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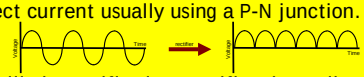
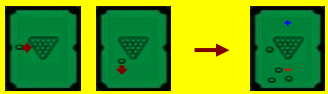
Ballistic Rectifiers FOR DUMMIES

What is a ballistic rectifier?

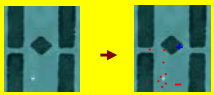
Firstly, a normal diode rectifier is an electrical component used to convert alternating current to direct current usually using a P-N junction.



A ballistic rectifier is a rectifier that relies on ballistic electron transport to operate. Ballistic electrons can be thought of as billiard balls, confined by the boundaries of the pool table.



Instead of a pool table, we have a 2DEG (two dimensional electron gas) confining the electrons to two dimensional motion and also confining them to the device boundaries we created.

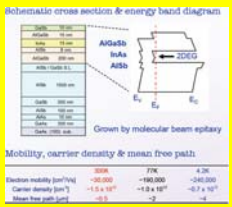


Why ballistic rectifiers?

Current P-N junction rectifiers aren't capable of high frequency operations. The only limiting factor in a ballistic rectifier is the distance the electron must travel, which is very small, making them ideal for high speed operations (in the terahertz range).

The substrate

The substrate consists of many layers. It starts as a GaAs substrate which then has other materials deposited by MBE (molecular beam epitaxy) creating the final InAs/AlGaSb heterostructure.

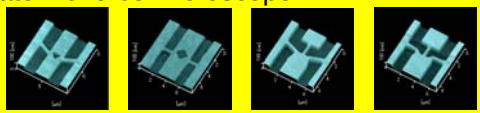


Fabrication

The fabrication process begins on the MBE grown InAs/AlGaSb heterostructure substrate. Then the device is outlined using electron-beam lithography, and then formed with wet chemical etching.

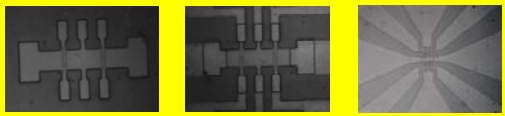
2 Samples: 1000x magnification

The device is then measured using an atomic force microscope.



AFM images of four different designs of ballistic rectifiers
The darker area was etched by E-beam Lithography

Next the isolation pattern, ohmic pattern, and big electrodes are created using photo lithography. These are used to access the device electrically.



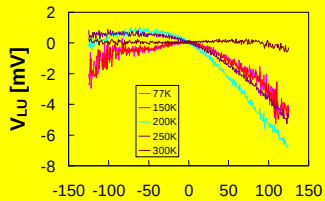
Isolation pattern ohmic pattern big electrodes

About 240 nm of SiO_2 is deposited as an insulator, and In and Au (40 nm and 250 nm) are deposited for conductivity.

Results

Samples were measured at temperatures between 77K and 300K with varying current in the micro-ampere range.

Color coded system used to measure the devices



The graph to the left shows the results from testing the above design

Non-linear electron transport properties were observed using several different designs of ballistic rectifiers. In the data shown above, rectification effects were observed - especially at 150K and 77K.

Future Work

- Create the most efficient design(s)
- Utilize the properties of InAs to obtain room temperature (300K) rectification effects in future devices

Acknowledgements

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