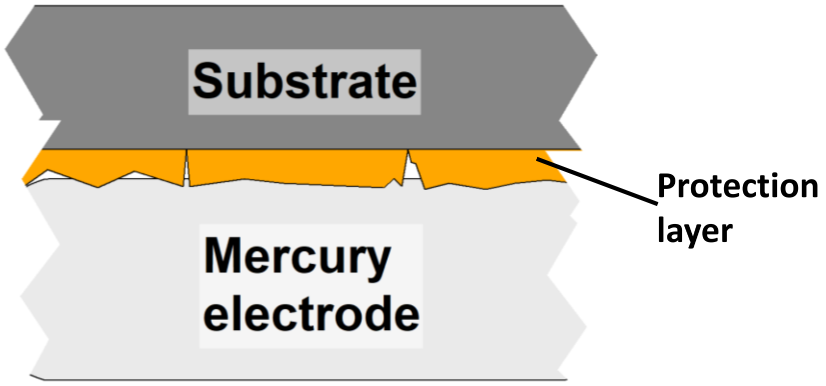


HV electrode

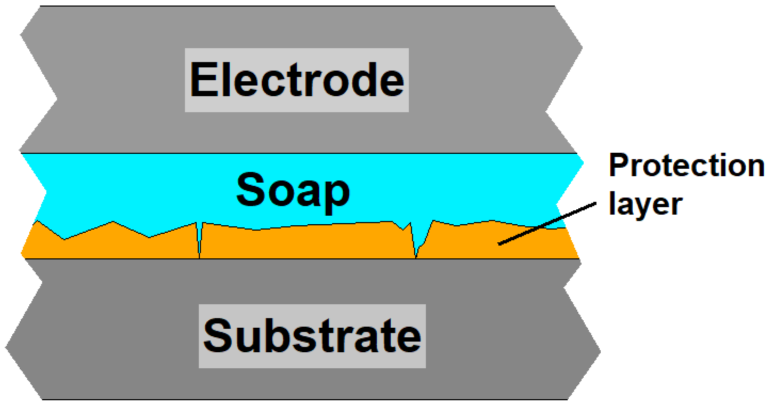
Return contact to pA meter

Mercury vs soap, which is best?

- **Mercury** has **high surface tension**
  - It may not fill pinholes
  - Does not always follow surface roughness well



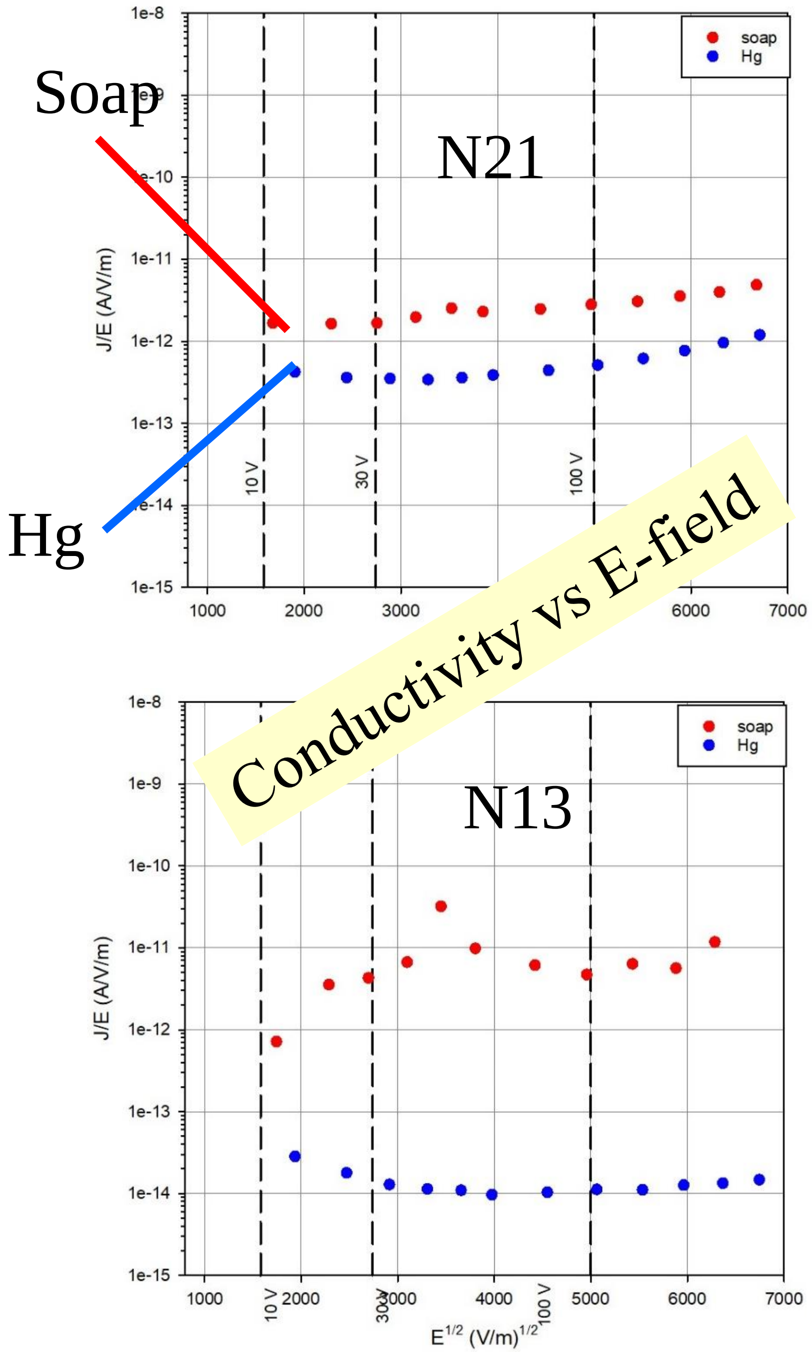
- **Soap water** has **very low surface tension**
  - Creeps in every pinhole
  - (with the soap measurements I noticed some light sensitivity)



- What simulates best detector operation in gas?
  - Gas also fills every hole and unevenness

Which probe?

