

Characterization of Photoconductive Diamond Detectors as a Candidate of FUV /MUV Transfer Standard Detectors

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Background

- Increasing needs for quantitative measurements in the FUV, VUV
- Problems for existing photodetectors such as Si photodiodes of degradation, non-uniformity etc.
 - Maximum absorption for all materials in these spectral regions
- Potential advantages of wide bandgap semiconductors in solar blindness, stability etc.

Objectives

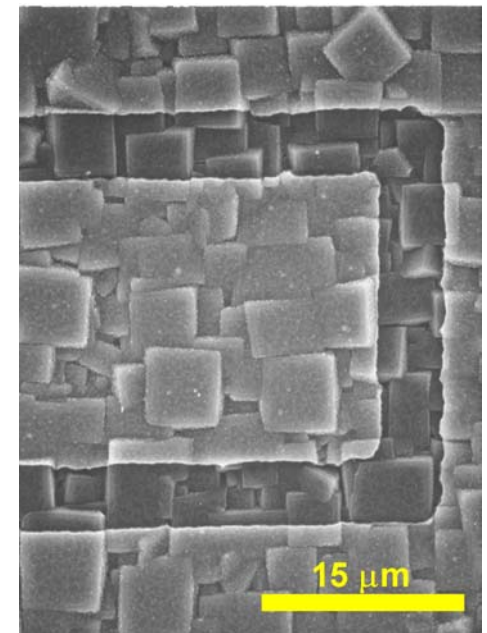
- To characterize photoconductive diamond detectors as a candidate for transfer standard detectors
 - Temporal response & Stability under irradiation
 - Spectral response
 - Spatial uniformity
 - Photoemission contribution to the output current
 - Low PEA or NEA + long electron escape depth
-
- lead to large contribution?

Device fabrication

- HOD (Highly Oriented Diamond) films grown by CVD
- Consisting of azimuthally oriented (001) facets
- Surface cleaning by acids
- Fabrication of interdigitated Pt electrodes

Electrode gap : $30\mu\text{m}$

Sensor size: $6.5\text{ mm} \times 6.5\text{ mm}$.



Experiments

Specimens: Photoconductive HOD detectors

- Measurements 1: Wavelength range 190-300 nm

Source: Deuterium lamp

Monochromator: 25 cm double grating

- Temporal response
- Spectral responsivity
- Spatial uniformity

- Measurements 2: Wavelength range 10-60 nm*

Source: Synchrotron radiation from TERAS (800 MeV)

