Measurement of Interface Traps in HgCdTe and InAs/GaSb Superlattice Metal-Insulator-Semiconductor Structure

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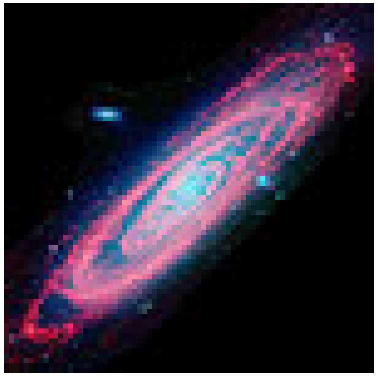
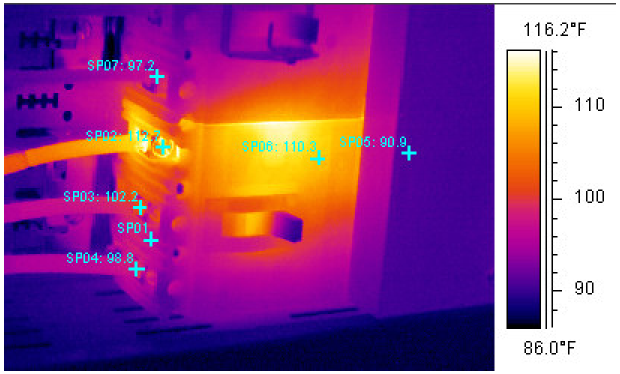
Applications



Astronomy



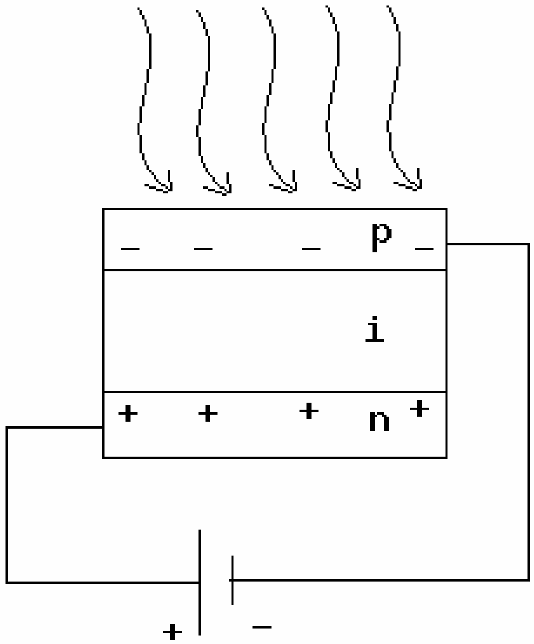
Electronics

Security

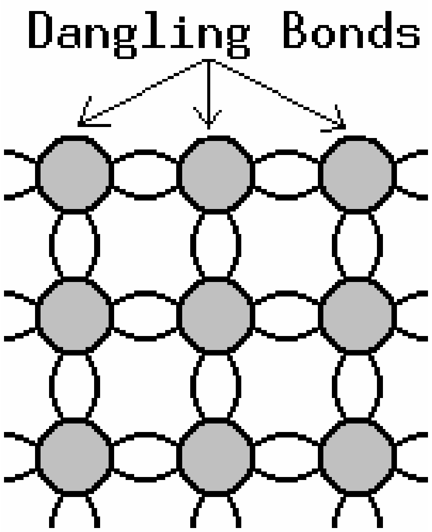
Medicine

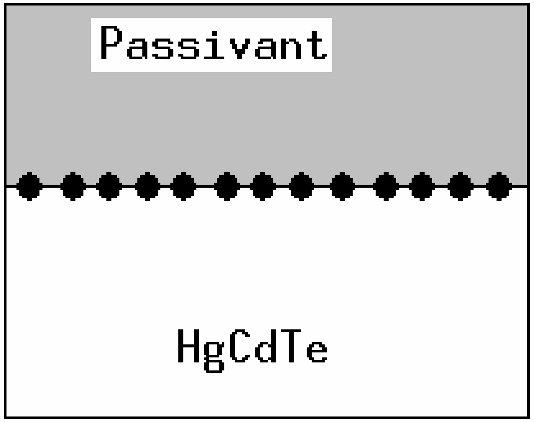
p-i-n Photodiode

- Current consists of the flow of "conduction band" electrons and "valence band holes"
- The p-i-n photodiode has 3 layers: mostly holes (p), mostly electrons (n) and a region of negligible carrier concentration (i)
- Ideally no current can flow under "reverse bias"
- Optically generated carriers can cause current flow
- As reverse bias is increased, avalanche effect begins and significant current flows
- Carriers are multiplied in the avalanche effect leading to increased signal