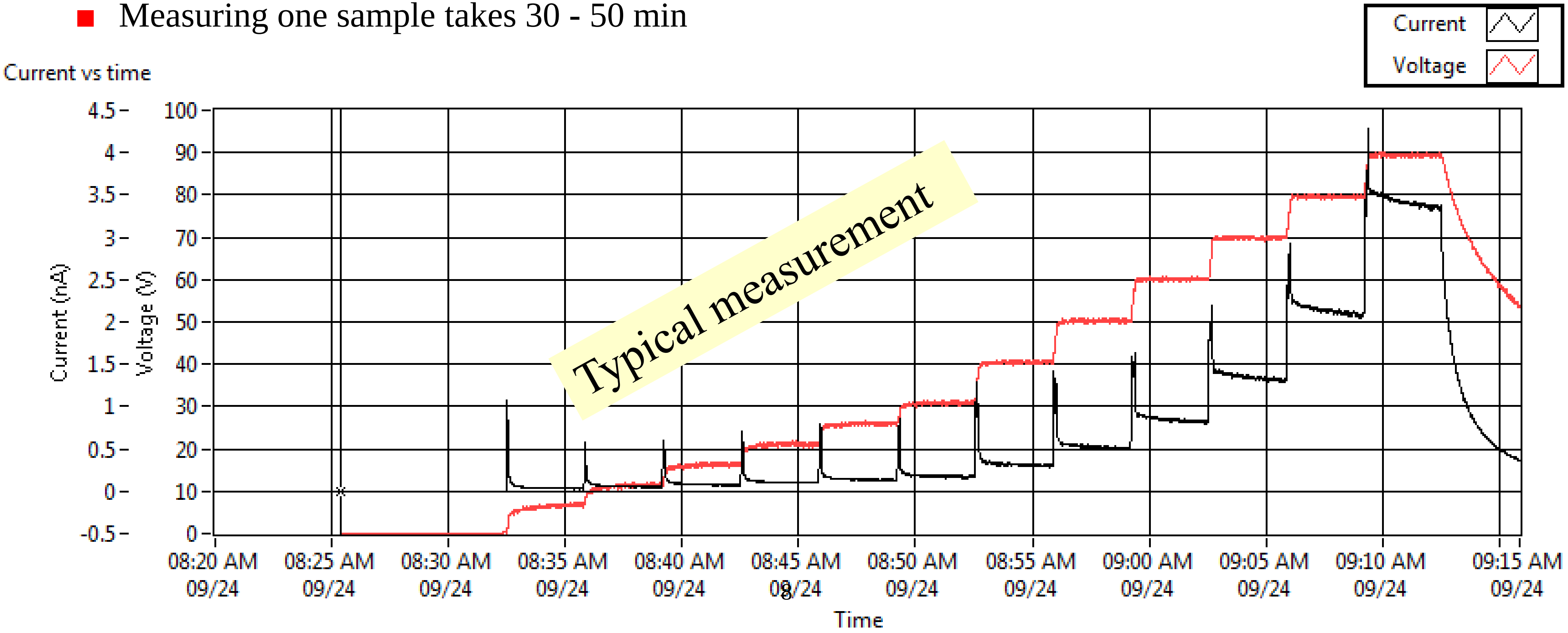
- The **mercury** probe normally gives stable, reproducible results
- The **soap** probe always gives **higher** conductivity
  - Sometimes well reproducible
  - But often unstable currents, discharge/breakdown like phenomena
- My guess: **soap** is sensitive for irregularities, pin holes, roughness of the layer
  - A layer with stable HV behavior in soap might give reliable HV protection
  - *So soap may be used as a quality check for the layer*



