Detection and removal of short-circuits on GEM-foils

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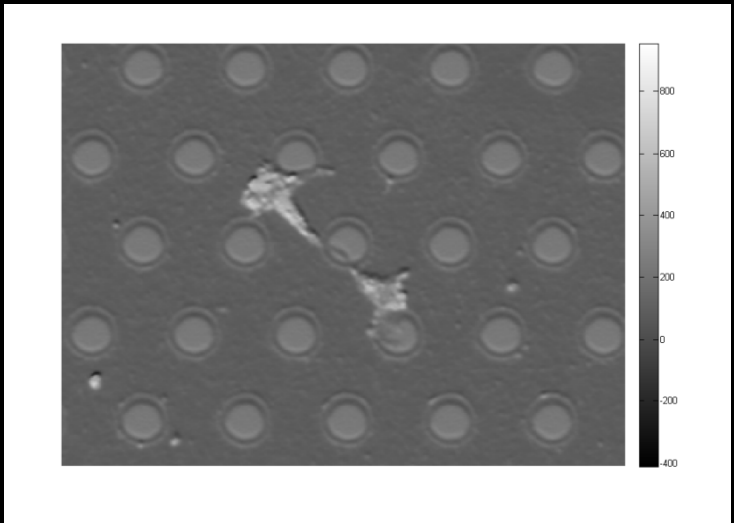
Outline

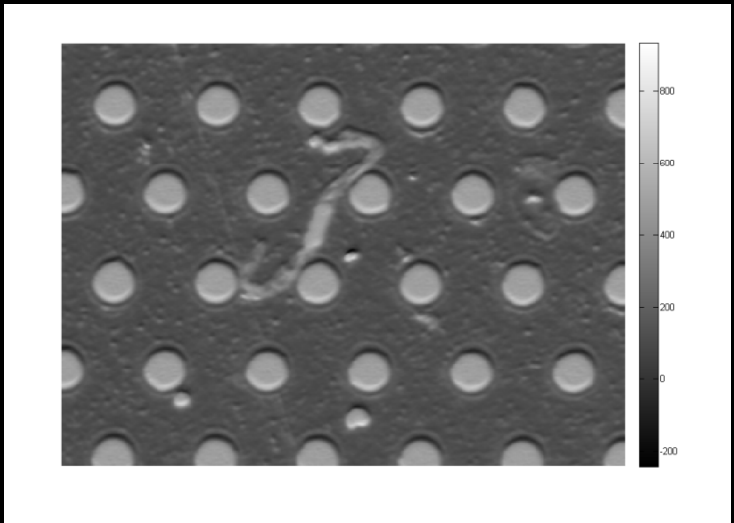
- Formation
- Detection
- Removal
- Conclusions

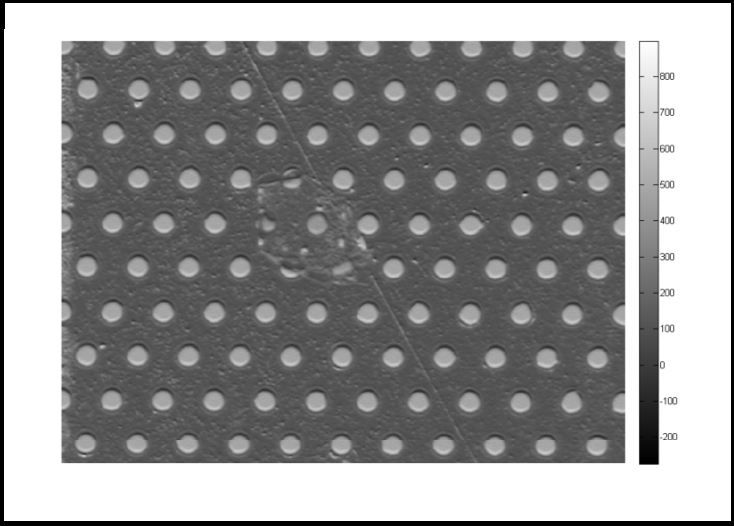
Formation of short-circuits

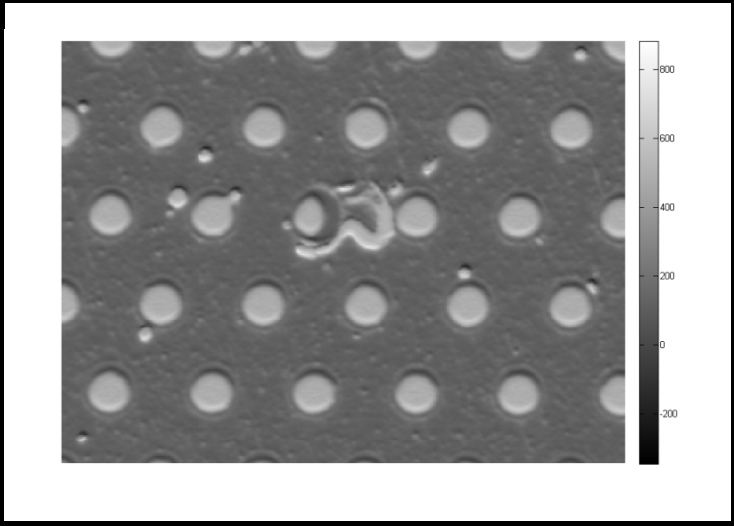
- At high gain, exposure to high radiation fluxes or release of large amount of charge can induce breakdown of the gas rigidity
- This will eventually lead to streamer and followed by discharge spark
- The temperature of the discharge is high enough to carbonize the polyimide inside the holes
- Impurities in materials decrease the amount of charge needed to form a discharge spark

