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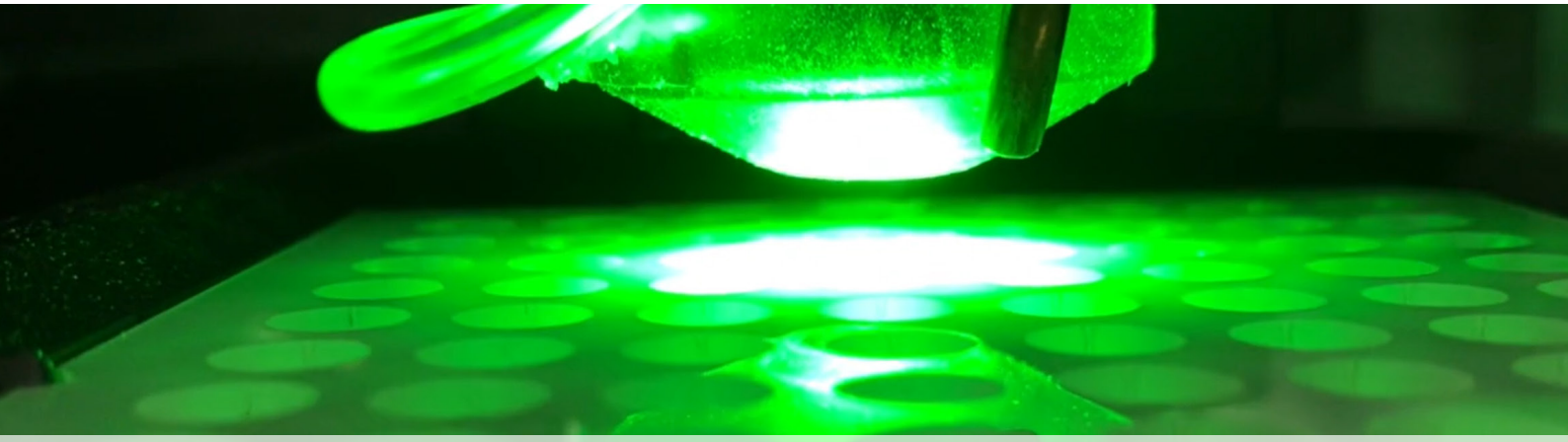
QDTI



## Quantum diamond biomarker detection

# Targeting simpler, faster and ultrasensitive medical diagnostics

A successful research collaboration between Element Six and Harvard University's spin out, Quantum Diamond Technologies Inc, aims to disrupt the medical diagnostic market by revolutionising the early detection and treatment of diseases.

"The relationship with Element Six pre-dates the foundation of QDTI. What we are trying to do wouldn't be possible without CVD diamond solutions with engineered spin centres and Element Six's desire to commercialise this groundbreaking concept."

John Pena, CEO, QDTI

**Customer: Quantum Diamond Technologies Inc (QDTI)**
Massachusetts, USA

QDTI is a start-up founded by researchers from Harvard University with the aim of leveraging the powerful properties of quantum spins in diamond to significantly improve the early detection of diseases. A close and long-standing collaboration with Element Six has been integral to the development of QDTI's technology, which relies on a multilayer diamond material solution powered by nitrogen vacancy (NV) centres for enhanced sensing.

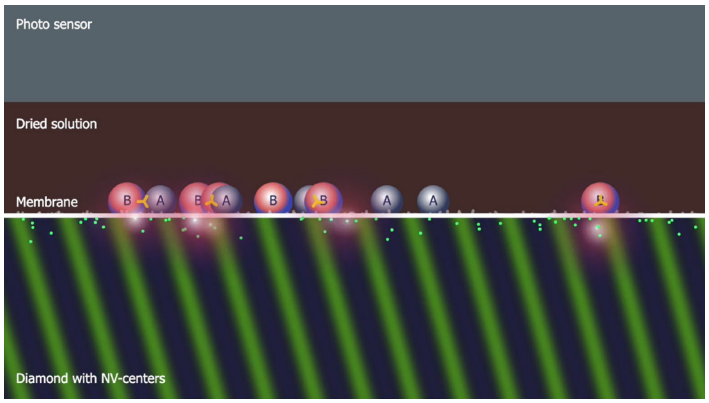
QDTI's goal is to deliver a very simple-to-use, rapid, point-of-care diagnostics platform to enhance patient care for medical conditions such as heart disease, Alzheimer's disease, and cancer. Patient outcomes greatly benefit from the detection of disease-specific biomarker molecules at an early stage. Based in Massachusetts, USA, the company has, amongst other sources, secured funding from DARPA, the Michael J. Fox Foundation and the Bill & Melinda Gates Foundation and is currently working with pharmaceutical companies in the biomedical research and development testing space.

## **The opportunity:** Early disease detection

For many diseases, early detection is vital to enabling effective treatment programs and improving patient outcomes. Fortunately, early disease detection and diagnosis can be achieved through the measurement of biomarkers such as proteins, nucleic acids and cells in a blood or saliva sample from the patient. The industry standard to measure these biomarkers is to bind the analyte of interest with a tag, such as a florescent marker, or an enzyme that acts upon the addition of a substrate to reveal a colorimetric signal. The concentration of the disease biomarker in the blood, for example, is determined by comparing the optical signal intensity against a standard curve. Such analogue measurements, while not sensitive at the single-molecule level, have nevertheless been versatile and robust enough to support a global testing market worth well over $25B annually.