Passivation





- ➢The surface of the semiconductor has dangling bonds and allows Hg to evaporate
- ➢Dangling bonds and Hg evaporation reduce device sensitivity
- ➢The surface can be passivated to reduce these problems
- ➢Passivation itself leads to other problems
- ➢Surface states will appear at the interface that will allow carrier recombination

•HgCdTe Infrared Detector Material: History, Status and Outlook, Rogalski, A

InAs/GaSb Superlattice

- ➢The InAs/GaSb superlattice consists of alternating layers of InAs and GaSb
- ➢The band gap of InAs is about .8eV, while that of GaSb is about .4eV
- ➢The result is a periodic potential

InAs/GaSb Superlattice

- The potential resembles a “particle in a well”
- The Schrödinger equation can be used to find the electron wave function

$$-\frac{\hbar^2}{2m}\frac{\mathrm{d}^2\psi(x)}{\mathrm{d}x^2}+V(x)\psi(x)=E\psi(x)$$

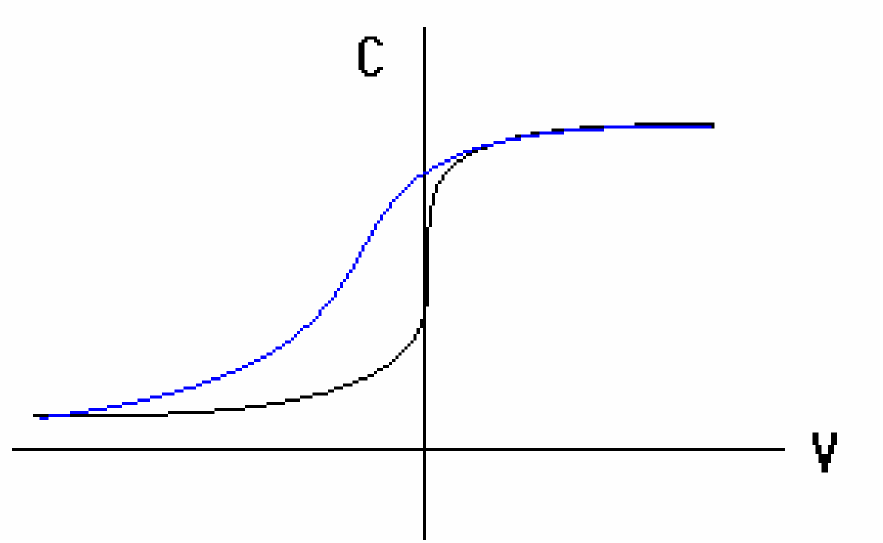
- The solution can be found exactly. While not difficult, this is tedious and the resulting expression is very long
- The result is that there is a single lowest allowed energy level for electrons in the conduction band that can be altered by varying the superlattice geometry

HgCdTe

- Hg1-xCdxTe has a narrow band gap that varies with x
- Band gap corresponds to energies in the IR spectrum
- “Direct band gap”: High absorption coefficient