Monochromator: 1 m toroidal grating

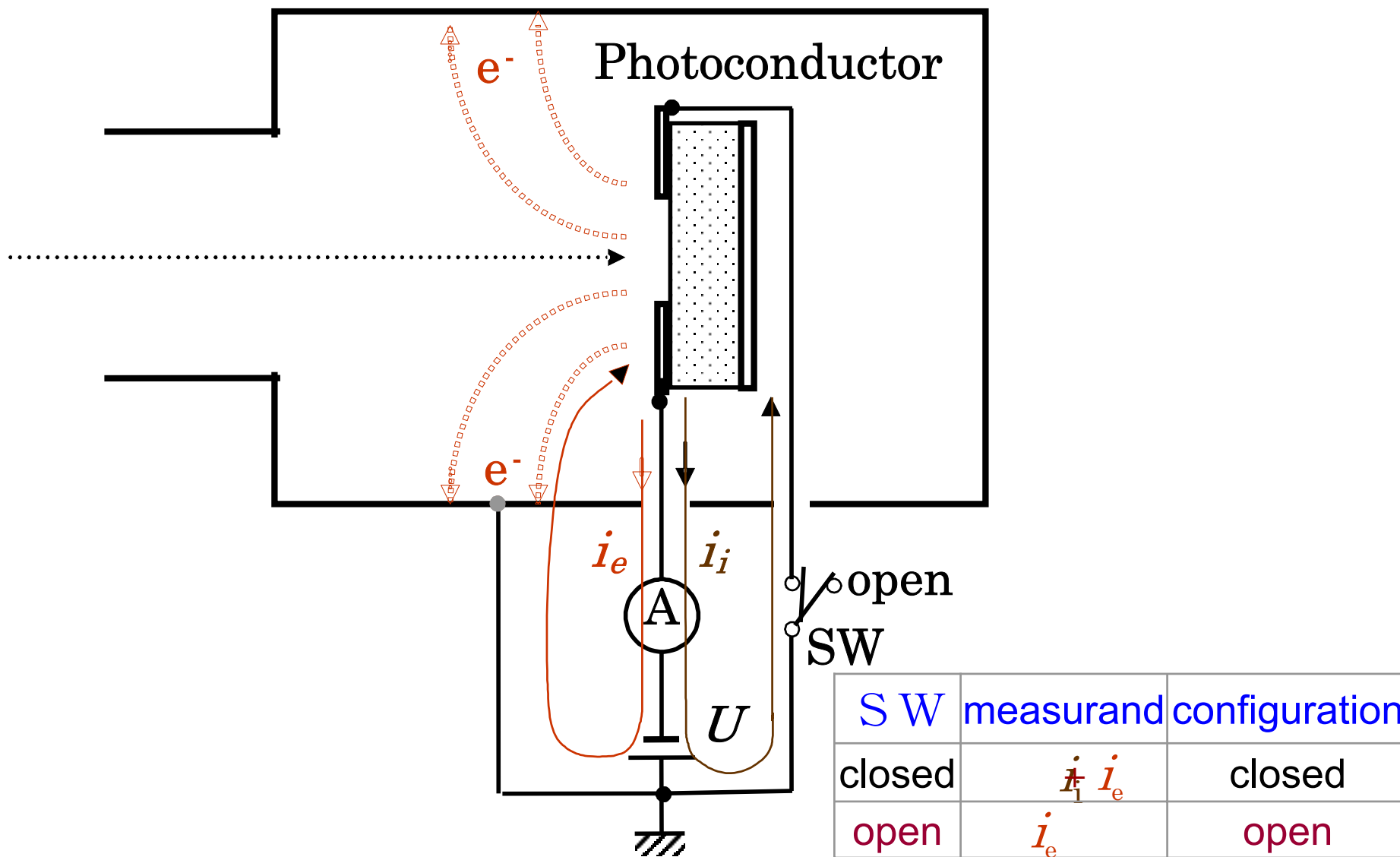
- Spectral responsivity distinguishing photoemission contribution

* *T. Saito and K. Hayashi, Appl. Phys. Lett. 86 (2005) 122113.*

- Measurements 3: Wavelength :172 nm (Xe excimer lamp)