Measuring method

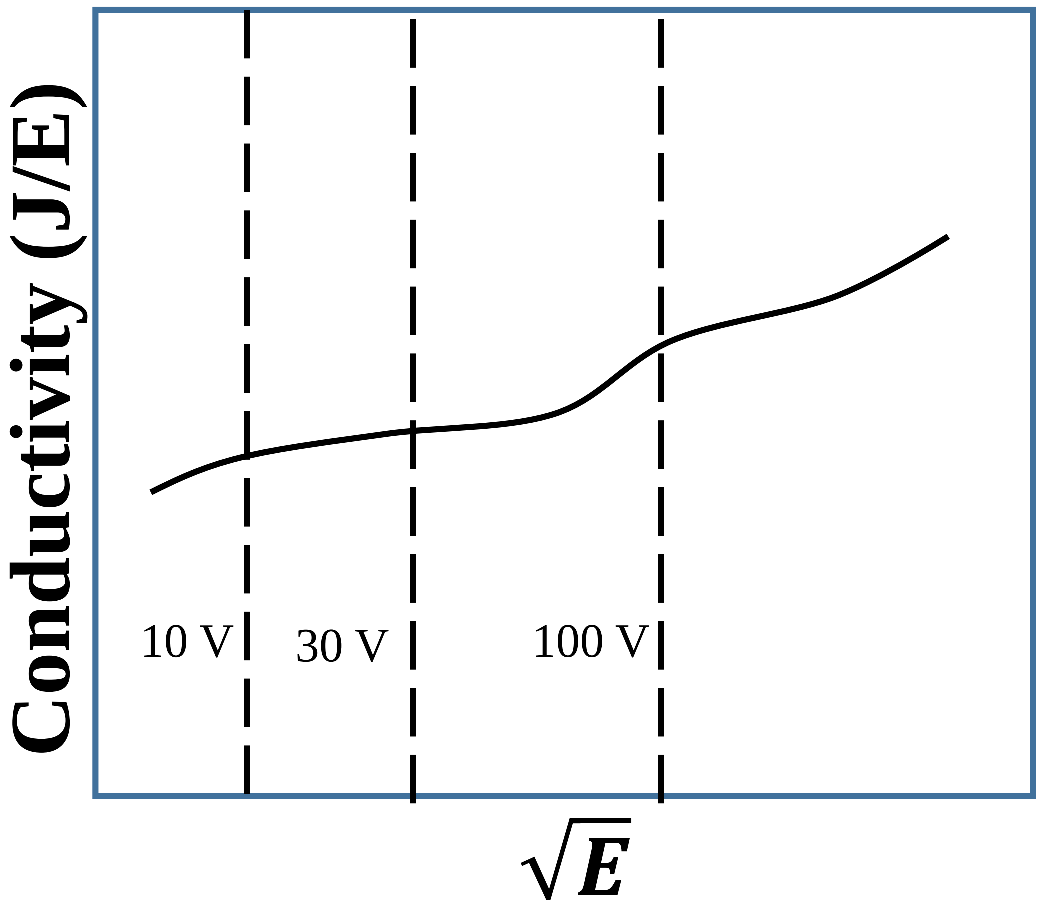
- LabVIEW program
  - Applying negative bias voltages of 0, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80 and 90 V
    - The higher voltages were tested to check the discharge protection
  - The average of 50 – 100 current measurements in the last 25 – 33% of the measuring period was registered
  - Currents were sometimes a few pA => long time needed to stabilize
  - Single negative bias voltage point takes 2 – 4 min
  - Measuring one sample takes 30 - 50 min

5 samples were also tested at **positive bias**
No significant difference was observed



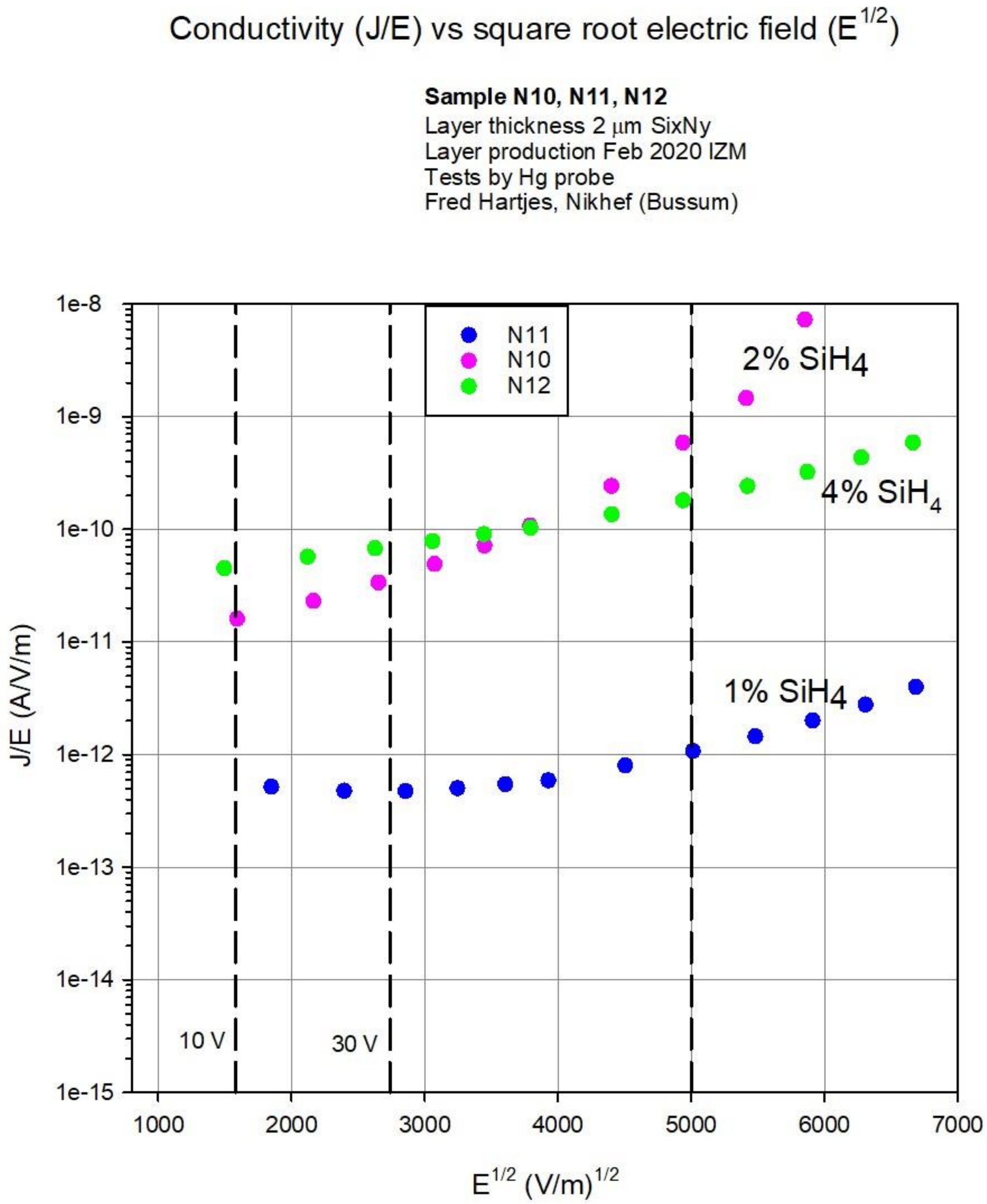
Way of plotting

- **Conductivity** vs **square root of the field** across the layer
- Common practice when studying electrical thin layer properties
- Three reference lines plotted as potentials across 4 μm protection layer
  - 10 V => 75% gain for T2K gas
  - 30 V => 40% gain for T2K gas
  - 100 V => 5% gain for T2K gas
- We aim for the <u>highest conductivity</u>
  - Giving the highest rate capability



