Project completion summary

Adapting doped diamond to capture solar energy

Project details

Title	Lithiated nanoparticle diamond energy converter
EIC Portfolio	Renewables
Program	International Research Initiative
Participant	University of Bristol, UK
Location	UK

Opportunity

Finding more efficient methods of harvesting renewable energy to realize greater carbon reductions and improve energy security is a key energy research goal. Advances in materials research are at the heart of technologies being developed for harvesting solar power.

Advanced nanodiamond materials promise efficient and highly emissive thermionic surfaces – central to the design of highly efficient heat-to-electrical power conversion devices.

In the Concentrated Solar Power (CSP) market this new technology could be offered as a cheaper alternative to conventional high efficiency photovoltaic panels for industrial and domestic use. For utility scale applications it could be installed alongside, or integrated into conventional solar thermal plant to improve system efficiency.

Project aims

The project aimed to demonstrate a nanodiamond-based solar energy converter that exhibits performance at much lower temperatures than those quoted for conventional metal-based converters.

A thermionic energy converter would make use of special electrodes comprising semiconducting nanocrystals of doped diamond made from low cost, readily-available industrial diamond powder. A lithium–oxygen surface is carefully constructed on the doped diamond to facilitate thermionic emission from the cathode to the collector.

As the system operates at a higher temperature than conventional PV, it should be more efficient, and since the thermionic device uses concentrated solar energy, then a smaller area of 'thermionic' material will be required than standard PV. The thermionic device should therefore be cheaper than standard PV.

The resulting solar-powered device would have no high speed moving parts or high temperature fluids, would have low maintenance and be able to deliver reliable electricity production over a long service life.

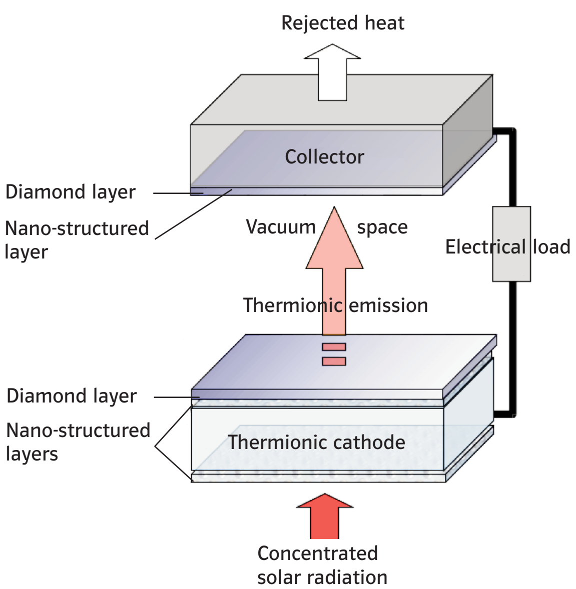
Scope of work

Work was divided into five areas of activity:

- Synthesis of semiconducting nanodiamond material, using an innovative method to apply single atomic layers of lithium and oxygen on the diamond crystal surfaces.
- Characterization and manipulation of semiconducting nanoparticles to form electronically active structures.

  A key piece of equipment to perform surface analysis of the diamond crystals – an ultra-high vacuum scanning probe microscope – was supplied by E.ON.
- Computer modeling of the converter device, simulating various design configurations.
- Developing a set of manufacturing techniques for fabricating vacuum-sealed converter assemblies and the application of coatings on the nanostructures.
- Power testing of prototype converters with diodes in a range of diameters, performance being measured against the best conventional technology.

  Prototype development sought to migrate promising components to a form which would be compatible with commercially available CSP systems.



Schematic of solar energy converter using nanodiamond layers. Solar energy is concentrated onto the energy converter and an electric current is produced by emission of electrons from a hot cathode.

Key findings

The project successfully created a stable lithium-oxygen surface on nanodiamond crystals with the type of characteristics required for a thermionic device to convert solar energy into electricity. The surface was easy to create and towards the higher end of temperature stability expectations.

The lithiated diamond electrodes will operate at temperatures as low as 550 – 750°C compared with the conventional metal-based devices which are designed to operate at temperatures well above 1,500°C.

To develop the novel electrodes, the project team innovated a method allowing a single atomic layer of lithium to be constructed on diamond surfaces.

It was discovered that the reactive lithium atoms are stabilized on the diamond by oxygen atoms, imparting 'remarkable' performance at elevated temperatures.

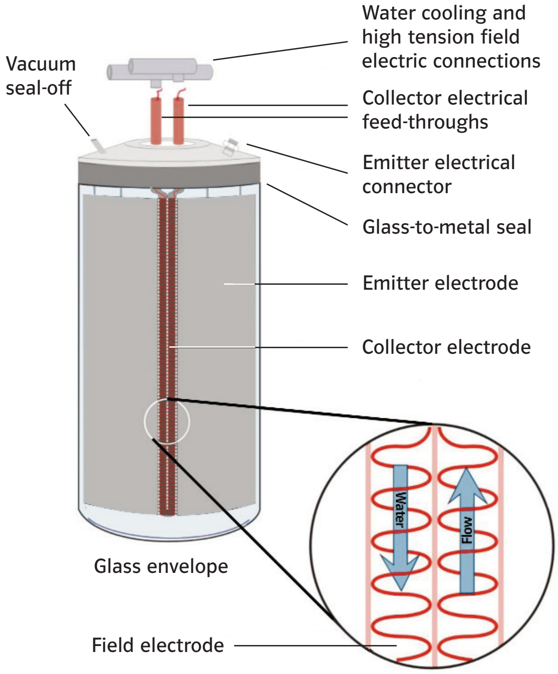
The diamond surface produced a larger-than-expected electron current when exposed to ultra violet light. The 'electron yield' was significantly larger than diamond surfaces created previously with hydrogen termination.

The breakthrough was made while analyzing the response of lithiated diamond surfaces to irradiation by ultra violet and X-ray sources.

This result is technologically important for radiation energy conversion devices, such as thermionic converters, where the low work function and high electron yield will significantly boost the performance.

Radiation detectors employing lithiated diamond are also expected to exhibit improved sensitivity and response time. A US patent application was filed describing this technique and its potential uses.

Solar test rig incorporating 1.5m diameter solar concentrator dish to test nanodiamond converters and two PV panels to provide benchmark data.



The research team's patented design for a compact Thermionic Diamond Converter which aims to improve efficiency, lower fabrication costs and increase power density.

Conclusion

Application and benefits to E.ON

The research team concluded that the lithiated diamond surface is excellent for thermionic devices, boosting the feasibility of thermionic energy convertors providing renewable energy in the future.

Knowledge gained from the work will also benefit research in other fields which require high performance radiation detectors, and high brightness electron and plasma sources.

However, the project's doped diamond electrodes have a high electrical resistance which significantly reduces any thermionic current developed. This poses a significant risk for any future work in this area since so far it has proved difficult to improve the conductivity of the diamond.

Whilst the lithium-oxygen surface is very good, at present there is evidence that the current process only results in about 60 percent coverage of the diamond.

Next steps

To produce an economically viable, high efficiency thermionic converter using the diamond surface developed by this project, a further phase of materials research and development would be required to reduce the resistance of the doped diamond. The university team has drawn up proposals for this research, but no further work is planned by E.ON.