C-V Measurements

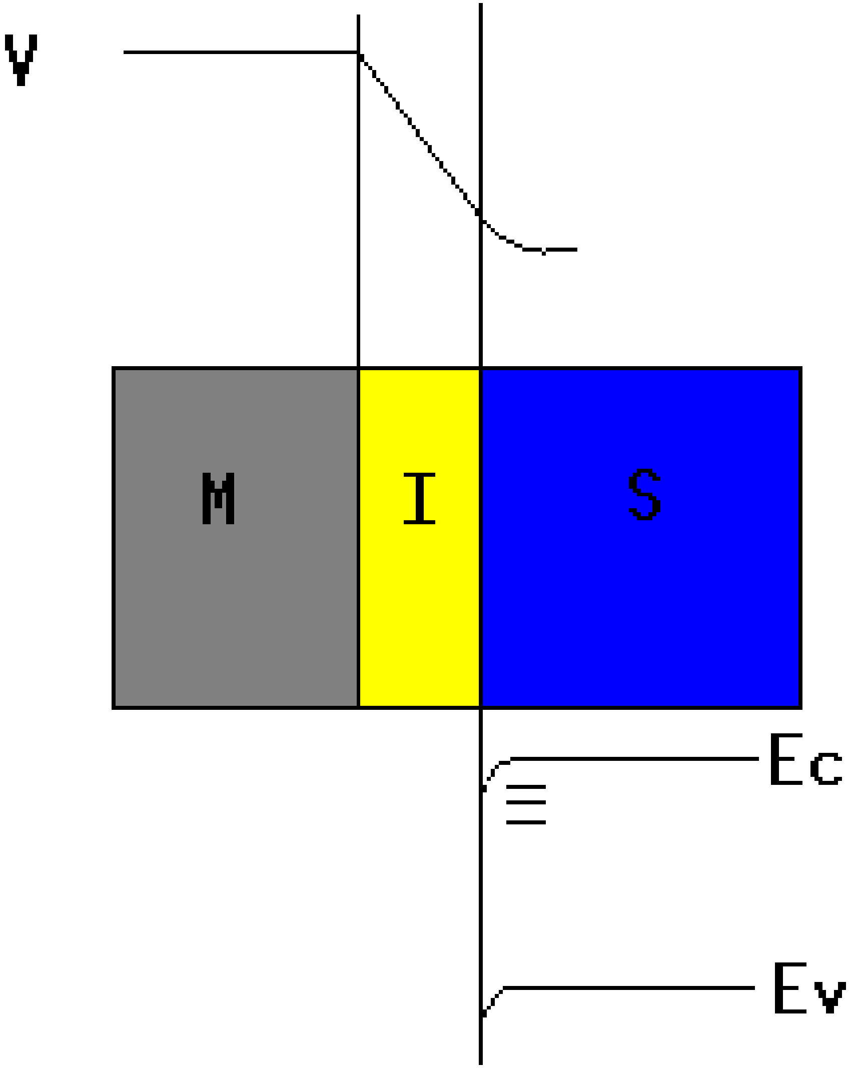
- Interface trapped charges can exchange charges with the semiconductor layer
- This increases the capacitance under negative voltage



Physics of Semiconductor Devices, Second Edition, Sze, S., Chap. 7, John Wiley and Sons, New York, 1981

