ESRF	**Experiment title:** **Evaluation of CVD diamond detectors as intensity monitors for X-ray spectroscopy applications**	**Experiment number:** MI-380
Beamline:	**Date of experiment:** from: 30/09/99 to: 02/10/99	**Date of report:** 25/02/2000
Shifts: 9	**Local contact(s):** V.A. Solé	*Received at ESRF:* 1 - MAR 2000

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Report:

With the advances in experiments using third generation synchrotron radiation sources, accurate control of the beam has become necessary. Conventional devices based on semiconductor photodetectors exhibit good detection features, but their inherent drawback is the complete absorption of the incoming radiation. Their use is therefore restricted to apparatus calibration, as well as to beam size or position probing experiments. For demanding experiments such as XAFS on ultra dilute samples or polarization dependant X-ray spectroscopy, it is necessary to control the beam instabilities with respect to both position and time. In order to measure the beam without significant attenuation, a low absorption cross section detector is required. Therefore, with the low X-ray energies involved, a low atomic number semiconductor such as diamond will be required. We have fabricated and used such devices, to enable in-situ permanent monitoring in beam lines.

Diamond layers were fabricated using the chemical vapour deposition technique in a microwave plasma from the dissociation of a gaseous precursor mixture consisting of methane diluted in hydrogen. From the films obtained, devices were made that have been used for a range of applications at ESRF, namely :

(*i*) Beam position monitors (BPM) that enable the monitoring of the position fluctuations of the synchrotron X-ray beam position with respect to time. These detectors enable the control and feedback of beamline optics in order to compensate for position displacements. For demanding experiments such as EXAFS, this feature allows real time monitoring of beam instabilities and therefore simultaneous position correction during data acquisition. Position resolutions below 2 µm were readily achieved. They are of considerable interest for experiment instrumentation as well as for beam diagnostics.

(*ii*) Beam profile monitors consisting of an array of parallel detectors with a typical 5 to 15 µm pitch. They enable the measurement of the beam shape and size, and give the intensity distribution across the beam radial axis. They can be used as a tool for optics characterisation or when focused beams are needed. Such devices have been delivered to ID26 for beam metrology.

(*iii*) Diamond sensors were developed to monitor the duration and lifetime of the synchrotron X-ray light source in the 100 ps range to enable the intensity monitoring of each individual pulse and thus give the temporal distribution of the individual X-ray pulses. Furthermore, these detectors exhibit very high radiation hardness and allow measurements to be performed using white beam. Some of these devices were successfully tested on BM5 and ID9, were the structure of the 2/3 filling mode could be directly probed using a diamond detector connected to a fast scope (Fig. 1).

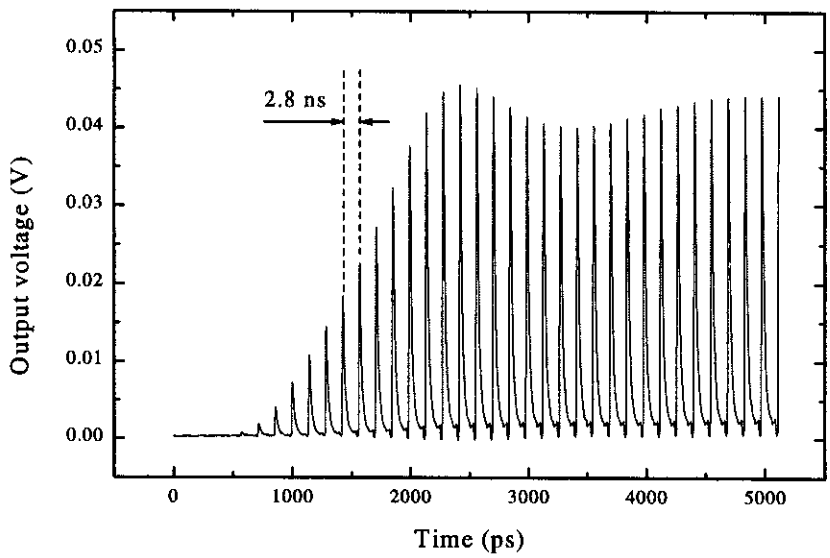

Fig 1 : Initial rise of the invidual track in the multi-bunch mode (2/3 filling) at the ESRF on (measurement performed under white light : mostly 8-20 keV on BM5)

One other feature of great potential is the ability to monitor with high accuracy the intensity of the beam. However, it has been observed that as a high band gap material, deep level defects caused by grain boundaries, vacancies, and/or dislocations result in the variations of the detection sensitivities of the diamond devices with time, temperature, and/or duration of use. This is highly detrimental for diamond in-line devices, and to now has limited their use to multi electrode detectors, where the device geometry enables the compensation of these features.