Formation of short-circuits



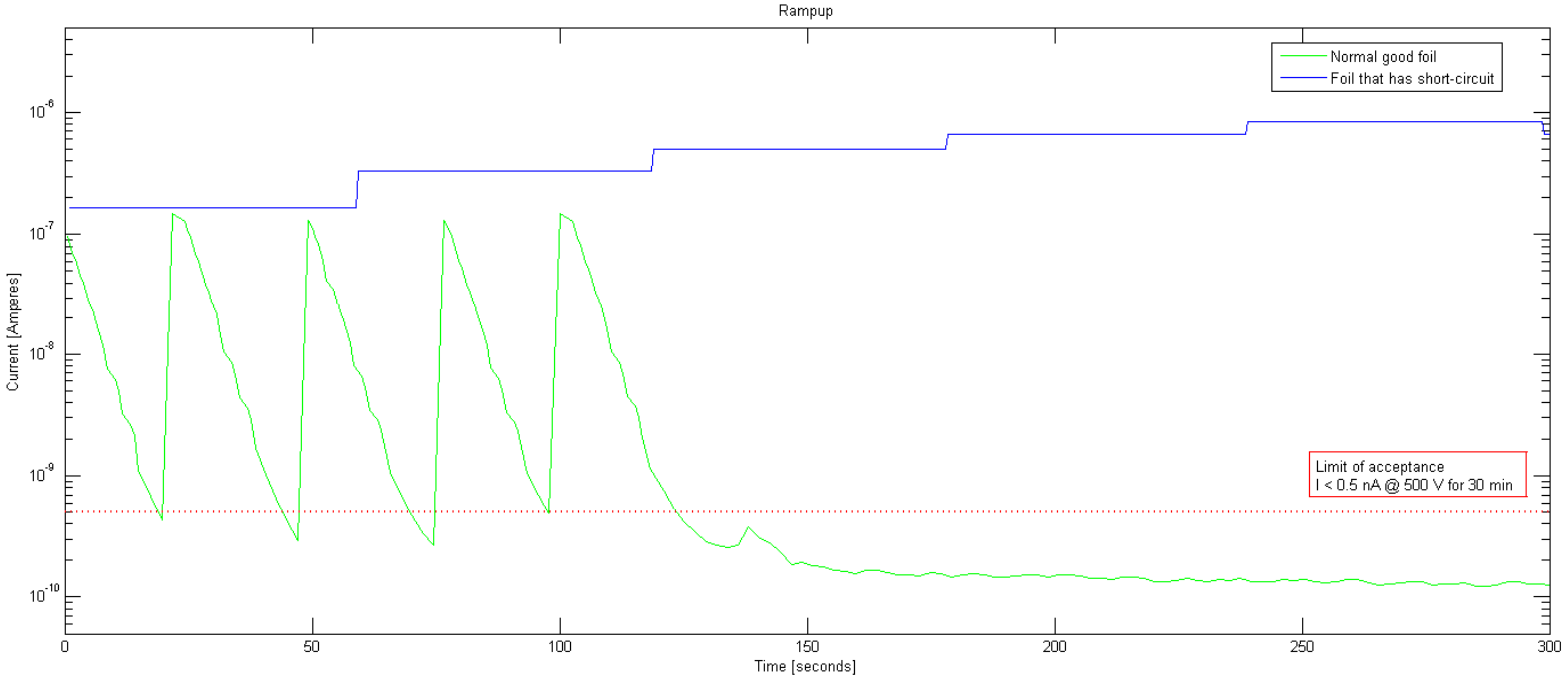






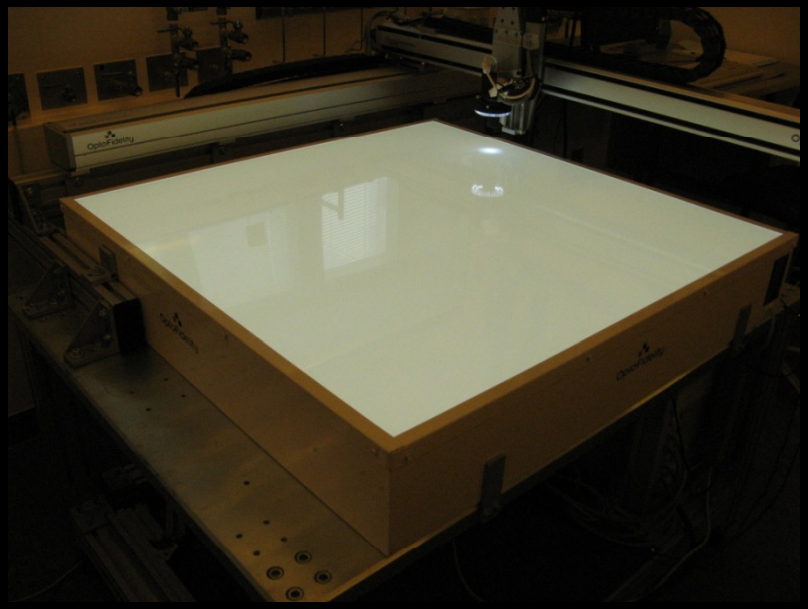
Effects on operation of GEM-foils

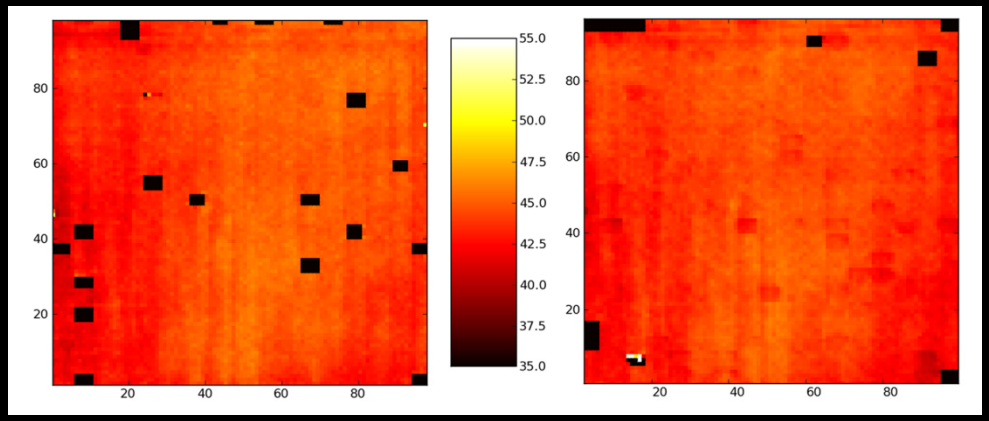
- Standard 10 cm × 10 cm foil has resistivity over 200 GΩ
- Resistivity is measured indirectly by using measurement of the leakage current over the foil
- Foil is ramped up to 500 V in steps
  - Acceptable foil has leakage current below 0.5 nA
  - Current will have to stay below limit over 30 minutes
- Foil with short circuit will show the current values through the guard resistors of the measurement circuit



Optical scanning system

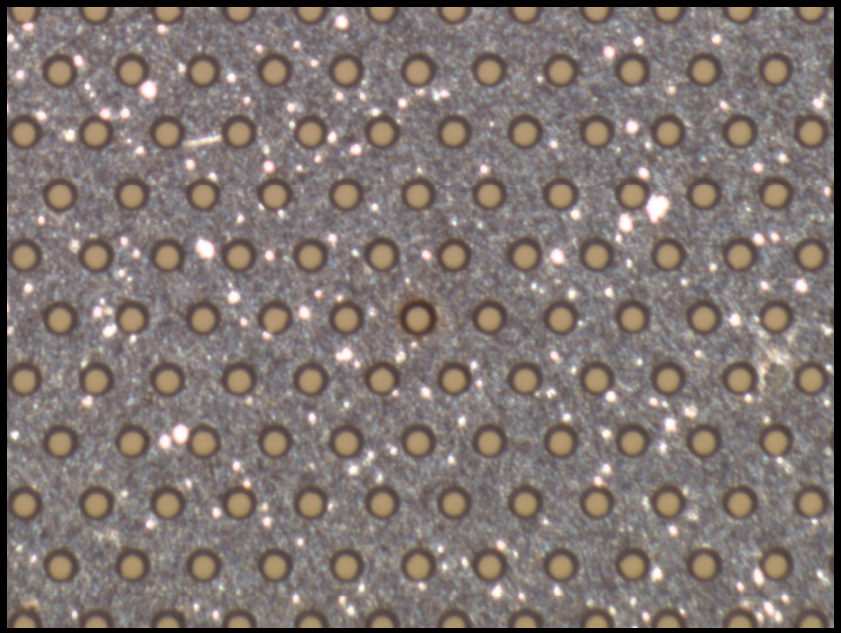
- An optical scanning system was obtained to study and monitor the quality and uniformity of GEM foils
- Active scanning area 95 cm × 95 cm
- 9 Mpix color CMOS camera
  - Resolution ~144 lp/mm in green and blue, ~128 lp/mm in red channel