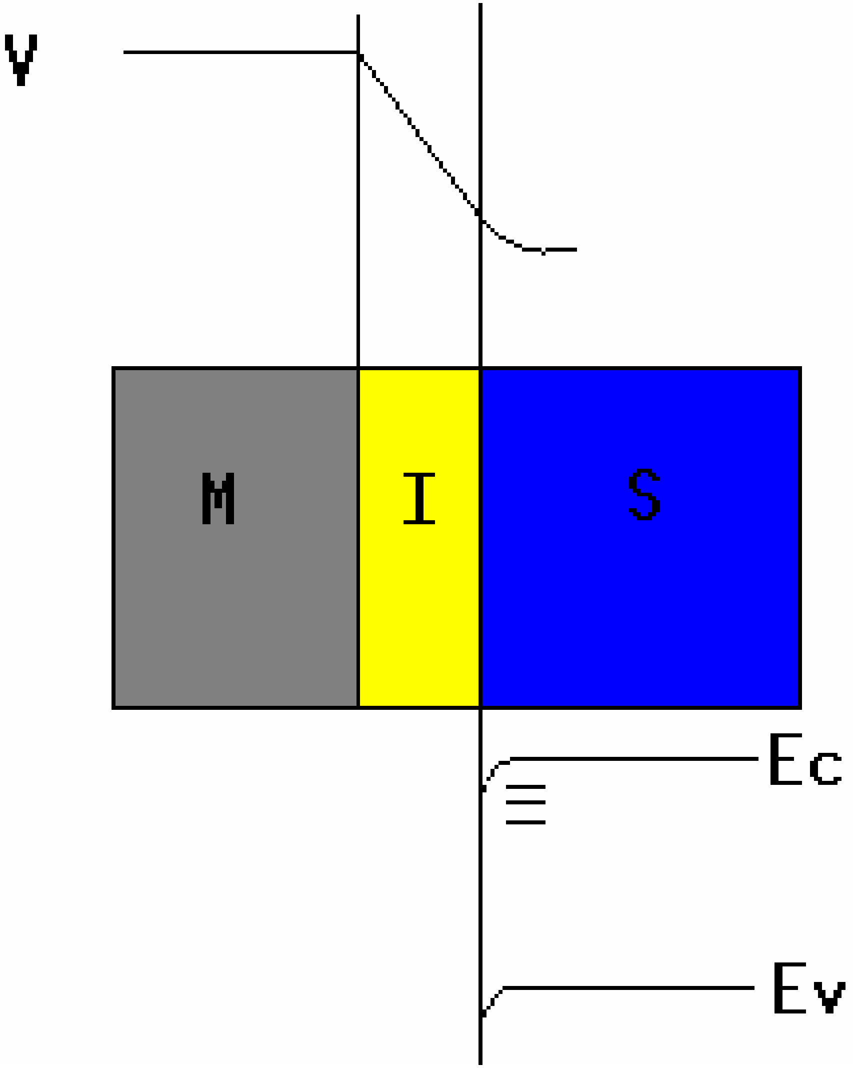
Terman Method

- The Terman method can extract trap density information from C-V data:
- When a voltage is applied across a Metal-Iinsulator-Semiconductor (MIS) structure, part of the voltage drop appears across the insulator and part occurs between the bulk and surface of the semiconductor. The second contribution is the “surface potential”
- From the charge that accumulates at the surface, the surface potential can be determined

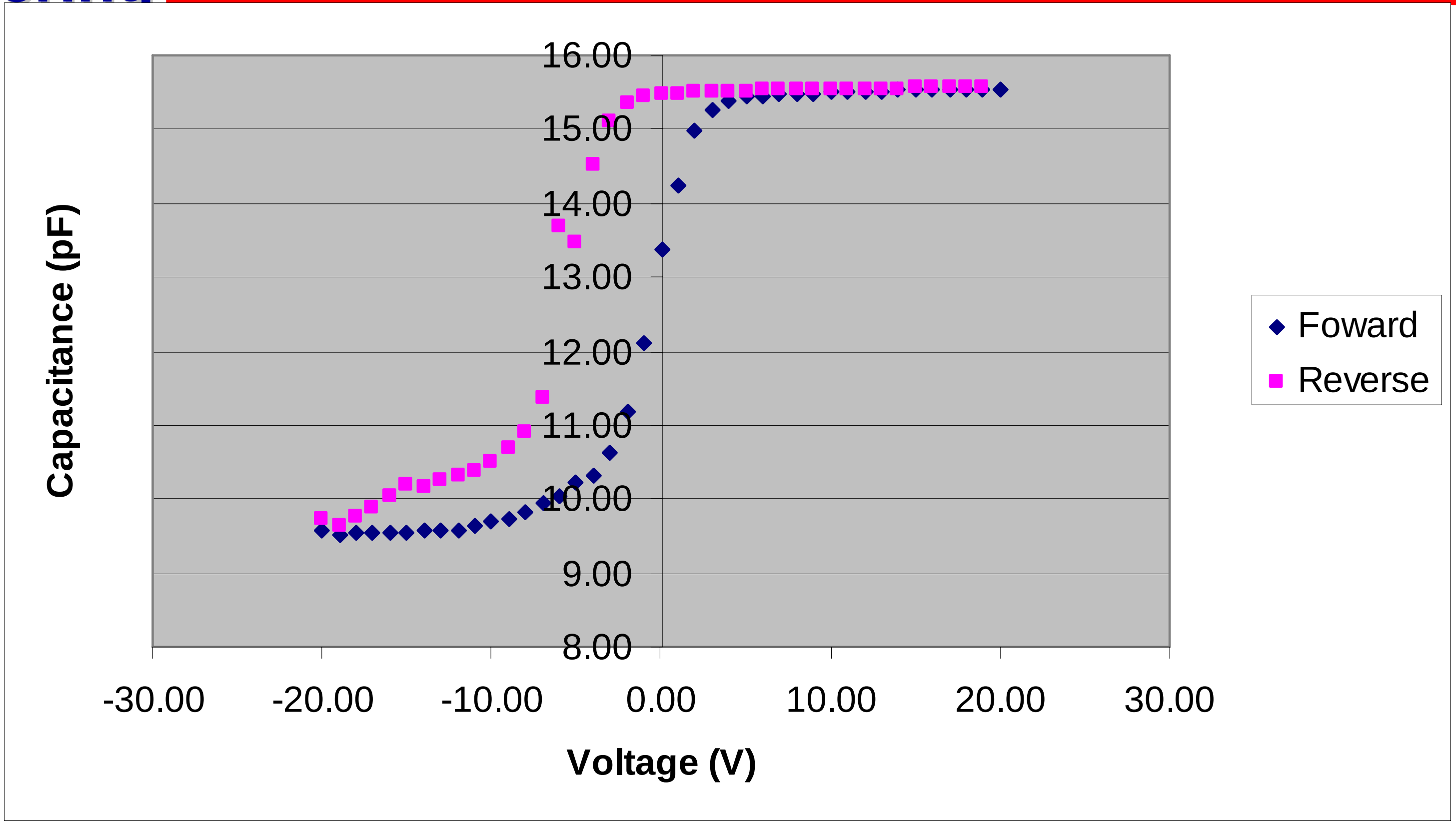


Terman Method

- Some of the charge will come from the normal doping of the semiconductor, while some will come from interface traps
- A surface potential function for the ideal case of no traps can be constructed
- The rate at which the difference between the actual applied voltage for a given capacitance and the ideal voltage at the same capacitance changes with respect to surface potential is proportional to the interface traps exchanging charge at that potential