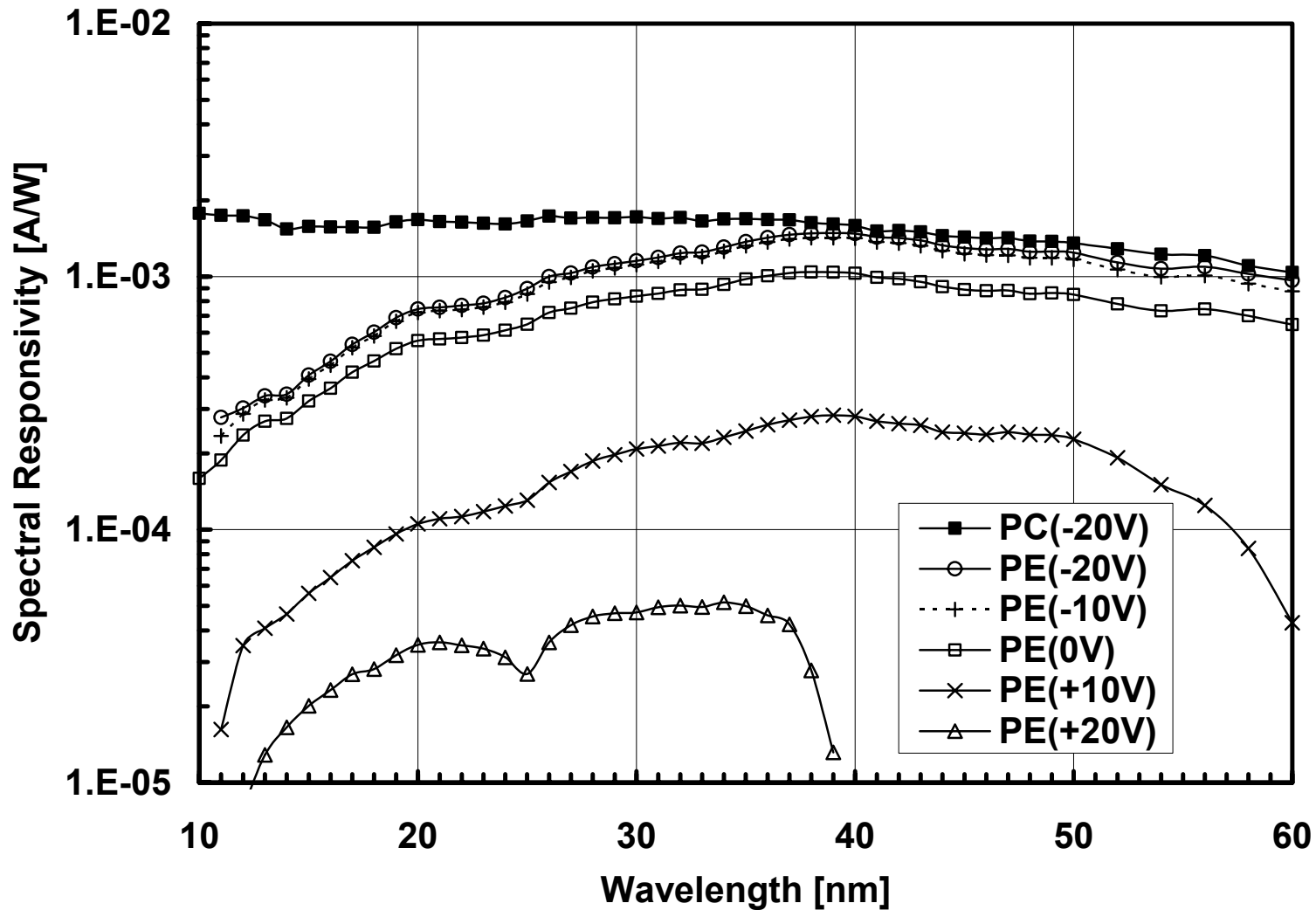
- Durability test & Temporal response

Measurement circuit



Spectral responsivity (10-60 nm)

