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

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Abstract. Photoconductive diamond detectors consisting of highly oriented film were characterized in temporal response, spectral responsivity and its spatial uniformity as a candidate of FUV/VUV transfer standard detectors. The results showed that the diamond detectors have a superior stability under 172 nm- irradiation but need to be improved for better carrier collection efficiency, uniformity and temporal response possibly due to photo-carrier traps.

Objectives

As a candidate for transfer standard detectors in the far ultraviolet (FUV) and vacuum ultraviolet region (VUV), we characterize photoconductive diamond detectors in temporal response, spectral response, and spatial uniformity.

Since diamonds are known to have low positive electron affinity or negative electron affinity, we investigate how much photoemission current contributes to the output signal.

Experimental

Devices under test were photoconductive detectors using highly oriented diamond (HOD) films [1-5]. The HOD films consist of azimuthally oriented (001) facets with typical area size of several μm^2 and a thickness of 10 μm. The HOD films were deposited on Si (001) substrates by microwave plasma chemical vapor deposition (CVD). A pair of interdigitated Pt electrodes were fabricated on the HOD film surface. Each electrode stripe was approximately 200-nm thick and 10-μm wide. The gap between the interdigitated electrodes was 30 μm, and the total detector area was approximately 40 mm^2.

Stability of the diamond detectors was tested by monitoring their photocurrent output under the illumination by a xenon excimer lamp whose emission is almost concentrated in the 172 nm-line and irradiance is about 37 mW/cm^2.

The spectral responsivity measurements were carried out in two wavelength regions, 10-60 nm and 190-1000 nm at the NMIJ spectral responsivity calibration facilities based on rare gas ionization chamber[6-7] and electrical substitution radiometer[8] respectively. In addition, uniformity and temporal response were characterized in the latter spectral range.

The VUV system mainly consists of the electron storage ring, TERAS as a synchrotron radiation source, pre-focusing mirror optics, a toroidal grating monochromator, post-focusing mirror optics.

The photocurrents were measured in two electrical circuits to distinguish photoemission contribution as shown in Figure 1. The first circuit is for photocurrent measurement with the switch (indicated by SW) closed (This will be referred to as the PC configuration). The second one is a circuit with the switch opened to measure the photoemission current (This will be referred to as the PE configuration). In the PC configuration, the measured current can contain both, photoemission current and photoconductive current, depending on the applied voltage.

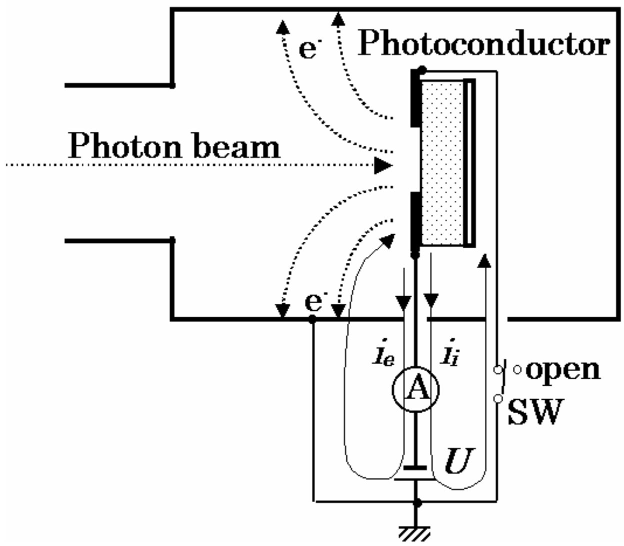

Figure 1. Schematic diagram of measurement configuration. A: electgrometer, SW: switch, *U*: applied voltage, i_i: internal photoconductive current, i_e: external photoemission current.

The longer wavelength (190-1000 nm) system mainly consists of deuterium/halogen lamps and a double grating monochromator and computer-controlled detector stage. Uniformity measurements were performed using a monochromatized beam with the beam spot size of 1 mm and the full-angle divergence of 20 mrad by controlling the lateral position of the detector stage.

