Nearly as good as water

True Innovation
First synthetic diamond for dosimetry

microDiamond

Synthetic Diamond Detector for High-Precision Dosimetry

PTW

microDiamond

A matter of technology:

Stable as a diamond, sensitive as a diode

As a synthetic diamond detector, which is reproducibly manufactured in a new, innovative production process, microDiamond combines the advantages of natural diamond detectors and silicon diode detectors almost perfectly.

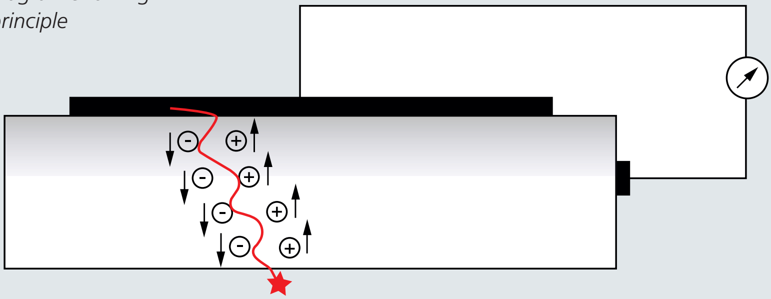
How it works

A Schottky diode develops below the top contact. The incident radiation generates positive and negative charge carriers. These are separated by the field of the diode, thereby producing a signal current that can be measured with an electrometer. No external bias voltage is required; the microDiamond detector can (and should) be operated at 0 V.

Highlights

- First commercially available synthetic single crystal diamond detector worldwide for radiation dosimetry applications
- Very small sensitive volume (0.004 mm³) – perfect choice for small field dosimetry for photon, electron, proton and carbon ion beams
- Suitable for all field sizes up to 40 cm x 40 cm
- Excellent radiation hardness, very low temperature, energy and directional dependence compared to commonly used silicon diode detectors
- Near-tissue equivalence
- No high voltage required. Suitable for all connecting systems.

Simplified diagram showing operating principle



Superior dosimetric characteristics

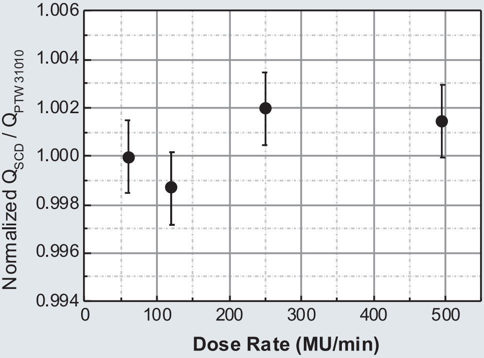


Fig. 1* Pulse repetition frequency dependence in electron beams

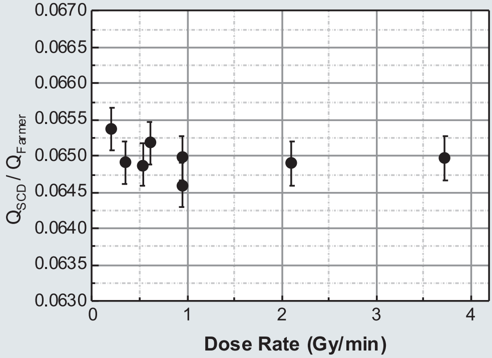


Fig. 2* Dose-per-pulse dependence in photon beams

Minimal dose-rate and dose-per-pulse dependence

The dose rate can be varied by either changing the dose per pulse or pulse repetition frequency of a linear accelerator. When measuring PDDs and profiles, the dose per pulse changes. Varying the dose rate of the LINAC changes only the pulse repetition frequency in most cases.

The microDiamond detector shows both a very small dose-per-pulse dependence (Fig. 2) and almost no dependence of the pulse repetition frequency (Fig. 1) and continuous dose rate (^{60}Co, data not shown).

Excellent spatial resolution

With its excellent spatial resolution, the microDiamond detector makes it possible to accurately measure profiles in very small fields as well as the penumbra region (Fig. 3).