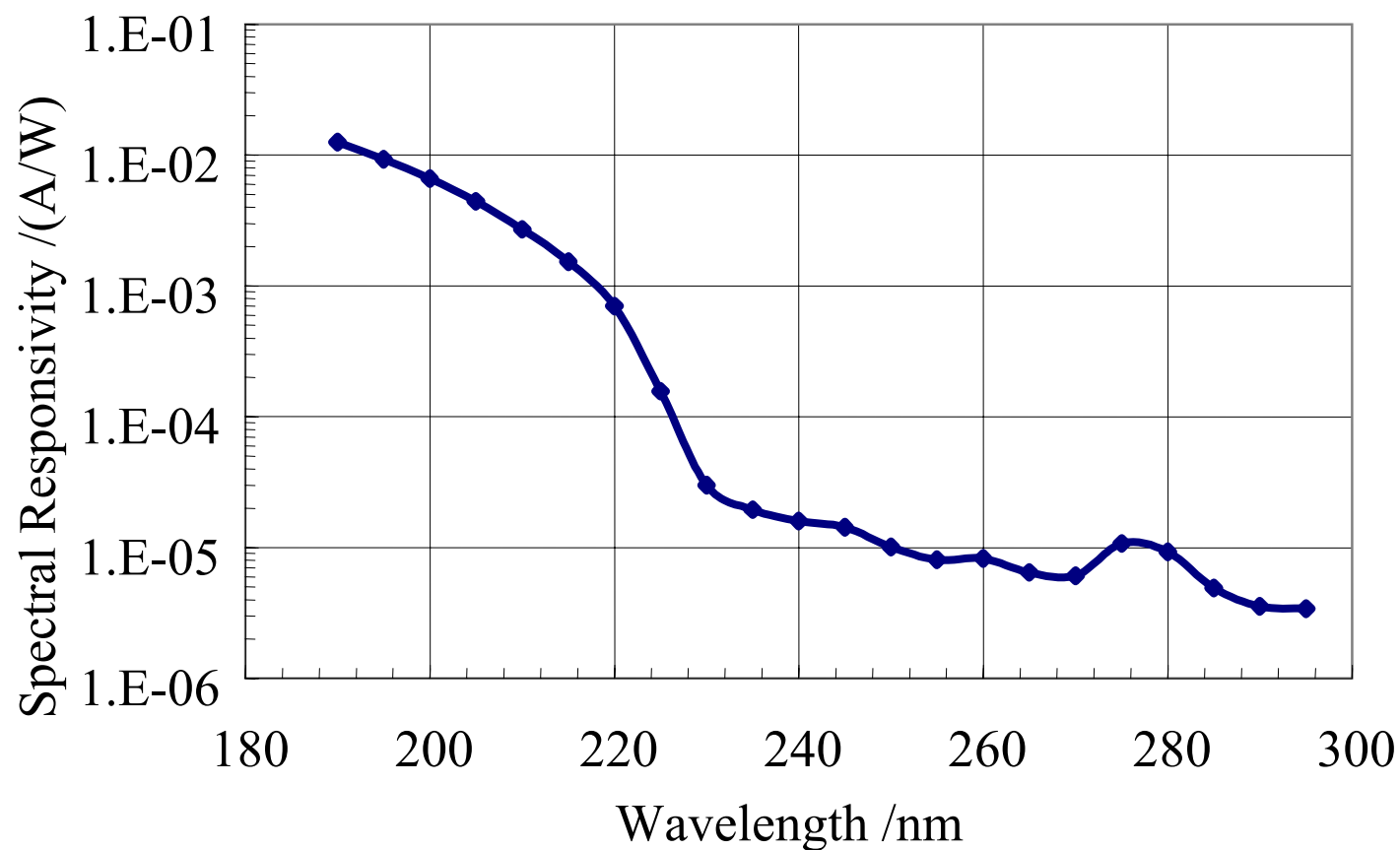
PC: Closed configuration PE: Open configuration



Spectral responsivity (190-295 nm)