Results and Summary

Successful operation of the photoconductive detectors was demonstrated in the VUV region. Detectors, which had been accommodated to industrial use [3], did not show any degradation during 700 hour-irradiation of the intense xenon excimer lamp radiation (37 mW/cm^2 @172 nm) as shown in Figure 2.

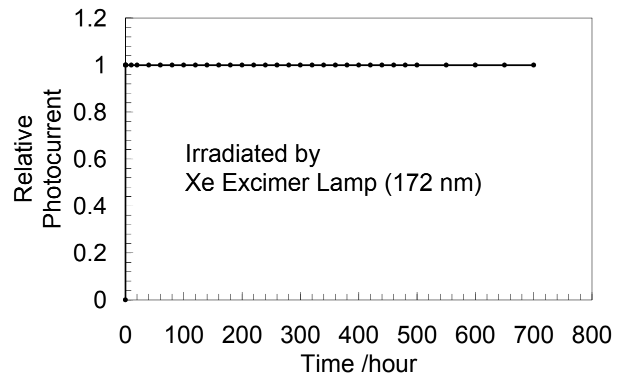

Figure 2. Stability of a diamond photoconductive detector under irradiation by xenon excimer lamp with irradiance level of about 37 mW/cm^2 at 172 nm.

Temporal measurement results for the longer wavelength region (190 – 1000 nm) showed a long time drift of the baseline that was not observed during an intense radiation, implying the presence of deep level carrier traps.

Spectral responsivities of the detectors increased with biasing voltages, but were still below those with perfect carrier collection efficiency and varied from one specimen to another even in the same batch implying the different densities of carrier traps.

All the detectors tested showed a gradual change toward a certain direction in their spatial uniformity, which was found to correlate with the facet size.

In the VUV measurements, photoemission current contribution was observed by comparison using positive and negative applied voltages, or directly (See Figure 3). Spectral responsivity including both (photoconductive and photoemission) current components becomes almost constant in the 10-40 nm wavelength range. The photoemission current contribution to the total output current can be dominant (at least 40-60 nm).

It was concluded that the successful operation throughout the FUV/VUV region and superior radiation hardness against 172 nm radiation were observed but the carrier collection efficiency, temporal response and spatial uniformity of the present detectors should be improved for the radiometric purposes. Optimizing the facet size or the device structure is expected to improve such shortcomings and might give sufficient properties required for FUV/VUV transfer standard detectors considering the proven superior radiation hardness.

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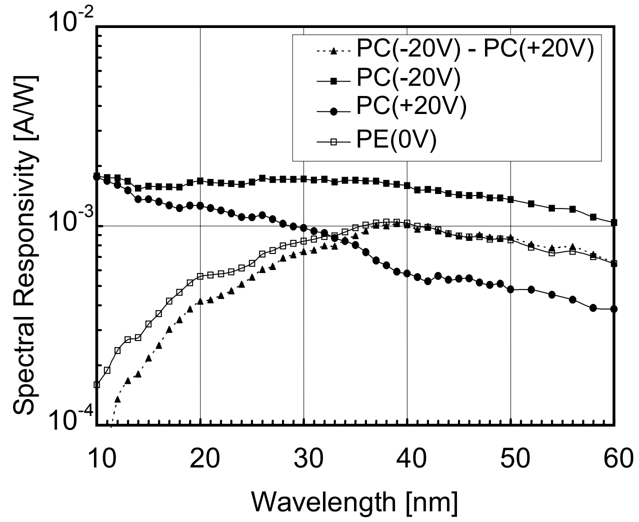

Figure 3. Spectral responsivities in the VUV obtained in the PC configuration. Applied voltages, *U*, are -20 V (filled squares) and +20 V (filled circles). The spectrum obtained in the PE configuration with *U*=0 (open squares) is also shown for comparison with the difference spectrum (filled triangles) subtracting the data for +20 V in the PC configuration from the data for -20 V in the PC configuration.

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