Sample N10 – N12
Plasma power 250 W

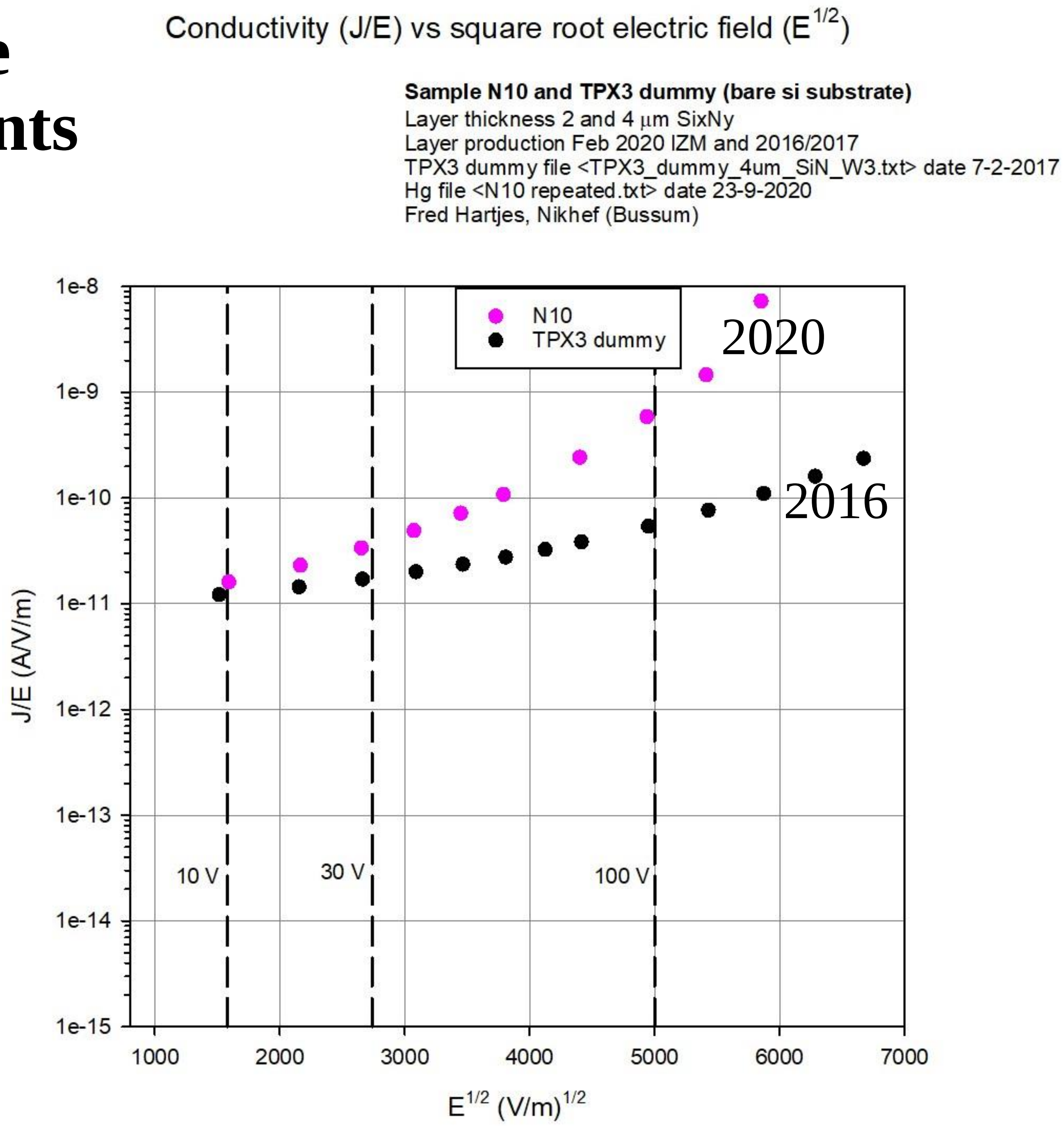
- Conductivity of N10 (2% silane, **reference**) grows largely at higher fields
- Conductivity of N11 (1% silane) is much lower, too low to be useful
- Conductivity of N12 (4% silane) shows much less variation than N10
  - Higher conductivity at low fields