Measured in the closed configuration

DiaNo3 +60V



Temporal response

for low output current

13 pA

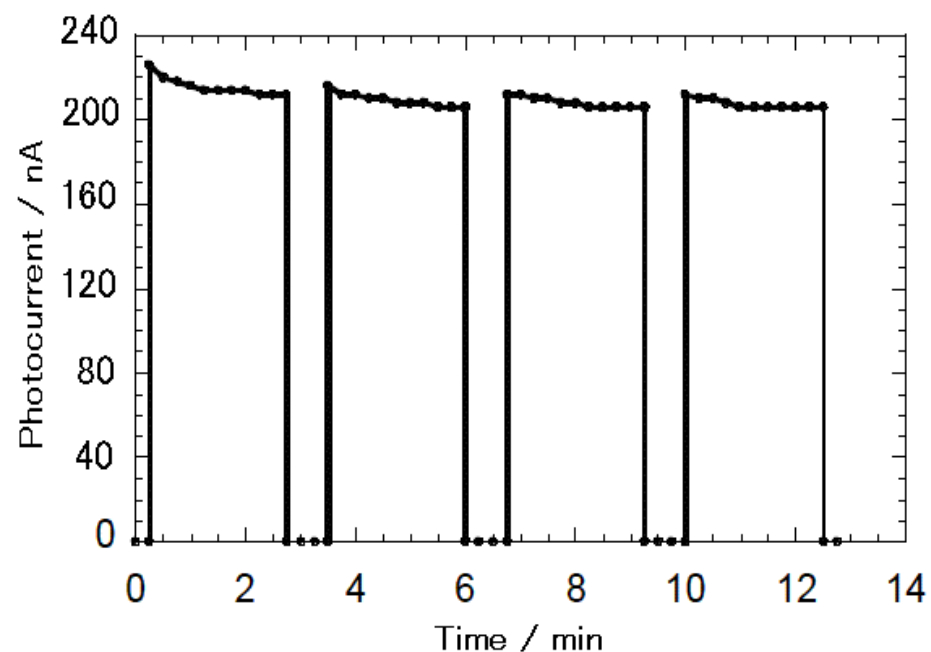
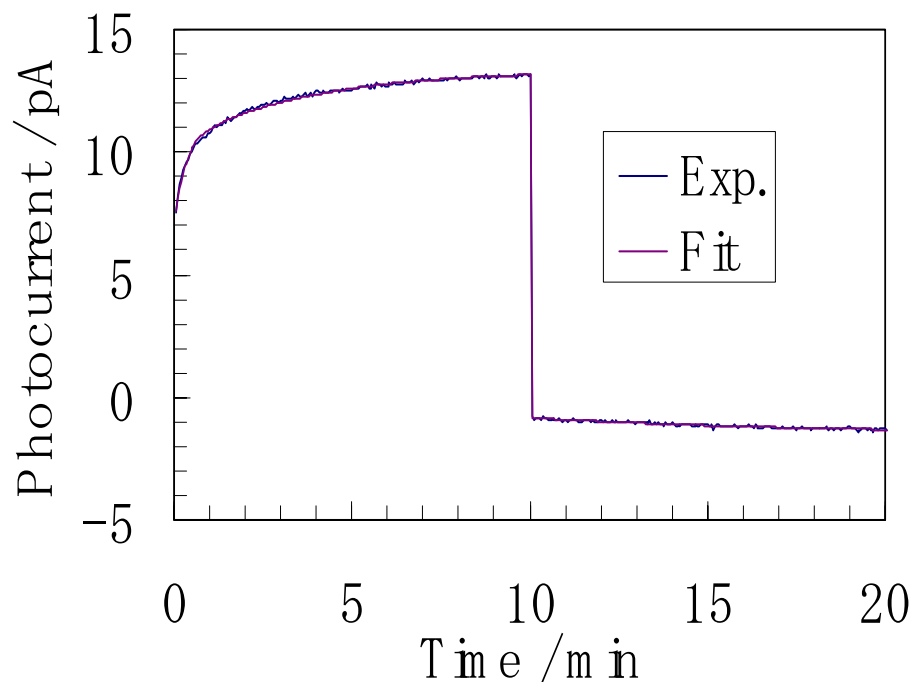
11 nW/cm² at 200 nm