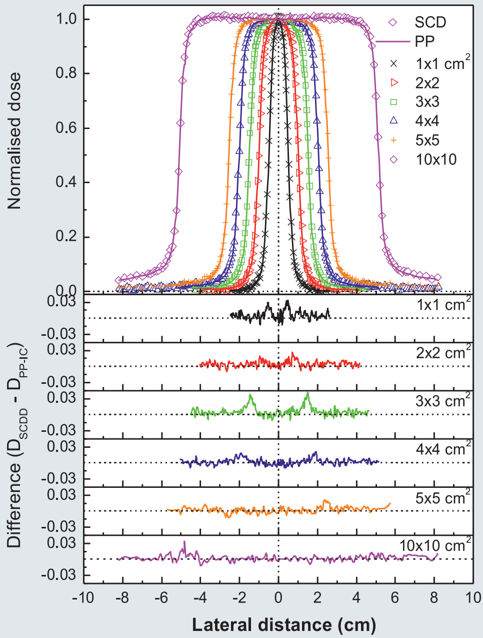
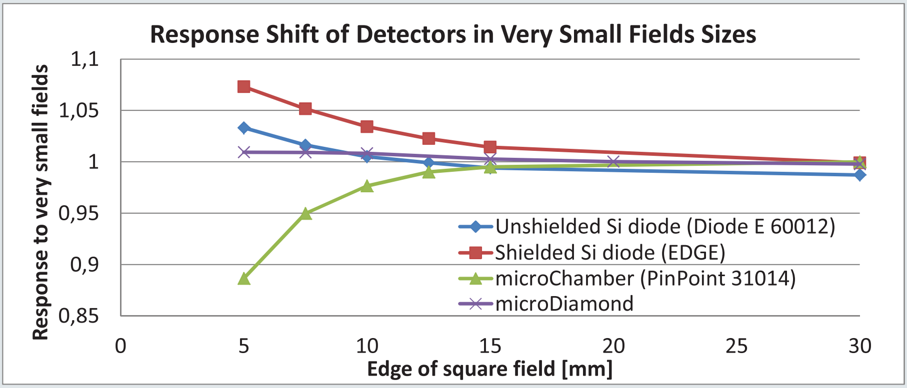


Fig. 3* Excellent agreement: Comparison of profiles measured with PTW PinPoint ionization chamber 31014 (PP) and microDiamond (SCD)

**Fig. 1 – 3 from: M. Marinelli et al., Dosimetric characterization of synthetic single crystal diamond diodes for radiotherapy application, ESTRO Forum 2013, Geneva*

Perfect choice for small field dosimetry

	microDiamond	Silicon diode detectors
Radiation hardness	Extremely resistant to radiation damage = long-term stable	Sensitive to radiation damage = unstable, reduced lifetime
Spatial resolution	High: 4 mm^2 active measurement area	Very high: 1 mm^2 active measurement area
Active volume	0.004 mm^3	0.017 … 0.25 mm^3
Thickness of volume	Extremely small: 0.001 mm	Small: 0.03 … 0.25 mm
Radiation quality	Photons and electrons in small and large fields – only one detector required	In large fields shielded diodes for photons, unshielded for electrons – two detectors required
Temperature dependence	Very low: $\leq$ 0.08 % / K	Higher than diamond: 0.3 … 0.6 % / K
Directional dependence	Very low: $\leq$ 1 % for ±40°	Significantly higher
Energy dependence	Very low	Very high in keV range, higher than diamond in MeV range
Dose-rate dependence	Very low (see Fig. 1, 2)	Often show dose-rate dependence
Field-size dependence	Up to 40 cm x 40 cm for photons	Without shielding up to 10 cm x 10 cm, with shielding up to 20 cm x 20 cm (SNC EDGE) or up to 40 cm x 40 cm (IBA PFD, PTW Diode P)
Response shift in very small fields	Very low	Higher (see fig. below)



Minimum deviations in extremely small fields

Compared to other detectors used in small field dosimetry, microDiamond only shows a very small deviation of absorbed dose to water even in the smallest field sizes starting from 0.5 cm x 0.5 cm thanks to its special material and design properties.

Detector comparison based on measurements and Monte Carlo simulations taken from P. Francescon et al, Med. Phys. ***38*** *(2011), 6513, and I.J. Das et al., Experimental Determination of k Factor in Small Field Dosimetry, Talk at AAPM, Austin, 2014*

Specifications

microDiamond
Type 60019

Detector type:	synthetic single crystal diamond detector (SCDD)
Design:	waterproof, disc-shaped, sensitive volume perpendicular to detector axis
Measuring quantity:	absorbed dose to water
Nominal sensitive volume:	0.004 mm^3, radius 1.1 mm, thickness 1 µm
Direction of incidence:	axial
Pre-irradiation dose:	5 Gy
Nominal response:	1 nC/Gy
Dose stability:	$<$ 0.25 % / kGy at 18 MV
Temperature response:	$\leq$ 0.08 % / K
Energy response:	$\leq \pm$ 13 % (100 keV … ^{60}Co)
Directional response:	$\leq$ 1 % for tilting $\leq \pm$ 40°
Detector bias:	0 V
Entrance window:	0.3 mm RW3, 0.6 mm Epoxy, 0.01 mm Al 99.5
Water-equivalent window thickness:	1.0 mm
Dimensions:	diameter 7 mm, length 45.5 mm
Radiation quality:	100 keV … 25 MV photons, (6 … 25) MeV electrons, (70 … 230) MeV protons, (115 … 380) MeV/u carbon ions
Field size*:	(1 x 1) cm^2 … (40 x 40) cm^2
Connecting systems:	BNT, TNC, M

The microDiamond detector was developed in cooperation with Marco Marinelli, Gianluca Verona-Rinati and their team at the Industrial Engineering Department of Rome Tor Vergata University, Italy.

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* *The microDiamond detector is well suited for measurements in field sizes smaller than 1 cm x 1 cm. Depending on the accuracy required by the user, correction factors may be required as described in international scientific literature. This applies to any detector used in very small fields.*

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Knowing what responsibility means