Development of imaging arrays for solar UV observations based on wide band-gap materials

Udo Schühle *a, Jean-François Hochedez b, José Luis Pau, Carlos Rivera, Elías Muñoz c, José Alvarez, Jean-Paul Kleider d, Philippe Lemaire *a, Thierry Appourchaux, Bernhard Fleck, Anthony Peacock e, Mathias Richter, Udo Kroth, Alexander Gottwald *a, Marie-Claude Castex f, Alain Deneuville, Pierre Muret *a, Milos Nesladek m, Franck Omnes n, Joachim John, Chris Van Hoof p, Emanuele Pace q

*a Max-Planck-Institut für Aeronomie; b Royal Observatory of Belgium; c Universidad Politécnica de Madrid; d Laboratoire de Génie Electrique de Paris; e Institut d’Astrophysique Spatiale Orsay; f European Space Agency Noordwijk; g Physikalisch-Technische Bundesanstalt Berlin; h Université de Paris-Nord; i Laboratoire d’Etudes des Propriétés Electroniques des Solides CNRS Grenoble; j IMO Institute for Material Research Diepenbeek; k Centre de Recherche sur l’Hétéro-Epitaxie et ses Applications (CRHEA-CNRS) Valbonne; l Interuniversity Microelectronics Ctr. Leuven; m XUVLAB Firenze
Outline of the talk

1. Introduction: Why new detectors?
2. Requirements for new detectors
3. Prospects towards new semiconductor devices
4. Prototype wide band-gap sensors: GaN, AlGaN devices
5. Efficiency measurements with new one-pixel devices
Conclusions of last years talk:

- SOHO UV instruments have been very stable due to the successful cleanliness program.
  
  but

- SOHO UV detectors have been remarkably unstable.

Those were either channel plate devices, or (intensified) CCDs!
MCP detectors

Cross delay line anode + time to digital converter

Cross strip anode + charge ratio centroiding
Anode design options

- Wedge and strip anode
- Cross Delay line anode
- Cross strip anode
- CCD
Example: flatfield of SUMER XDL detector

- Distortion
- ADC nonlinearity
- Multifiber bundles (hexagonal)
- Moire pattern (from 3 MCPs)
- Dead pores

Unstable due to scrubbing!
Intensified CCDs

MCP coupled to CCD via lens or fiber-optic taper

„Ultra Compact Design“
Quest for high resolution

0.5 arcsec
≈ 350 km at Sun
Solar Orbiter mission

High-resolution mission to the Sun and Inner Heliosphere

Payload instrumentation:
- EUV spectrograph
- EUV imagers
- UV coronograph
What are our goals?

- large pixel array
- radiation hard
- smallest pixel size
- high count rate
- sensitive in a huge wavelength range
- solar blind
- stable calibration
- low dark noise

Imaging sensors with high sensitivity and resolution,
Large pixel format but smallest pixel size!
Wide band-gap materials
## Advantages/disadvantages

<table>
<thead>
<tr>
<th>Silicon Detectors</th>
<th>Wide Bandgap Detectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need cooling to -60°C or less (Dark current &amp; radiations)</td>
<td>Room temperature operations (simpler &amp; cost-effective)</td>
</tr>
<tr>
<td>Contaminants stick and polymerize (cold trap)</td>
<td>Low contamination risk, long-term stability</td>
</tr>
<tr>
<td>Degradation of the charge transfer efficiency by ionizing radiation</td>
<td>Rad-hardness</td>
</tr>
<tr>
<td>Cosmic ray hits plague the signal (points &amp; strikes)</td>
<td>Whole mission lifetime increased</td>
</tr>
<tr>
<td>QE insufficient, inhomogeneous, and unstable</td>
<td>Smaller cross-section =&gt; less artifacts</td>
</tr>
<tr>
<td>MCP Intensifiers needed</td>
<td>Higher QE. Stability and flat-field improved</td>
</tr>
<tr>
<td>Minimal pixel size ~10 microns</td>
<td>VUV sensitive</td>
</tr>
<tr>
<td>Most sensitive in visible, filters needed (fragile, absorbing UV)</td>
<td>Visible-Blind</td>
</tr>
<tr>
<td></td>
<td>Some filters can be removed</td>
</tr>
<tr>
<td></td>
<td>Gain in effective area</td>
</tr>
</tbody>
</table>
Al$_x$Ga$_{1-x}$N Photodetector types

Photoconductors

M-S-M Photodiodes

Schottky Photodiodes

$p$-$i$-$n$ Photodiodes

M-I-S Photodiodes
Devices fabricated for tests

MSM GaN device

Schottky GaN device

1x 6 linear micro-array of MSM photodiodes fabricated on AlGaN/Si(111) samples
Single-photodetectors

Metal-semiconductor-metal

- Active areas: 500 x 500 µm²
- 250 x 250 µm²
- 50 x 50 µm²
- 30 x 30 µm²
- Finger widths (Pt/Ti/Au or Ni/Au) and spacings: 2, 4, 7 and 10 µm

Schottky photodiodes

- Extended Ti/Al or Ti/Al/Ti/Au ohmic contact.
- Active areas: 1 mm, 600 µm, 400 µm and 200 µm diameter disks.
- Semitransparent 100 Å-thick Au.
- Ni (300 Å)/ Au (1000 Å) pad.
- Passivation: SiO₂ or SiN.
Solar-blindness of present WBGS detectors

Pau et al. 2003.

Nitride

Diamond

Pace et al. 2000.
Micro-arrays

- Minimum pixel size: 30 x 30 µm².
- Finger widths: 2, 4 and 7 µm.
- Homogeneity studies.
- Pixel-to-pixel cross-talk analysis.
- Image persistence effects.
VUV efficiency of MSM GaN devices

Comparison of device structures

- DC Responsivity (a.u.) vs. Wavelength (nm)
- Finger width

Finger widths: 7 µm, 4 µm, 2 µm
EUV efficiency of GaN Schottky device

- Absolute responsivity measured at the electron storage ring BESSY II
- Compared to a calibrated PtSi reference diode