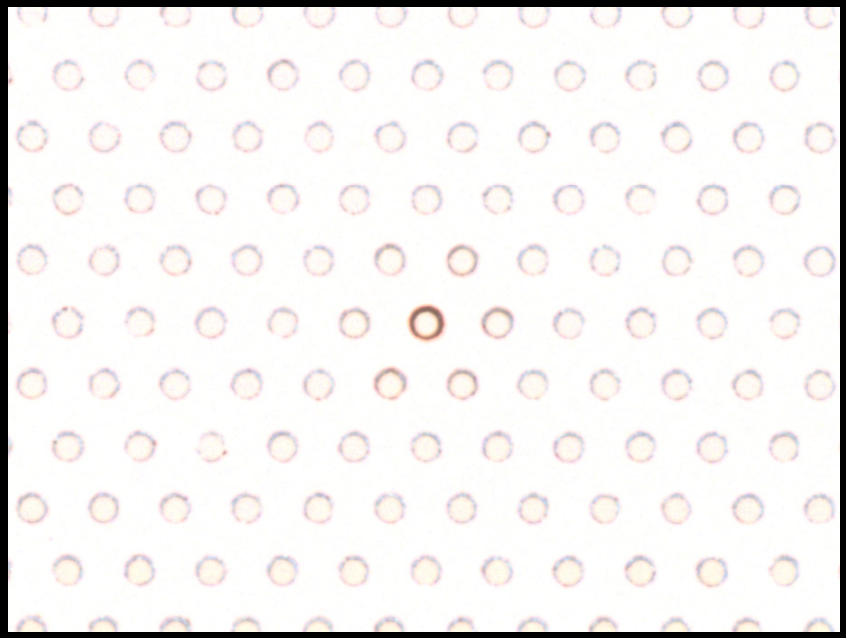




Detection of shorts with optical scanning system

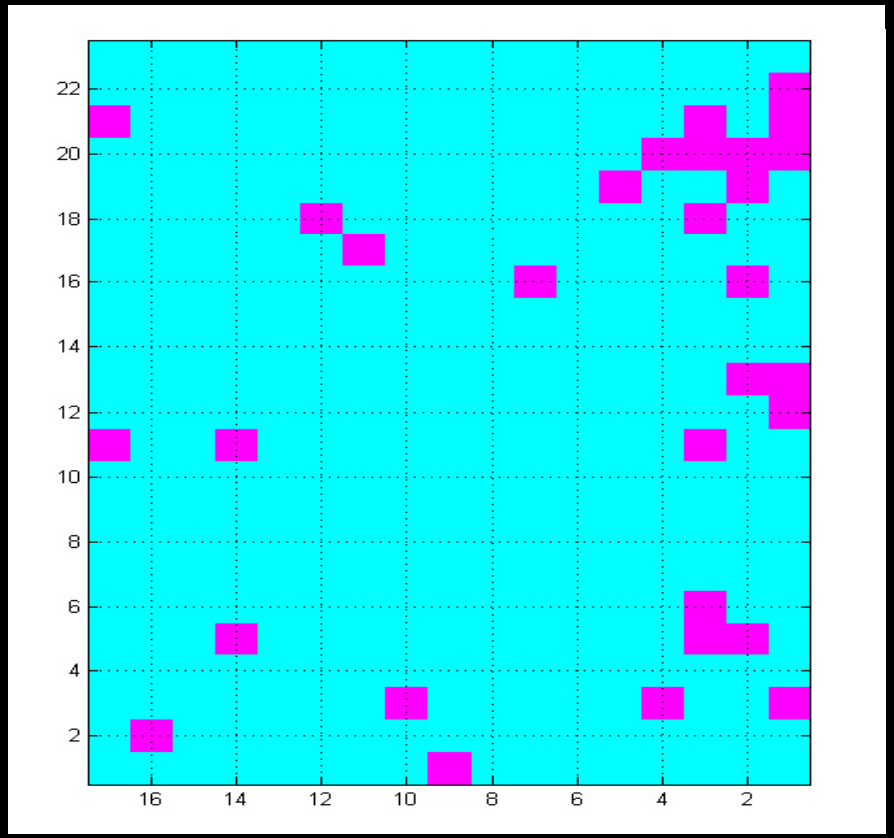
- Short circuits are expected to have carbonized areas
- Emissivity of carbonized polyimide higher than of copper or intact polyimide
- With threshold cuts areas of high emissivity can be located
- By increasing the intensity of the background light source and the exposure time of the camera the regions with low reflectivity are easily identified





Detection shorts with optical scanning system

- Located areas of low emissivity are mapped
- Foils are scanned from both sides and the maps are compared
- If the mark can be seen from both sides it is classified as plausible short
- Each discharge spark leaves similar mark so true identification cannot be done

