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VIEWPOINT

Heteroisomeric diode—a solid state neutron detector

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What is a heteroisomeric diode and why is it so interesting? A heteroisomeric diode is neither a heterojunction diode (a junction formed from two dissimilar semiconducting materials) or a homojunction diode (a junction made from the same material, but doped to create n- and p-type materials). A heteroisomeric diode is constructed of the same material, in this case boron carbide, yet does not require doping to create the diode. Caruso and co-workers [1] have developed a technique for constructing boron carbide heteroisomeric diodes. What truly makes this an exciting development is that this all boron carbide diode is also a solid state neutron detector!

The boron carbide films were grown by a technique known as plasma enhanced chemical vapour deposition, or PECVD. The apparatus consists of two parallel plates separated by a small gap of the order of an inch, effectively a capacitor, inside a vacuum chamber. Argon gas is introduced into the chamber with a small amount of a molecular vapour. In this case the molecular vapour is either orthocarborane (closo-1,2-dicarbadodecaborane ($C_2B_{10}H_{12}$)) or metacarborane (closo-1,7-dicarbadodecaborane ($C_2B_{10}H_{12}$)), where the only difference between these two cage molecules is the position of the two carbon atoms in the cage: positions 1 and 2 in orthocarborane and 1 and 7 in metacarborane, respectively. Simultaneously a radio frequency (rf) discharge, or plasma, is struck between the two parallel plates at a frequency of 13.56 MHz. The purpose of the plasma is to ionize the Ar gas, thereby liberating electrons that eventually collide with the extremely stable orthocarborane or metacarborane causing them to dissociate into fragments that are adsorbed onto a surface forming the boron carbide thin films of the diode.

Using two almost identical molecules, how did they manage to make a heteroisomeric diode? One might say that they took advantage of the memory of the two molecules used to grow the boron carbide thin films. From their studies of the electronic structure of molecular films of orthocarborane and metacarborane they discovered that orthocarborane molecular films are intrinsic materials (equal amounts of positive and negative charge carriers), while molecular films of metacarborane were n-type materials (more negative carriers than positive carriers). Remarkably, when decomposed in the plasma and reconstructed into a film they effectively remembered what type of material they were in molecular form, i.e., intrinsic or n-type.

What is the advantage of forming a heterisomeric diode as opposed to a heterojunction diode or homojunctions? The answer is simple: the more boron in the diode the more sensitive the neutron detector. Boron has a very large neutron cross section and therefore the larger the concentration of boron in the detector the greater its sensitivity to neutrons. Furthermore, the elimination of metal dopants (typically used in boron carbide homojunctions) significantly reduces the number of false positives in the detector.

From the standpoint of technology, a low cost, high efficiency neutron detector would vastly reduce the cost of neutron detectors for research, as well as the operation of nuclear reactors in terms of safety. The most significant impact of heteroisomeric diodes from the standpoint of the average person on the street is as an anti-terrorist tool. The ability to construct low cost, highly portable, solid state neutron detectors will greatly increase the capabilities of governments around the world to combat terrorist attacks utilizing nuclear material.

While there is much work still to be done on boron carbide heteroisomeric diodes, the potential impact is enormous. Scientists and engineers alike will be watching the progress made in the next few years on these novel neutron detectors.

References

[1] Caruso A N, Billa R B, Balaz S, Brand J I and Dowben P A 2004 The heteroisomeric diode *J. Phys.: Condens. Matter* **16** L139–46