Recent experimentations have been performed, on ID26 (MI380) and ID21 (MI347) to characterise the defects that are responsible of the detection sensitivity variation. In particular, MI-380 enabled the probing of a range of devices of varying qualities that were manufactured for the purpose of these experiments. The principle of operation of the diamond beam position monitor is shown in fig.2. Electrodes are positioned on both sides of the membrane and an external voltage is applied to produce an electric field in the device. When the photon flux interacts in the diamond, it generates free carriers (electrons and holes) that will drift along the electric field and induce a current in the external circuit. The devices fabricated here consists of 20 µm thick undoped polycrystalline diamond layers. The film was deposited on a silicon substrate which subsequently had the central area (Ø = 8 mm) chemically etched. Electrical gold contacts with a 500 Å thickness were evaporated on both sides to form electrodes. The contact material thicknesses used are too thin to induce any significant attenuation. Fig. 3 shows the difference between two film qualities : it shows the evolution of the current generated in the device as the beam is opened. In the device on the left, it clearly appears that the sensitivity takes several seconds to get stable. This reveals that the detector may not be able to accurately follow the variations of the beam intensity, and therefore that it may lead to a non-linear detection characteristic. On the other hand, the response displayed on the right shows that the device here exhibits a much faster response, and therefore is more likely to satisfy the specifications required for the fabrication of diamond based intensity monitors. The difference between the two film qualities was obtained via the adjustment of the diamond layer growth conditions. The trend observed on the second response has revealed the importance of the growth parameters.

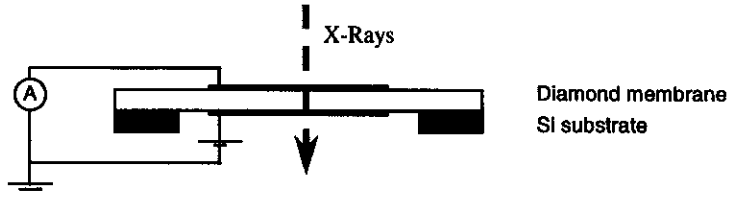

Fig 2 : Design of a diamond intensity monitor

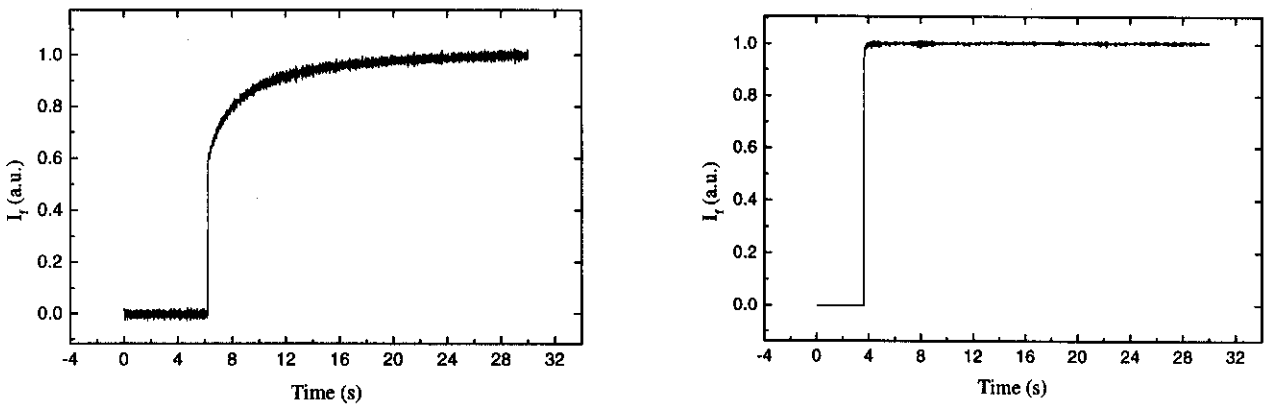

Fig 3 : Initial rise of the measured currents on two intensity monitors.