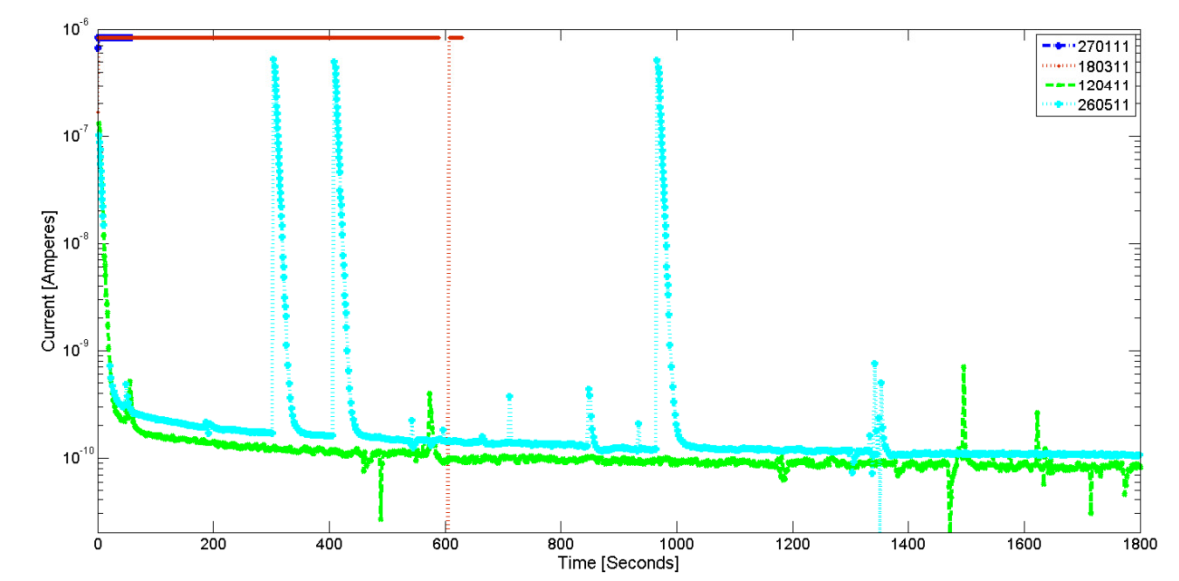


Removing short circuits

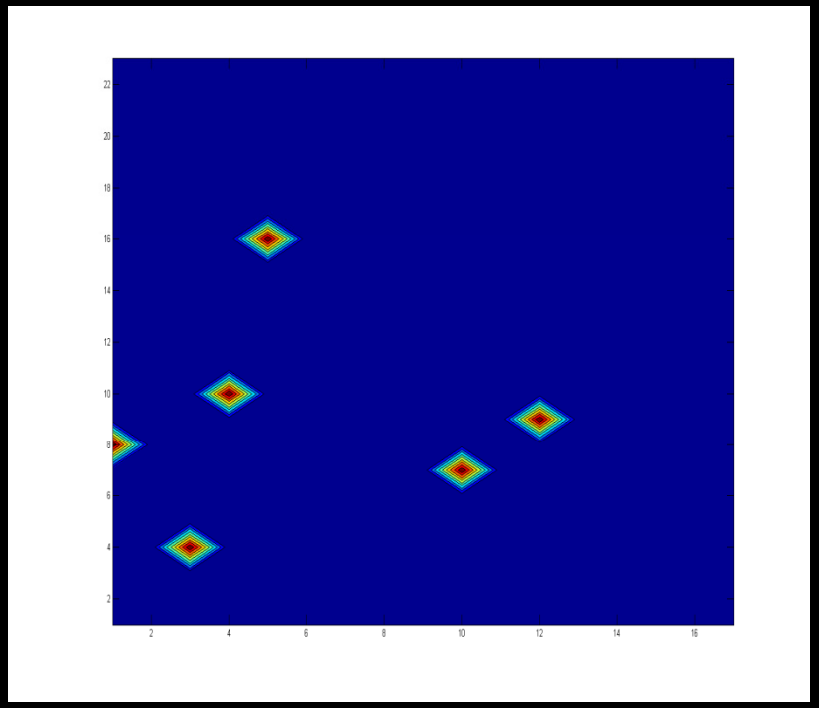
- Several methods to remove short circuits from standard bi-conical 10 cm × 10 cm GEM-foils have been studied
  - Electrical with high current
  - Acoustic
  - Washing in ultrasonic bath
  - Washing with ultrasonic probe
  - Caustic solutions

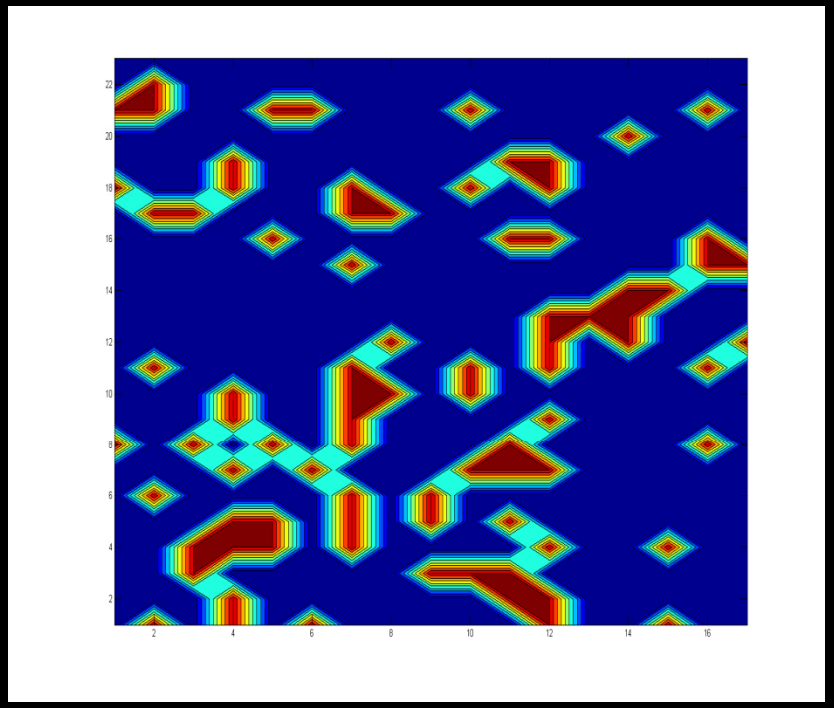
”Burning shorts” method

- Standard method to remove the short circuits from the GEM-foils
- Foil is connected directly to the high voltage power supply with high current limit
- Voltage is increased in steps until plasma arc will flake off carbonized area
- Might create several sparks all over the foil
- Doesn’t always remove the short circuit but damages the foil even further



