Ricky's Afterthought:

Silicon Gunn Effect

A.C. (Ricky) Metaxas
Life Fellow St John's College Cambridge UK
Email: acm33@cam.ac.uk

As it is well known, gallium arsenide (GaAs) is at the heart of the Gunn Effect which is used for the generation of microwaves. It was discovered by J.B. Gunn in 1962 at IBM in the USA. Put simply, as the voltage in a Gunn diode increases the current increases but at a certain point the mobility of the electrons starts decreasing producing a negative resistance and it is this inherent property which enables oscillators to be produced at high frequencies. Fig.1 shows a typical I-V characteristic depicting such an effect.

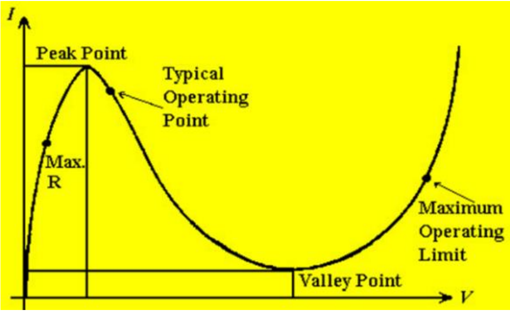

Fig.1: Gun effect showing a typical operating point

Gunn Diodes consist only of n-type semiconductors unlike other diodes that have both n and p-types. It is termed a diode because it has two terminals. They do not conduct current only in one direction and do not rectify alternating currents hence it is best to refer to these as Transfer Electron Devices. Apart from GaAs other materials are used such as Indium Phosphide, InP. It is necessary to use n-type material because the Transferred Electron effect is only applicable to electrons and not to holes found in a p-type material.

The principle behind its operation lies behind the discovery by British physicists Brian Ridley, Tom Watkins and Cyril Hilsum, known as the Ridley-Watkins-Hilsum theory, that some semiconductors could exhibit negative resistance thus opening the possibility of the generation of microwaves.

GaAs Gunn diodes are used in radio links, speed radar traps, automatic door openers, antilock brakes and airborne collision avoidance radar systems.

But GaAs, as a material, is expensive so a collaborative research project from the Physics Dept at Chalmers, Sweden, Dept of Electrical Engineering and Computing Science at Texas A&M University, Kingsville, USA, Dept of Electrical and Computing Engineering, University of Waterloo at Ontario, Canada and the Dept of Electrical Engineering University of Washington, at Seattle, USA, considered whether cheaper materials may exhibit a Gunn-type Effect. Indeed the researchers using Density Functional Theory, Semi-Empirical 10 Orbital (sp3d5s*) Tight Binding and Ensemble Monte Carlo computer models, established that tiny ***silicon nanowires*** with diameters of 3.1nm and when an electric field of 5 kV/cm is applied, a Gunn-type Effect is produced when stretched presenting the possibility that microwaves can be generated with a material which is abundant and far cheaper that GaAs. However, it is noted that about 100000 bundled together would be needed to produce a product as large as a human hair! Although that is a no mean feat, nanofabrication techniques are available which bundle together bulk silicon into nanowires and therefore are capable of producing a Gunn Effect. The researchers believe that the stretching mechanism could act as a switch to turn the Effect on and off, and possibly vary the frequency, which would render this device suitable for a host of new applications.

For further reading

For more detailed information regarding this research visit the following link: https://www.nature.com/articles/s41598-018-24387-y