for high output current

200 nA

10 mW/cm² at 172 nm

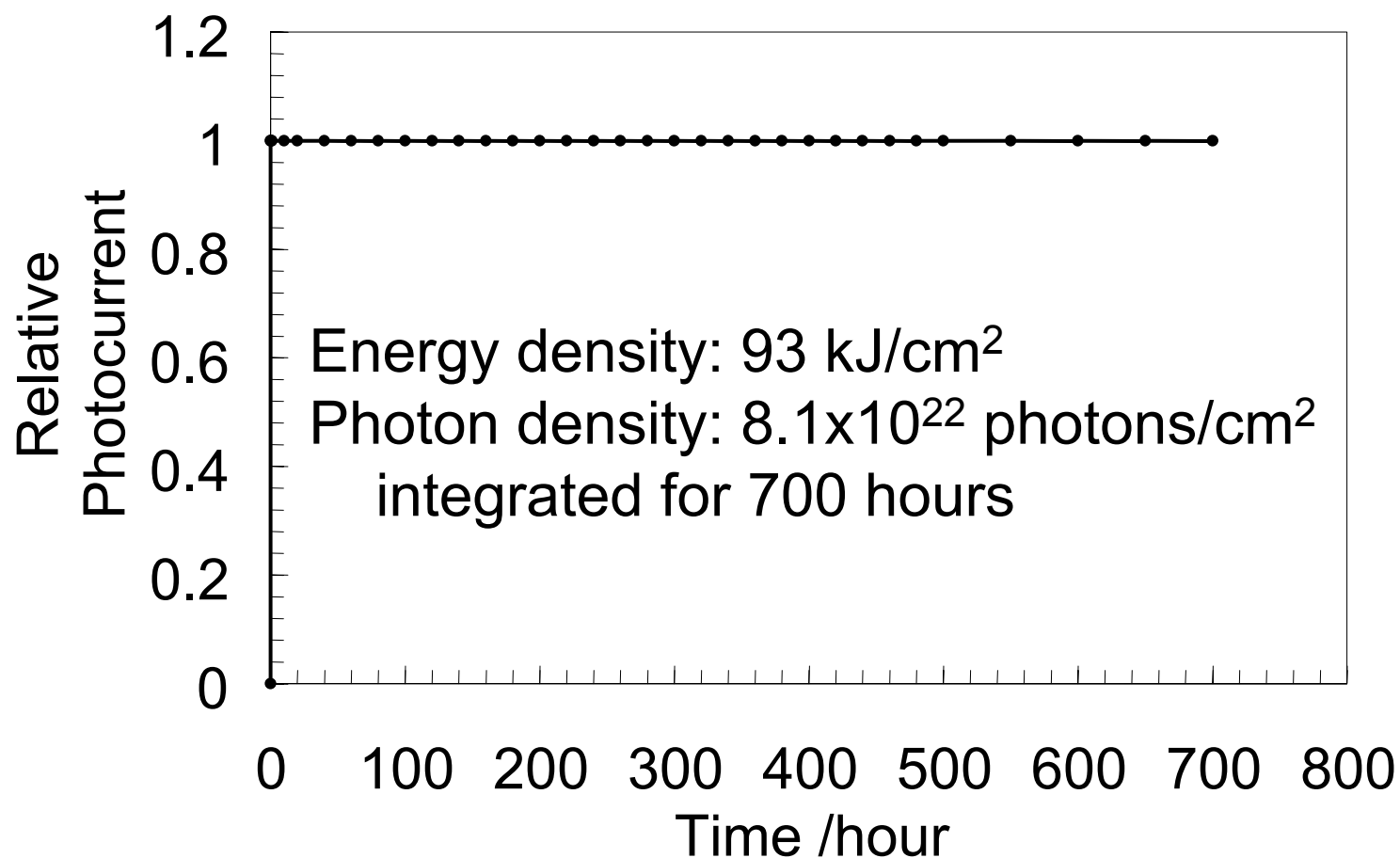
(Xe excimer lamp)



Stability

Exposure test to Xe excimer lamp (172 nm)