”Burning shorts” method

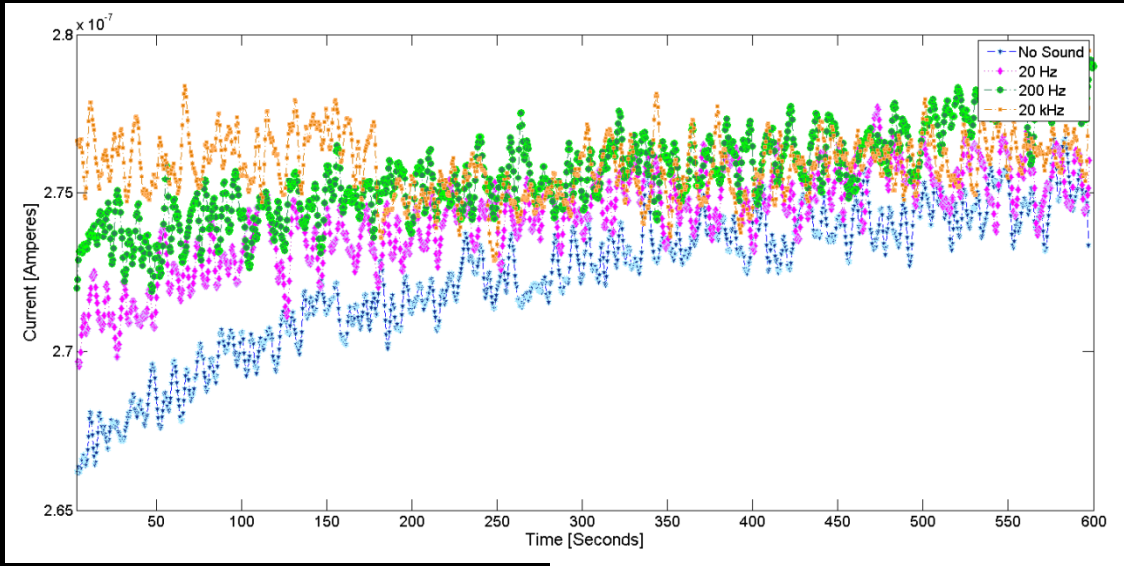


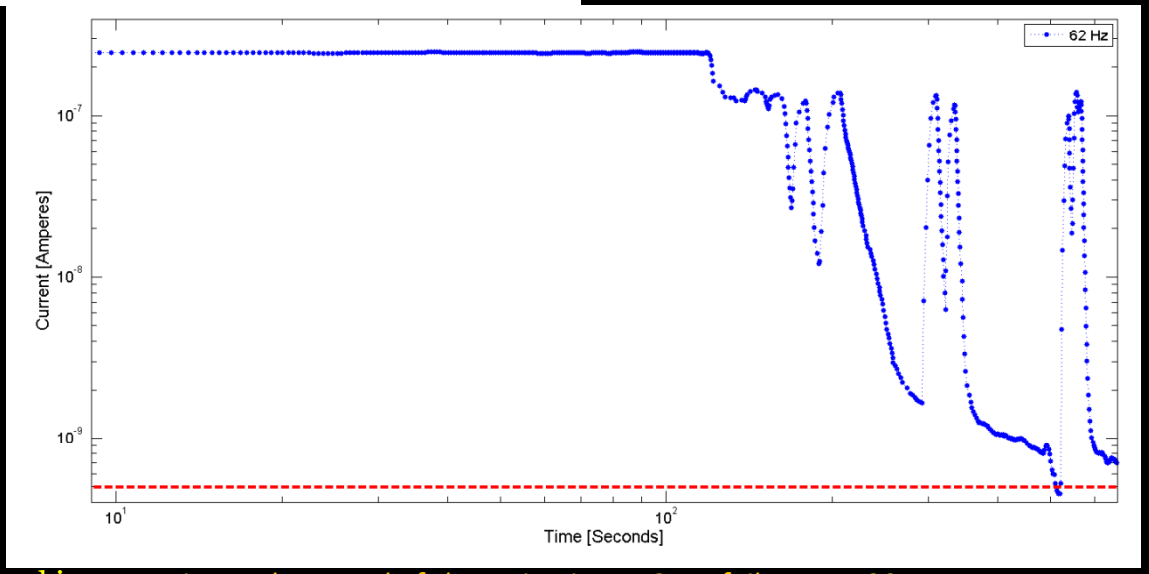


Acoustic treatment

- Foil was attached on solid platform and a loudspeaker was placed above the foil
- Frequency regions of 1 Hz – 20 kHz were studied
- Leakage current was monitored simultaneously with the setup
  - The voltage over the foil was ramped to 500 V