Comparing reference sample N10 with earlier measurements

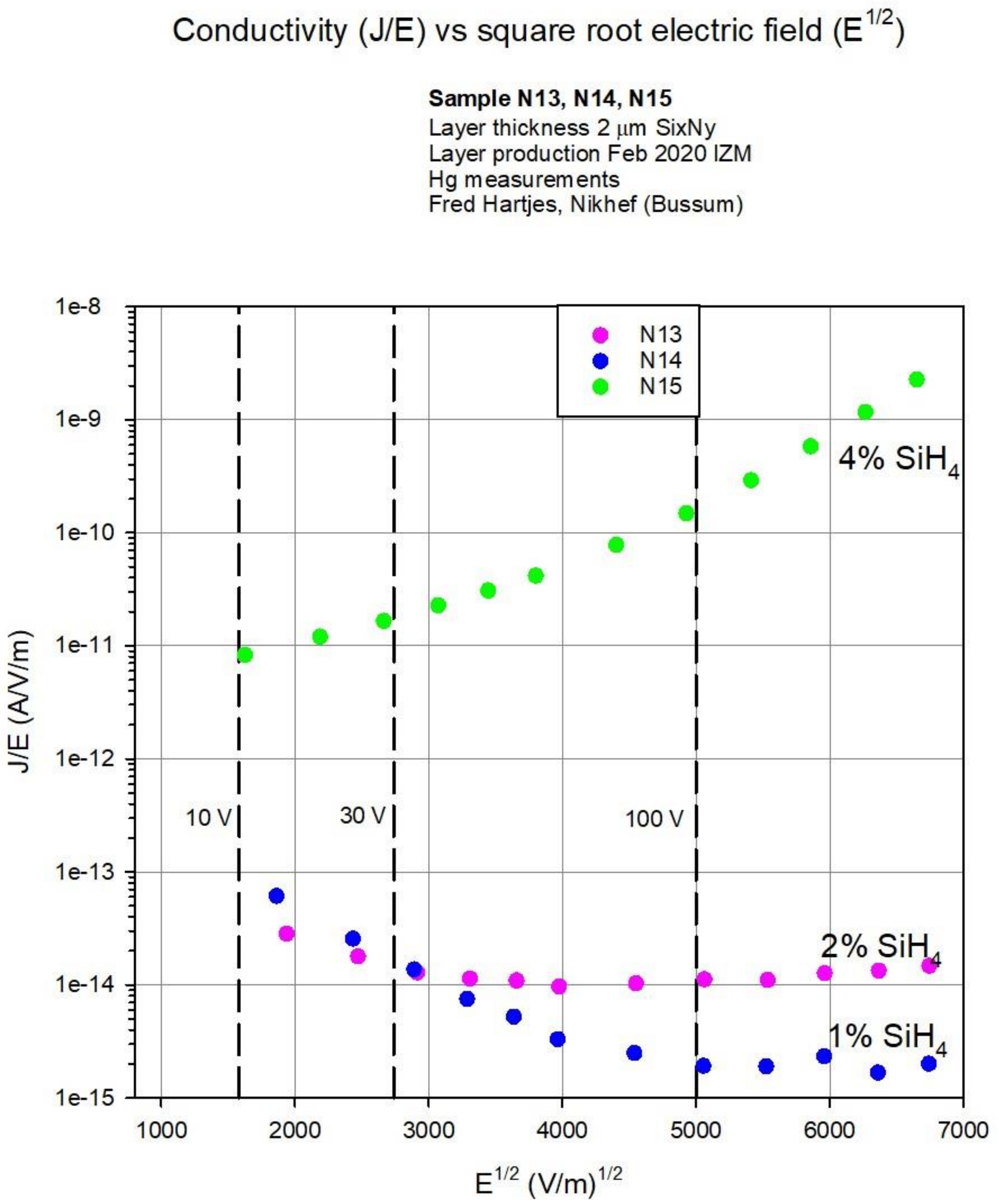
- Production of **test samples in 2016**
  - Using a bare silicon substrate covered with the protection layer (TPX3 dummy)

- At low layer potentials N10 and TPX3 dummy converge but for higher potentials the conductivity of N10 grows more rapidly
  - Less good spark protection??



Sample N13 – N15
Plasma power 450 W

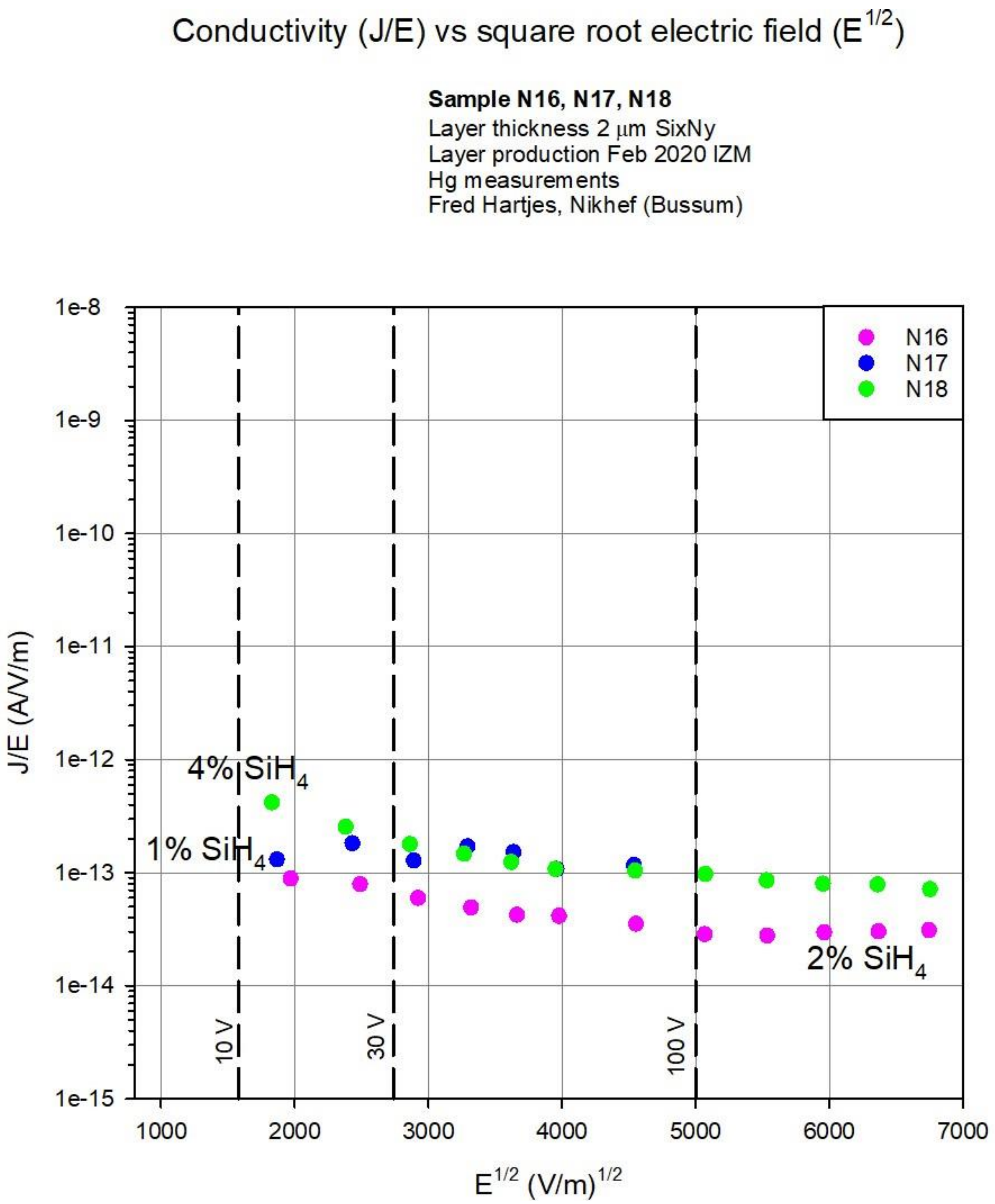
- N15 (4% silane) is best, but still not as good as N12 or N10
- N13 and N14 have very low conductivity
  - Hard to measure (pA currents)