One other feature that was probed is the effect of the detector bias on the sensitivity. In fact, trapping in extended defect levels is likely to be affected by the electric field in the material. For this purpose, a similar experiment to that presented in Fig. 3 was performed, where the temporal response of a diamond device was probed as a function of the electric field in the material. Indeed, it reveals that at low fields, the temporal response of diamond based intensity monitors is more linear with the beam intensity variations.

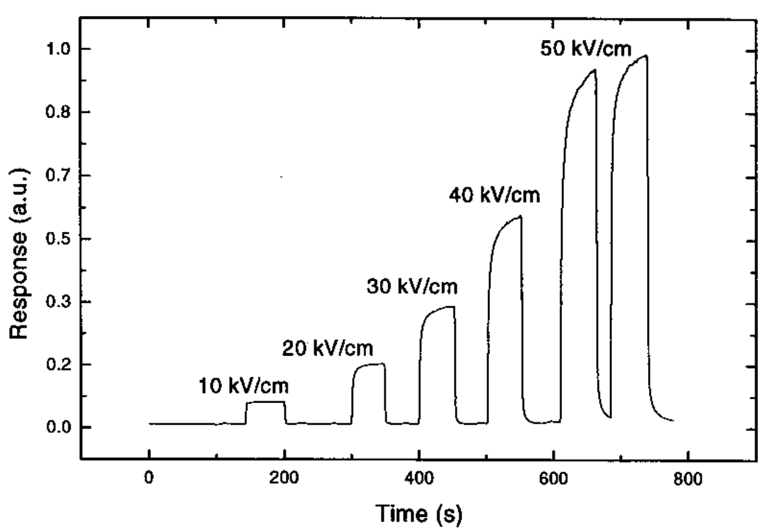

Figure 4 : Effect of the electric field on the sensitivity and on the temporal response

In summary, the experiments MI-380 have enabled the characterisation of a range of diamond detection devices designed for the in-line intensity monitoring of X-ray beam lines. The experiments have revealed that the optimisation of the design geometry as well as of the material property can be of high benefit to the linearity of the response of the detectors.

Publications directly relevant to this work :

Geometrical non uniformities in the sensitivity of polycrystalline diamond radiation detectors
Tromson-D, Brambilla-A, Foulon-F, Mer-C, Guizard-B, Bergonzo-P, R. Barrett*, to be submitted to Diamond and Rel. Materials.

Diamond in-line monitors for demanding synchrotron experiments.
Bergonzo-P., Tromson-D, Brambilla-A, Mer-C, Guizard-B, Foulon-F,
MRS FALL meeting 99 proceedings, in press

Diamond as a tool for synchrotron radiation monitoring : beam position, profile, and temporal distribution.
Bergonzo-P, Brambilla-A, Tromson-D, Mer-C, Hordequin-C, Guizard-B, Foulon-F, Solé-VA*, Gauthier-C*
To be published in Diamond and Related Materials (+ Proc Diamond'99, Prague)

Diamond devices as characterisation tools for novel photon sources
Bergonzo-P, Brambilla-A, Tromson-D, Mer-C, Guizard-B ,Foulon-F
To be published in Applied Surf. Sciences (+ proc E-MRS 1999, Strasbourg)

Semitransparent CVD diamond detectors for in situ synchrotron radiation beam monitoring
Bergonzo-P; Brambilla-A; Tromson-D; Marshall-RD; Jany-C; Foulon-F; Gauthier-C*; Sole-VA*; Rogalev-A*; Goulon-J*
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Diamond-based semi-transparent beam-position monitor for synchrotron radiation applications
Bergonzo-P; Brambilla-A; Tromson-D; Marshall-RD; Jany-C; Foulon-F; Gauthier-C*; Sole-VA*; Rogalev-A*; Goulon-J*
Journal-of-Synchrotron-Radiation. vol.6, pt.1; 1 Jan. 1999; p.1-5
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