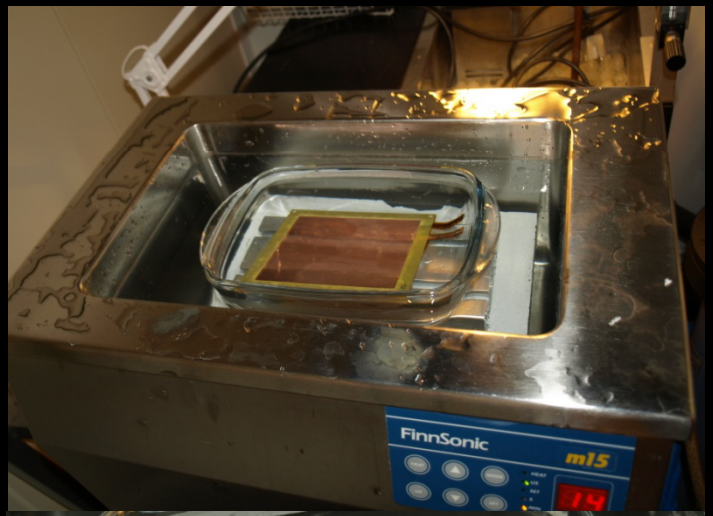
Acoustic treatment

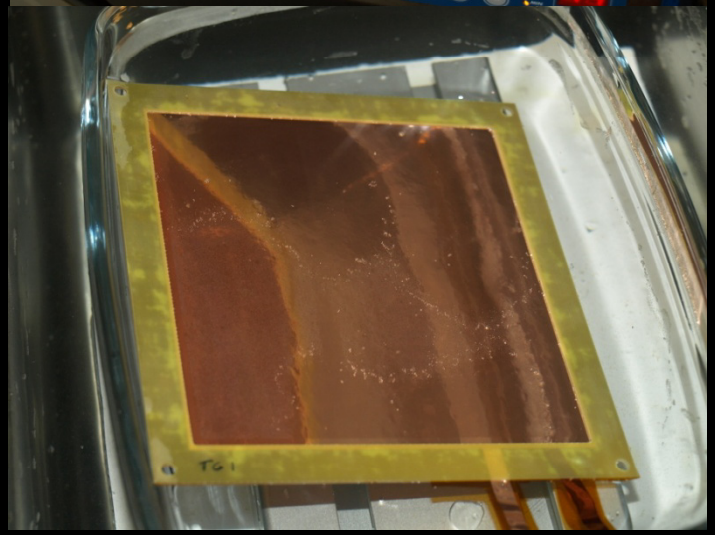




Ultrasonic wash

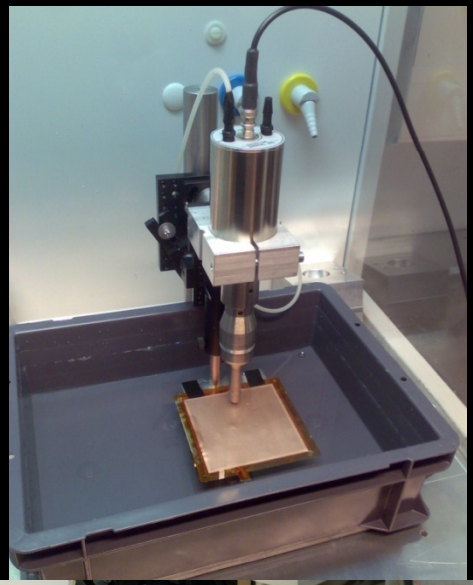
- FinnSonic m15 ultrasonic parts washer was used
  - Ultrasonic frequency of 40 kHz
- Foil was placed on ultrasonic wash basin in de-ionized water
- After treatment the foil was dried in vacuum oven
- After the oven the foil was scanned and measured for leakage current
  - No effects to the regions of interest was observed
- Treatment was repeated by using 10 % ethanol solution in washing
  - No changes in leakage current