Sample N16 – N18
Plasma power 900 W

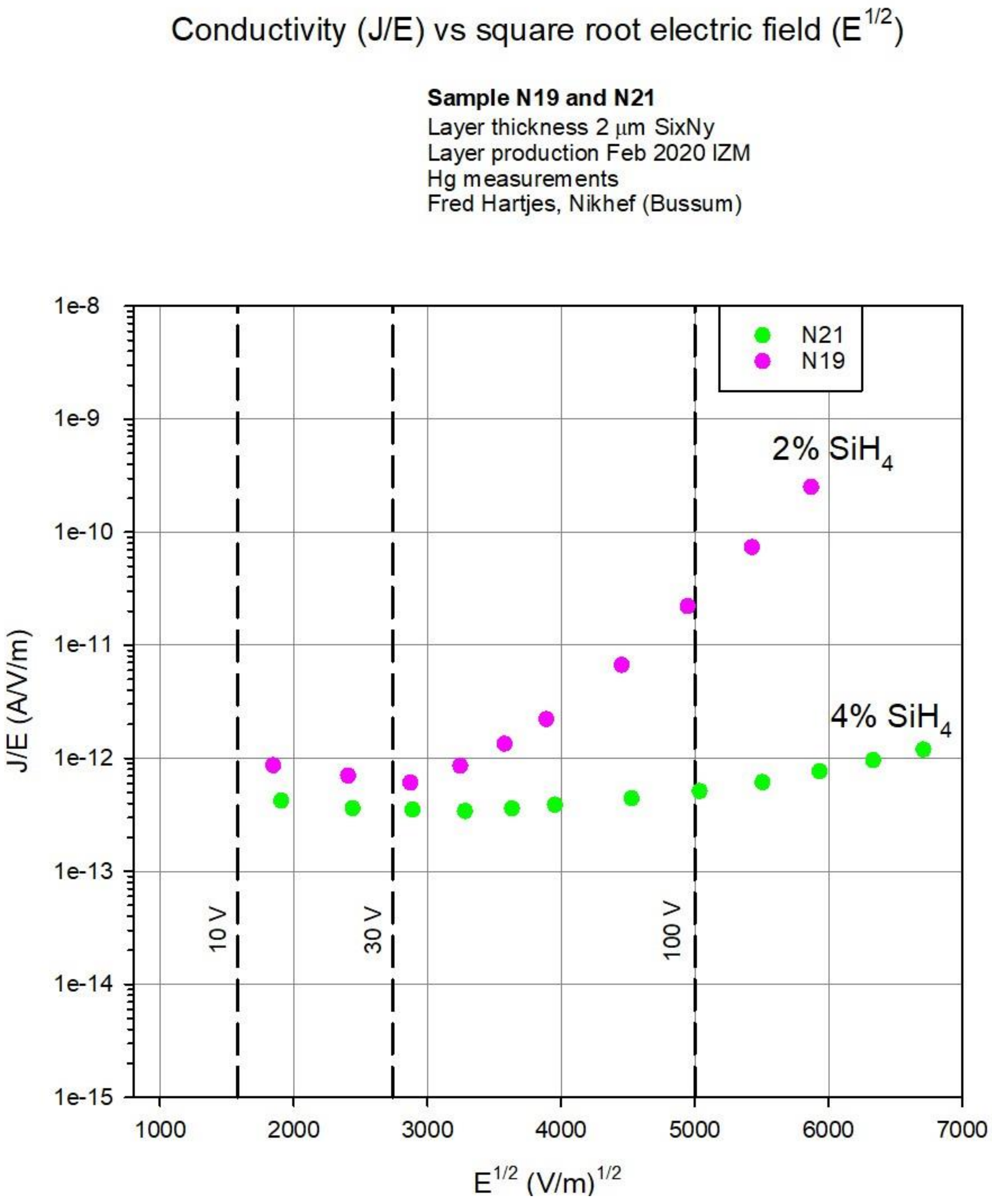
- All very low conductivity, almost **no effect on silane concentration**