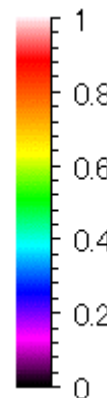
Irradiance: 37 mW/cm²



Spatial Uniformity

Contour interval: 2%
Bias voltage: +60V

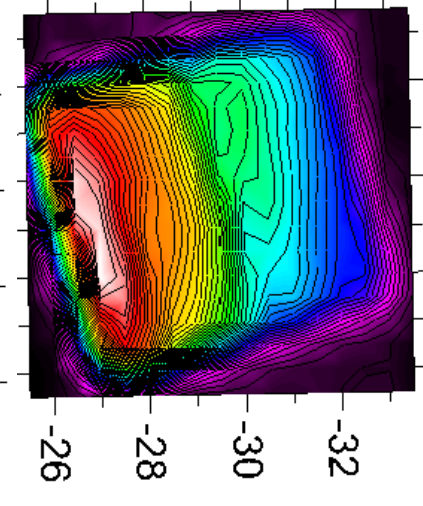
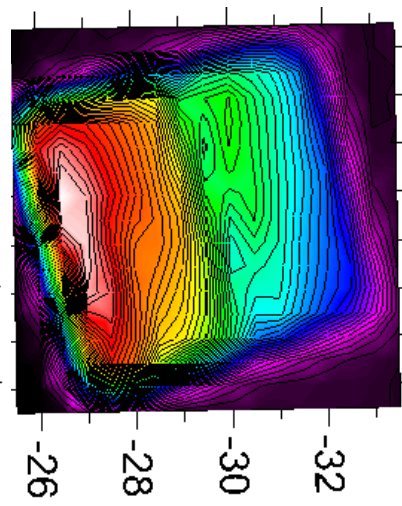
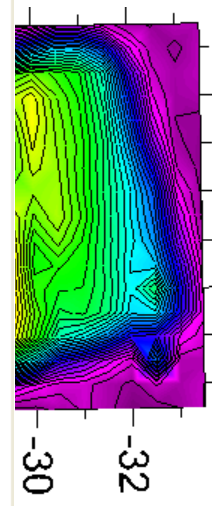
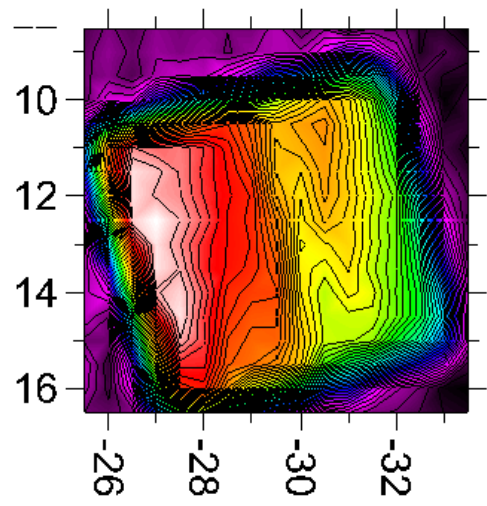
Diamond No.3



200 nm

210 nm

220 nm



Summary

- The diamond detector output was proven to be very stable and reproducible under the intense VUV irradiation (37 mW/cm² at 172 nm by Xe excimer lamp) over 700 hours.
- Faster temporal response was observed for higher photocurrent while a slow rising time was observed for lower photocurrent. The result can be explained by the presence of long-lifetime carrier traps.
- The nonzero spectral responsivity below the band-gap photon energy also supports the presence of long-lifetime carrier traps.

Summary (continued)

- The photoemission current contribution to the total output current can be dominant at least from 40 to 60 nm.
- All the detectors tested showed poor spatial uniformity.
- A strong correlation was found between the average facet size (observed by SEM) and the spatial responsivity. It suggests that the origin of the carrier traps can be attributed to the defects in the grain boundaries.

Conclusion

- The photoconductive diamond detectors, even at the present stage, can be used for radiometric purposes limited for intense and spatially homogeneous radiation.
- Further improvements for better carrier collection efficiency, uniformity and temporal response are necessary for low power measurement by reducing the carrier trap density.