  - No differences between the optical scans

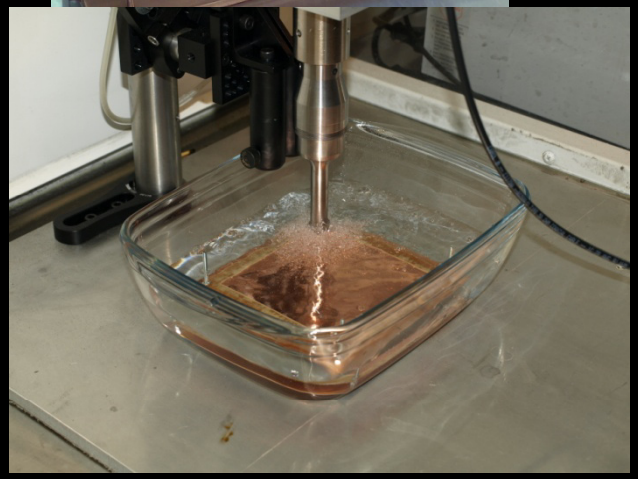




Ultrasonic probe

- To focus the ultrasonic pulse, VibraCell ultrasonic processor with cleaning probe was used
  - Resonance frequency 20 kHz
  - Power 500 W
- De-ionized water with 5% Etax A was used as detergent





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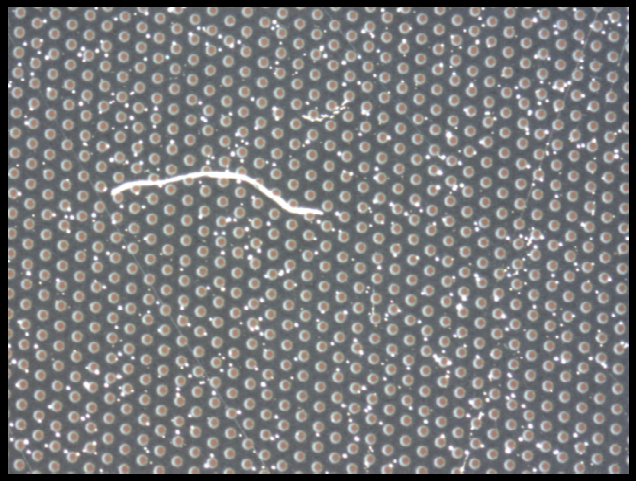
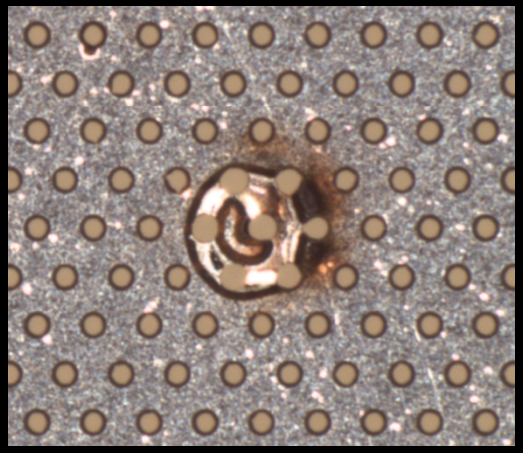
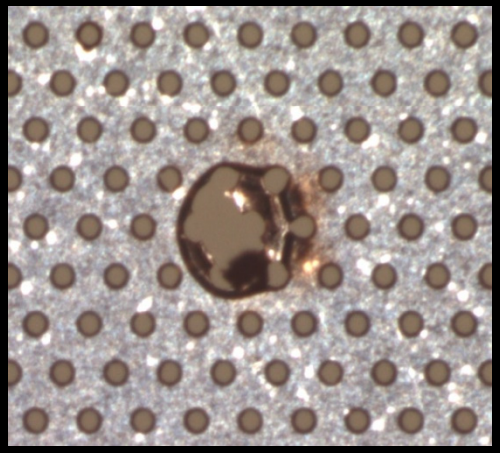
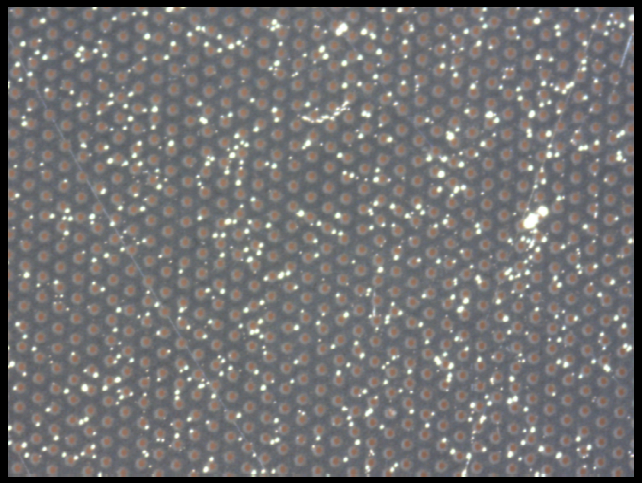
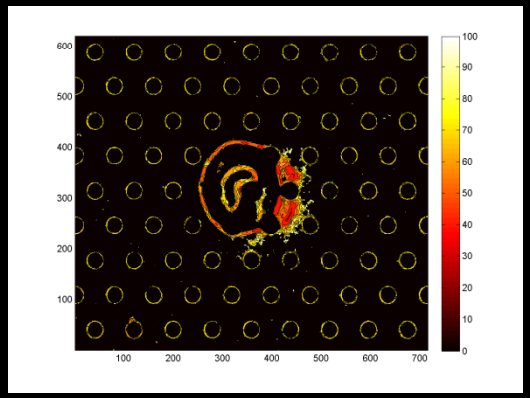
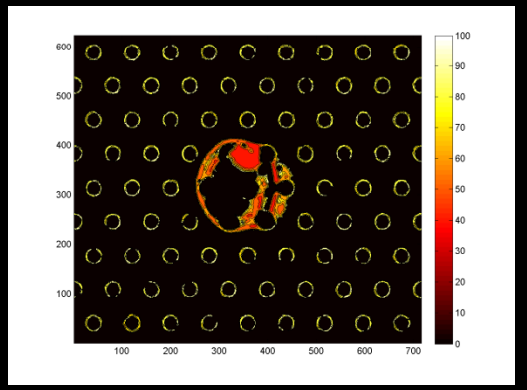