- Observed differences on conductivity between various silane concentration not significant



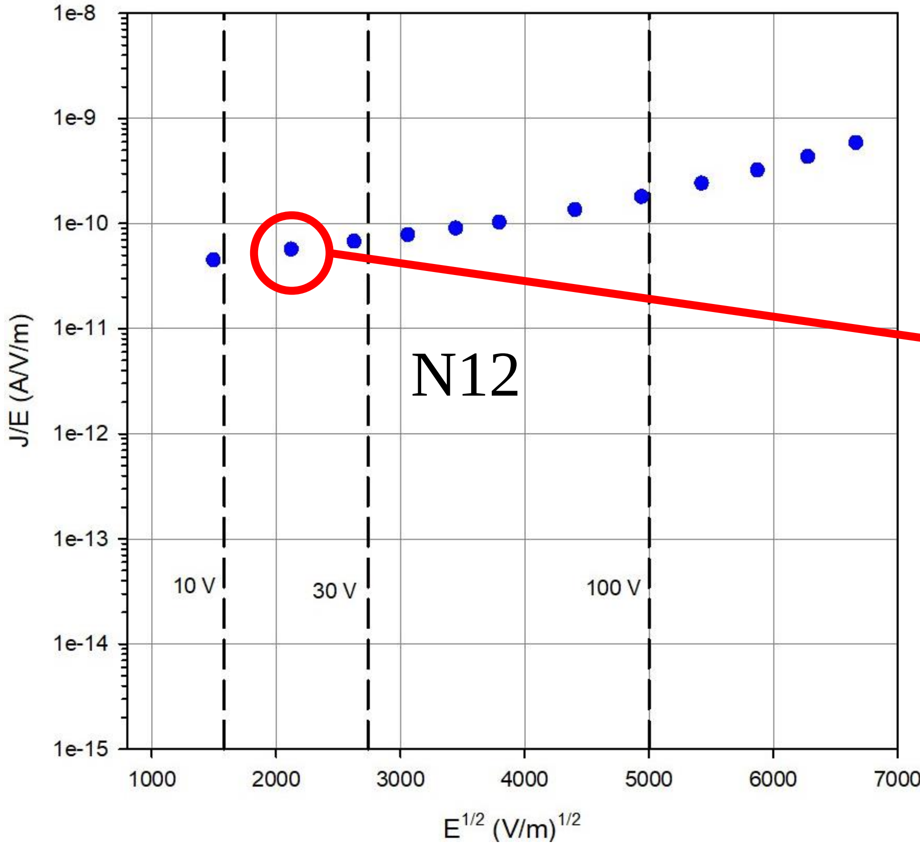
Sample N19 and N21 Plasma power 250 W low frequency plasma

- Surprisingly the 4% silane sample has a **lower conductivity** than the 2% one
- All conductivities are lower than the reference sample N10

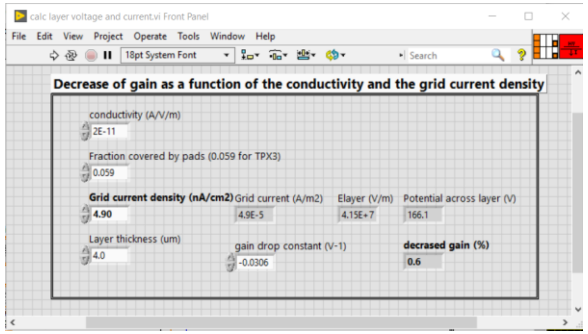


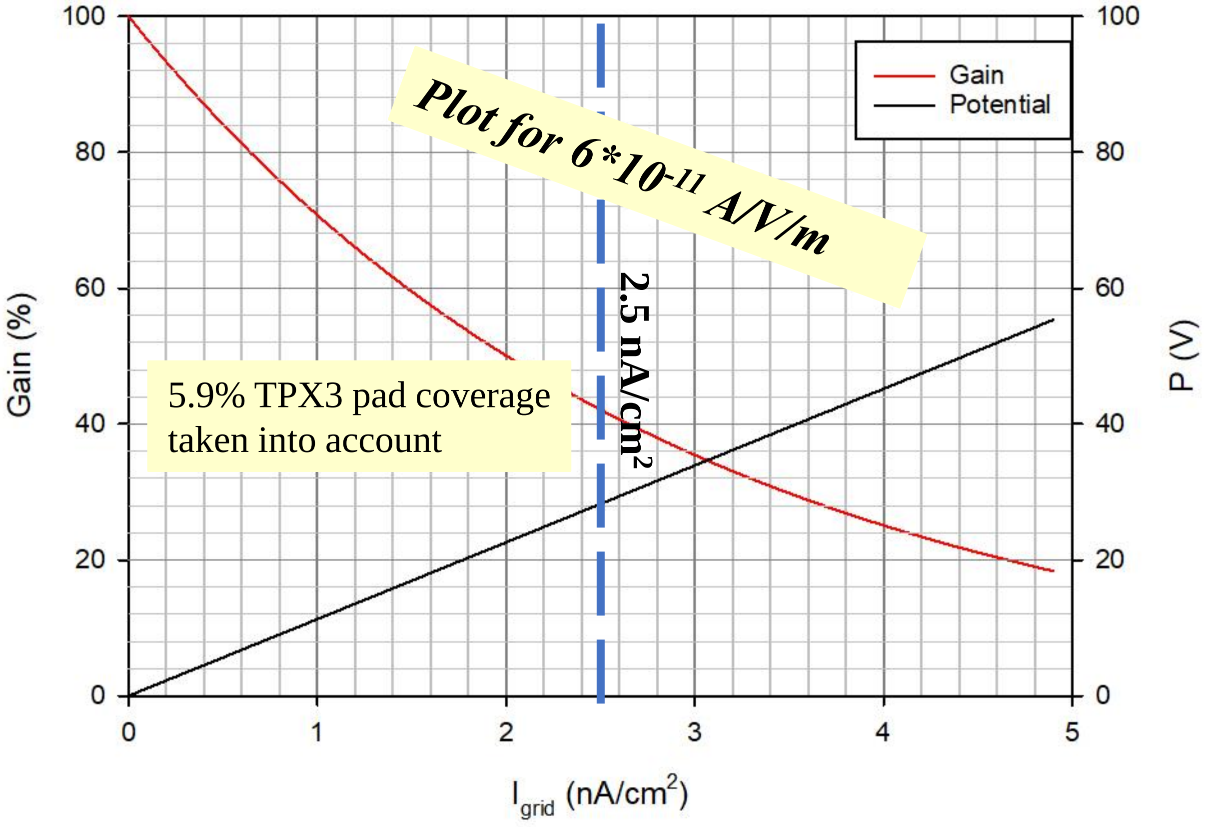
Gain as a function of conductivity and grid current

