X-UV Diamond detectors for space applications

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Ideal XUV detector for space

- Radiation hardness
- High sensitivity
- Very low noise
- Large area
- Solar blindness
- Chemical inertness

REQUESTS
Its main properties are hereafter summarized:

- $E_g = 5.5$ eV $\rightarrow$ dark current $< 1$ pA
  $\rightarrow$ visible rejection (ratio $10^{-7}$)
  $\rightarrow$ high XUV sensitivity
- Highly radiation hard
- Chemical inertness
- Mechanically robust
- High electric charge mobility $=$ fast response time
- Low dielectric constant $=$ low capacitance

Diamond is an appealing material for XUV photon detection.
Why diamond

Higher performances
No cooling
Less optics & no filters
No coatings
No radiation shielding
Mechanical hardness

Low power
Light system
Long durability
Clean environment

SPACE SYSTEM IMPROVEMENT
Applications

Soft X-Ray Microscopy
Short wavelengths offer spatial resolution near that of an electron microscope, but without the complex sample preparation requirements. Typical range 280-540 eV (water windows).

Soft X-Ray Photoligraphy of semiconductors
Short wavelengths can decrease the feature sizes of integrated circuits relative to optical methods. Soft X-ray detectors can be used to image photomasks, characterize photoresist and sources, and monitor soft X-ray spectra.

Plasma physics
Plasma in tokamaks and other experiments emit soft X-ray flux. Detectors can be used to image or spectroscopically characterize the plasma, including impurities which may contribute to energy transport.

Astronomy from space & XUV spectroscopy
XUV astronomy and synchrotron radiation are new field of investigation. Detectors having highly improved performances are requested to meet their experimental constraints.
Diamond detectors

Coplanar geometry

Sandwich geometry
CVD Poly-Diamond

Diamond layer

Interdigitated electrodes
Diamond imagers

Synchrotron beam profiler

C. Schulze-Briese et al., NIMA 467–468 (2001) 230–234

Laser beam profiler

Electronic structures
Pixel array UV detectors

- Lift-off photolithographic technique
- Al contacts (blocking)
- 20 μm interelectrode spacing
- 70 μm pitch
Dark current

-2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5

Electric field (V/μm)

-10
-5
0
5
10

Current (fA)

-200
-100
0
100
200

Electric Field (V/μm)

scCVD

pCVD

Current (fA)

-200
-100
0
100
200

Electric Field (V/μm)

scCVD

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Titolo e data
VUV external quantum efficiency

\[ \text{EQE} = \eta G \]
Soft-X external quantum efficiency

![Graph of EQE (electrons/photon) vs Energy (eV) for 10 V and 30 V, showing a decrease in EQE with increasing energy.]

![Graph of EQE (electrons/photon) vs Wavelength (nm) for 14 V, showing a peak at approximately 150 nm.]
Soft-X ray responsivity
Soft-X ray responsivity

Responsivity (A/W)

Energy (eV)
Solar blindness

Comparison with other VUV detectors

Diamond trackers

RD42 Collaboration, NIMA 436 (1999) 326-335

RD42 Collaboration, NIMA 434 (1999) 131-145

Particle detectors @ CERN: ATLAS & CMS
Square-pixel devices

Sandwich geometry

A. De Sio, E. Pace, S. Scuderi, Diam. Rel. Mat. 2004
Quantum efficiency

EQE (e⁻ / Photon)

Wavelength (nm)

Single crystal

A. De Sio, E. Pace, R. S. SAussmann, APL, 2005
Time response for scCVD

160 nm

210 nm
EUV electro-optical performance

M. Marinelli, G. Verona-Rinati, A. De Sio, E. Pace, Diam. Rel. Mat. 2005
Bias voltage effect

- 58.4 nm
- 30.4 nm

Dark current

M. Marinelli, G. Verona-Rinati, A. De Sio, E. Pace, Diam. Rel. Mat. 2005
Soft-X performance

M. Marinelli, G. Verona-Rinati, A. De Sio, E. Pace, Diam. Rel. Mat. 2005
Pixel array: cross talk

M. Marinelli, G. Verona-Rinati, A. De Sio, E. Pace, Diam. Rel. Mat. 2005
Conclusions

- Diamond detectors show excellent responsivity, signal-to-noise ratio over a large spectral range.
- Photoconductors have better response than junctions.
- Single crystals are now available and pave the way to transverse geometry, i.e., pixel devices.
- Time response must be improved even if it is already interesting for space applications (mainly astronomy).
- Diamond technology requires further improvements (electric contacts).