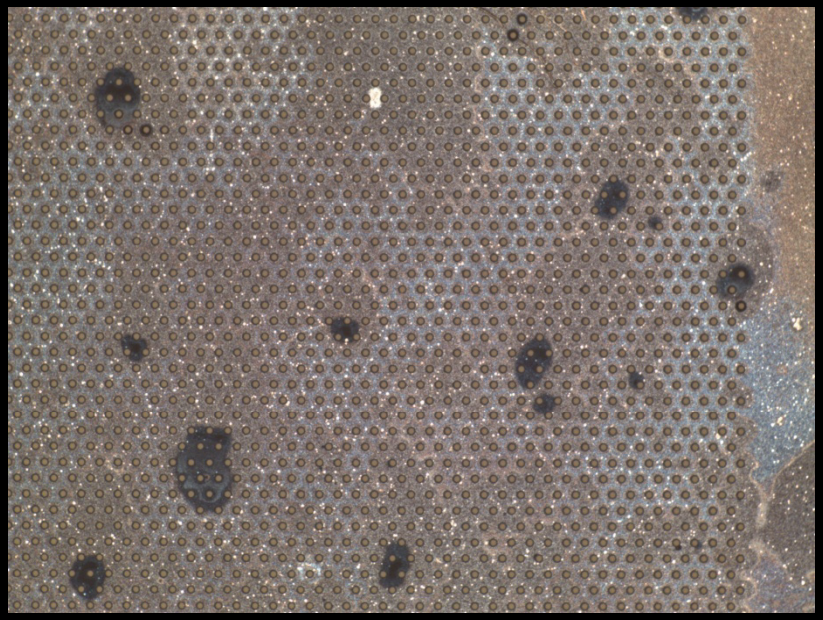


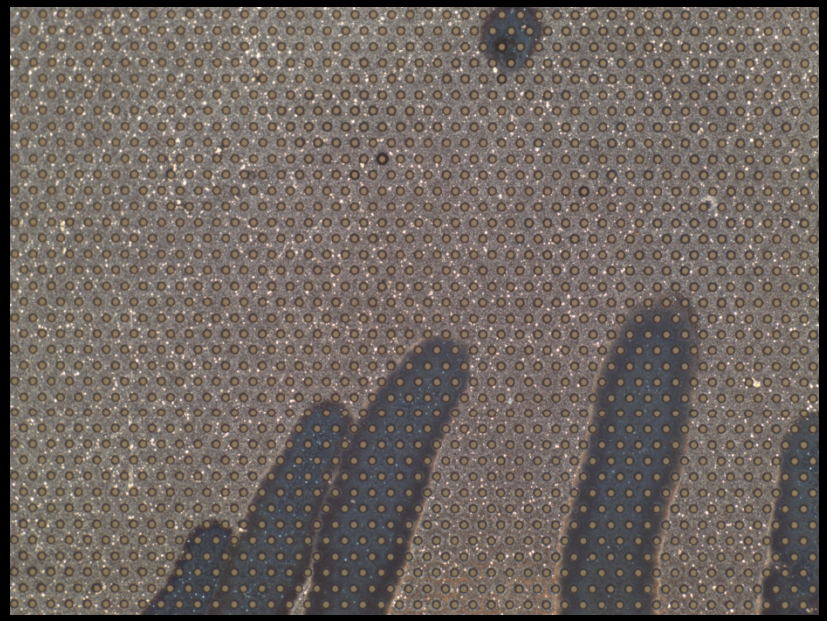


Chemical methods

- Since the foils are manufactured with chemical etching methods, similar methods could be used to remove carbonized areas
- Solutions should be less erosive to keep the shapes of the holes
  - Monitoring of exposure time and temperature crucial

Chemical methods





Conclusions

- Simple method to locate the regions that might have short circuit using optical scanning system is being developed
- Several methods to remove the short circuits have been studied
- Standard method of using high current is the fastest method and only one that can be used if the foils cannot be disassembled from the detector
- Further studies and development of new methods are needed