- The highest conductivity from these samples is given by **N12**
  - 4% silane, 250 W, HF
  - Conductivity @ 10 V: $5*10^{-11}$ A/V/m
  - Conductivity @ 30 V: $8*10^{-11}$ A/V/m
  - => at **2.5 nA/cm²** we have a gain drop of 50% for T2K gas
  - **Reference N10**: 50% gain drop at **0.7 nA/cm²**



LabVIEW routine

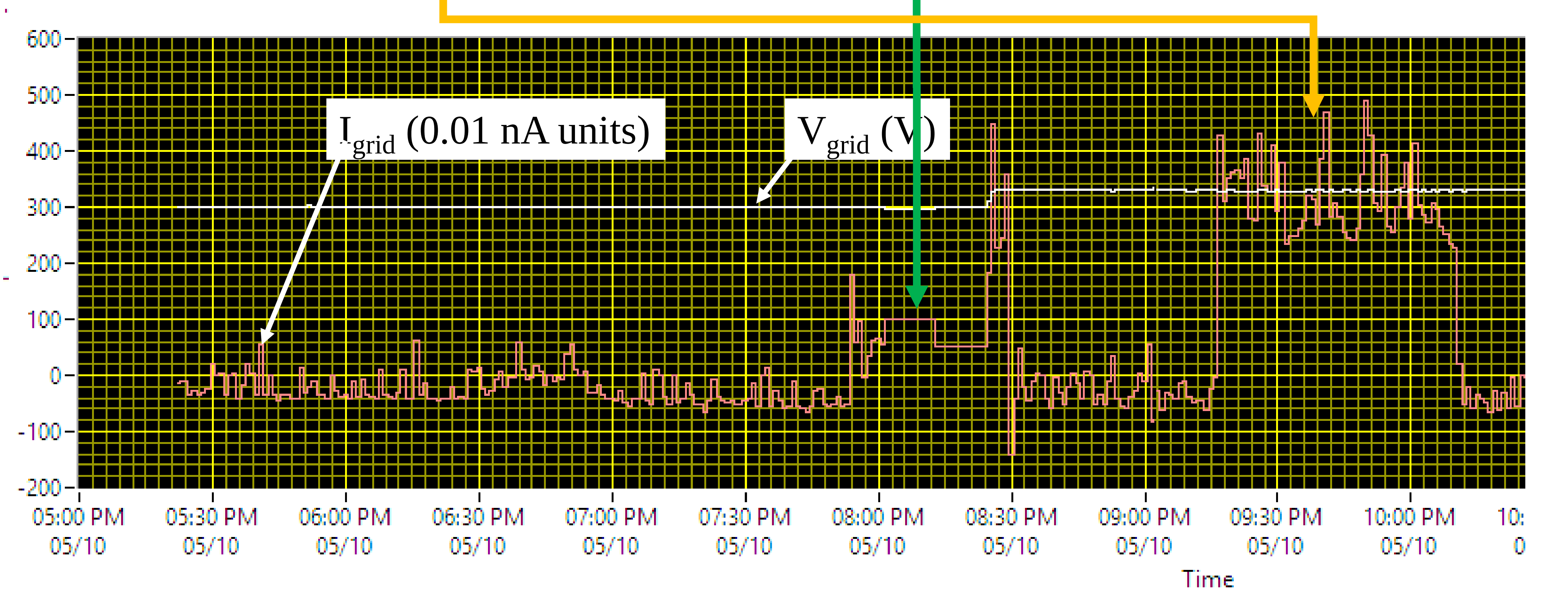




Grid currents during 2018 testbeam in Bonn

- 1 nA @ 300 V_{grid} => **0.4 nA/cm²**
- 2.7 nA @ 330 V_{grid} => **1.1 nA/cm²**

Covered surface by beam ~ 2.5 cm²



Additional remarks and conclusions

- While testing I found some indication of a **temperature dependence**
  - Conductivity **increasing at higher temperatures**
  - During operation the chips have a temperature increased by 10 – 20 °C, this may significantly enhance the rate capability
  - In Bonn the chip temperature was possibly ~ 40 °C => reduced rate effects
- *At my home I have no opportunity to study this effect*

- Most samples show **worse performance** compared to the reference N10
- **Only N12** has higher conductivity but the improvement compared to N10 is limited
  - A significant improvement (3 – 4) can be achieved by enlarging the TPX3 pad size by postprocessing
  - The pads of TPX3 cover only **5%** of the chip surface

- Before using the recipe of N12 on a new batch of chips, at first extensive tests have to be done to check the reproducibility of the process and the spark protection (the **soap probe test**)