## **The challenge:** The need for a simpler, more accurate detection method

Ultrasensitive protein detection methods are required to detect several diseases or disorders, such as heart conditions, as early and accurately as possible. However, immunoassays with florescent or colorimetric tags suffer from unwanted background due to auto-florescence from extraneous biomolecules or reagents, which can limit the sensitivity of the immunoassay. A lengthy sample processing procedure is therefore necessary to remove the background before accurate measurements can be made. The required sample processing directly translates into longer time to results for patients.




Imaging platform: NV centres provide magnetic field map image

## **The solution:** Diamond nitrogen vacancy (DNV™) magnetometry

QDTI is able to harness the unique properties of DNVs by labelling the target biomarker in a patient's sample with a magnetic tag, rather than a florescent or colorimetric tag. Once this step is complete, the quantum diamond solution allows for direct, digital quantification of labelled targets through magnetic imaging of the now-tagged disease biomarker on the diamond surface. This provides high resolution and allows for the elimination of cumbersome sample processing steps. By optimizing the concentration and placement of the NV centres in the diamond, QDTI has demonstrated single-event spatial resolution with wide-field DNV™ magnetic microscopy over a field-of-view of ~1 $mm^2$. This enables ultrasensitive protein quantification in under an hour, in contrast to the many hours required by commercial platforms in the research market segment.

Thanks to QDTI's innovation, combined with Element Six's diamond manufacturing and modification expertise, new, simpler methodologies for isolating and counting key biomarkers at high sensitivity are now feasible, in smaller hardware systems with improved time to results. QDTI estimates that its platform could lead to at least a 90% reduction in technician hands-on time as well as greatly reducing the volume of reagents and disposables required for processing the patient's sample. The resulting benefit will be faster diagnosis times for patients at significantly lower cost, as well as a more environment-friendly product.

Leveraging its successful collaboration with Element Six, QDTI is currently developing a new commercial immunoassay detection system powered by Element Six's NV centre-enriched diamond, coupled with high value immunoassays. The product will initially target the biomedical and research markets, with the objective of a commercial launch by the end of 2021. Element Six and QDTI are also currently exploring methods to refine the NV performance and manufacturability to further reduce the protein quantification time.

"When your technology is as disruptive as ours, you need someone you can trust to support you and help solve your technical challenges. Element Six has been that partner for us. Their NV centres in high purity diamond are the workhorse of QDTI's technology."

**John Pena, CEO, QDTI**

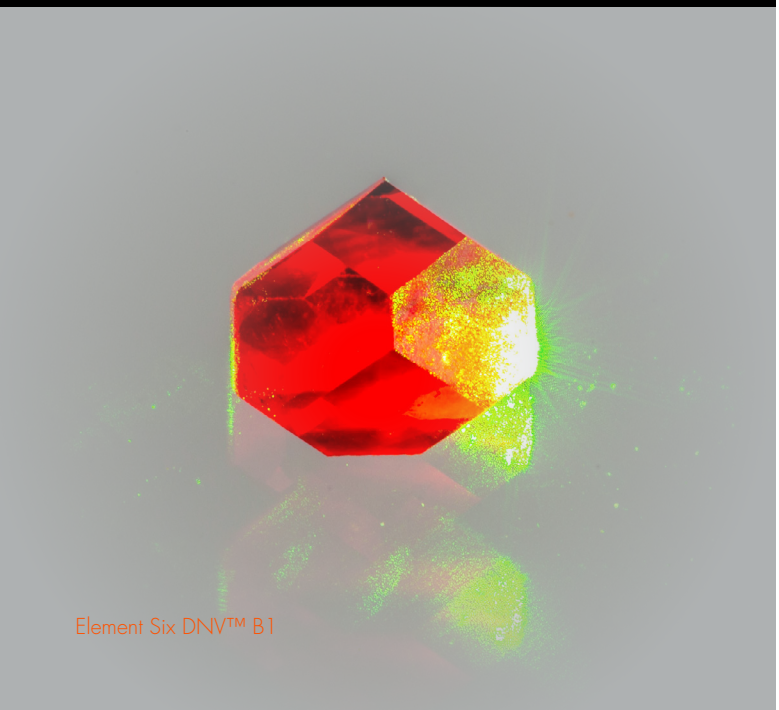
## Why diamond

Diamond nitrogen vacancy (DNV™) magnetometry surpasses all other technologies for high-throughput, high-resolution imaging of microscopic magnetic signals. CVD-grown diamond sensors can image millimeter-scale areas with sub-micrometer resolution and exceptional sensitivity, collecting data from millions of pixels simultaneously in a few seconds. Unlike conventional magnetometry methods, there is no need to scan a probe over each pixel, manage electrical connections to many sensors, or operate under vacuum or extremely low temperatures. Instead, the entire image is read out at once through light, using a compact, room-temperature device. This imaging technology enables QDTI to directly pinpoint magnetic tags corresponding to individual protein molecules.

## What is a nitrogen vacancy (NV) centre?

A series of pioneering studies in the 2000's demonstrated that the electronic spin associated with a nitrogen vacancy centre can be manipulated and read out at room temperature using simple optical techniques. Synthetic diamond, manufactured by the chemical vapour deposition (CVD) method, allows for these quantum defects to be introduced into the material with a high degree of precision and performance.

NV centres are created by removing two adjacent carbon atoms from the diamond crystal structure and replacing one of them with a nitrogen atom, leaving a gap or vacancy next to it. The NV has an electronic spin that is highly sensitive to magnetic fields, forming the basis for sensitive magnetometry. The electronic spin can be detected and aligned simply by shining a green light onto the NV centre and measuring the intensity of red light emitted, making the platform incredibly powerful.



Element Six DNV™ B1


QDTI benchtop immunoassay detection instrument

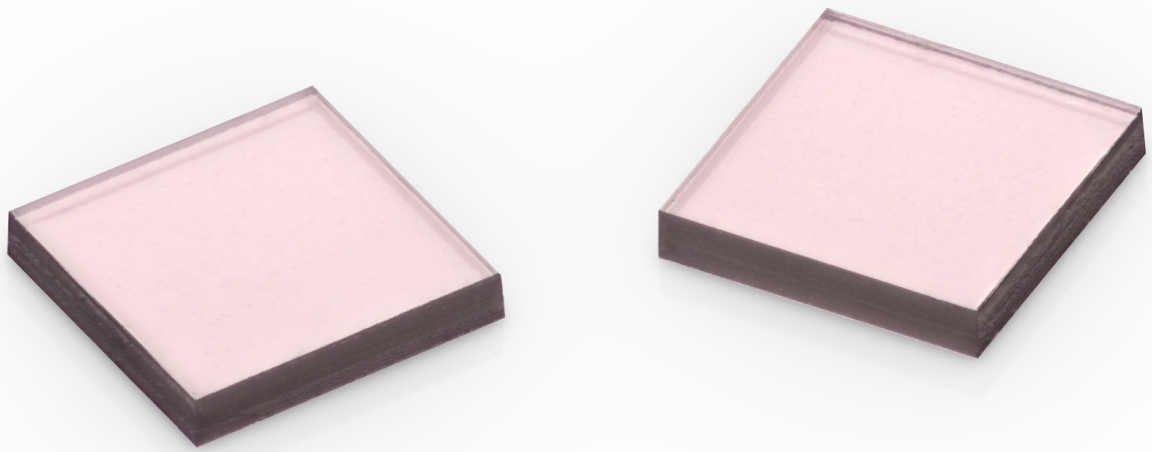
## The future: Point-of-care diagnosis

QDTI's ultimate focus is on patient diagnosis at the point-of-care. Because diamond NV magnetometry can be conducted at room temperature, QDTI is confident that, with Element Six's support, it can produce a smaller and more compact cartridge-based device. This new solution won't require an experienced professional to operate and is set to open up a range of possibilities for clinical and even at-home testing. The first prototypes of this device are expected to be ready for testing by 2023.

Moreover, the next generation of DNV™ magnetometry tests may be able to identify marker proteins for neurological conditions, inflammation and concussion. Another avenue of development is the detection of nucleic acid markers for cancer and infectious diseases.

"We are in awe of QDTI's ability to tackle incredibly complex and important problems and, each time, find a solution. To see their units being already used in real benchmark tests is a testament to how much they have achieved in a short amount of time."

**Daniel Twitchen**
**Chief Technologist, Element Six**



Element Six's DNV™ B1 – the first commercially-available, general-purpose quantum grade diamond

## About Element Six

Part of De Beers Group, Element Six is a pioneering manufacturer and supplier of diamond synthesised to contain NV centres using the CVD method. Working with researchers and commercial companies around the world, Element Six has developed, manufactured and supplied quantum grade diamond used in many of the most exciting recent breakthroughs in quantum technology.

Read more about diamond quantum applications here.

## About Quantum Diamond Technologies Inc

Quantum Diamond Technologies Incorporated (QDTI), a privately held company based in Somerville, Massachusetts, USA was started to exploit quantum systems intelligently engineered into the diamond crystal – called nitrogen vacancy (NV) centres – based on world-leading research at Harvard University. QDTI is using the NV technology to build a quantum sensor capability with the potential to disrupt the biomedical detection and medical diagnostics fields. They are developing simple-to-use, rapid and highly sensitive diagnostics for the biomedical research, central lab and point-of-care market segments.

## For more information about Element Six CVD single crystal diamond solutions please contact:

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## Further reading


1. The diamond quantum revolution - M Markham & DJ Twitchen, 2020, PhysicsWorld
2. Synthetic diamond – secret facets for endless possibilities - DJ Twitchen & G Sciarrone, 2021, Nature
3. Single cell magnetic detection using a quantum diamond microscope - DR Glenn et al, 2015, Nature Methods
4. Optical magnetic imaging of living cells - D Le Sage et al, 2013, Nature