Results



- Graph shows CV data for MIS device with 4000Å ZnS passivant layer

Results

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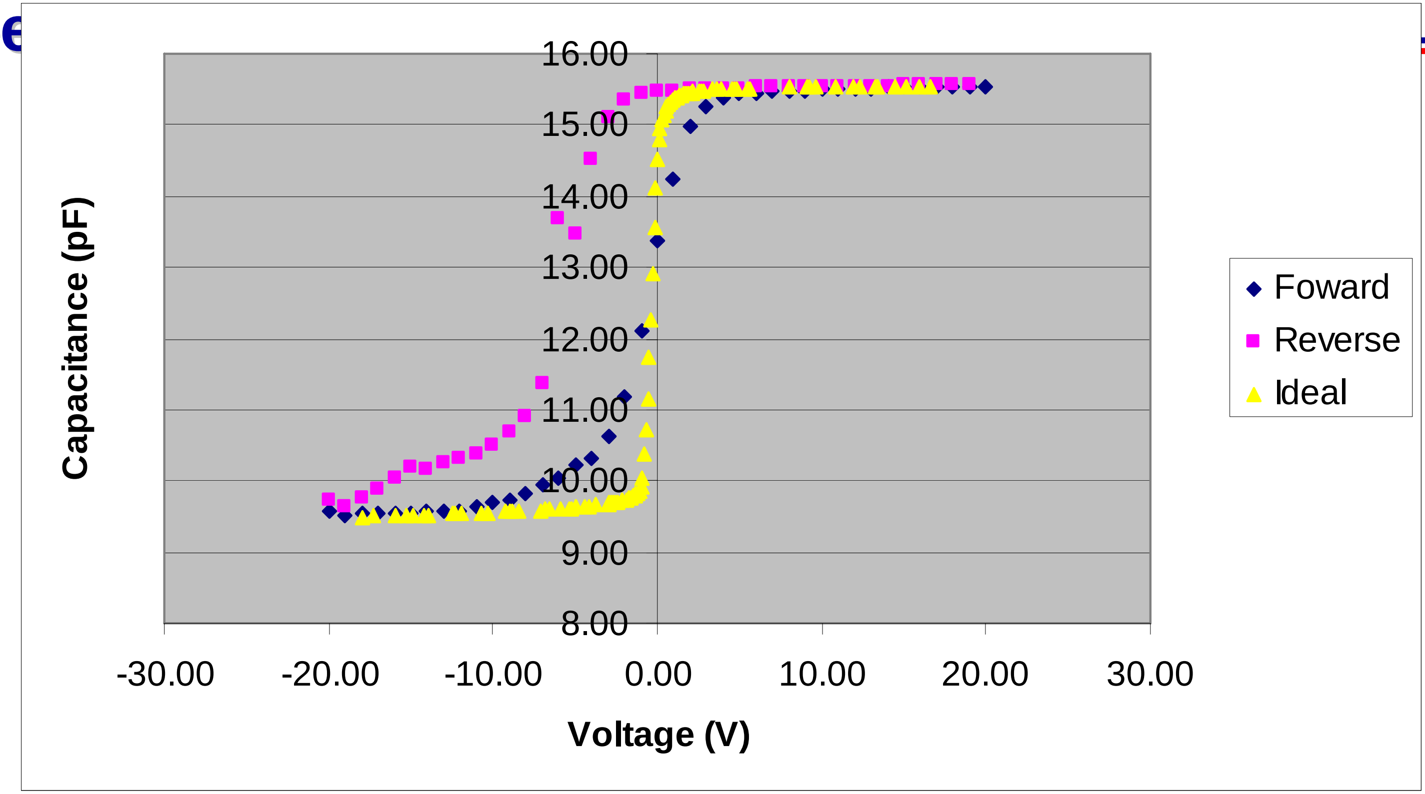
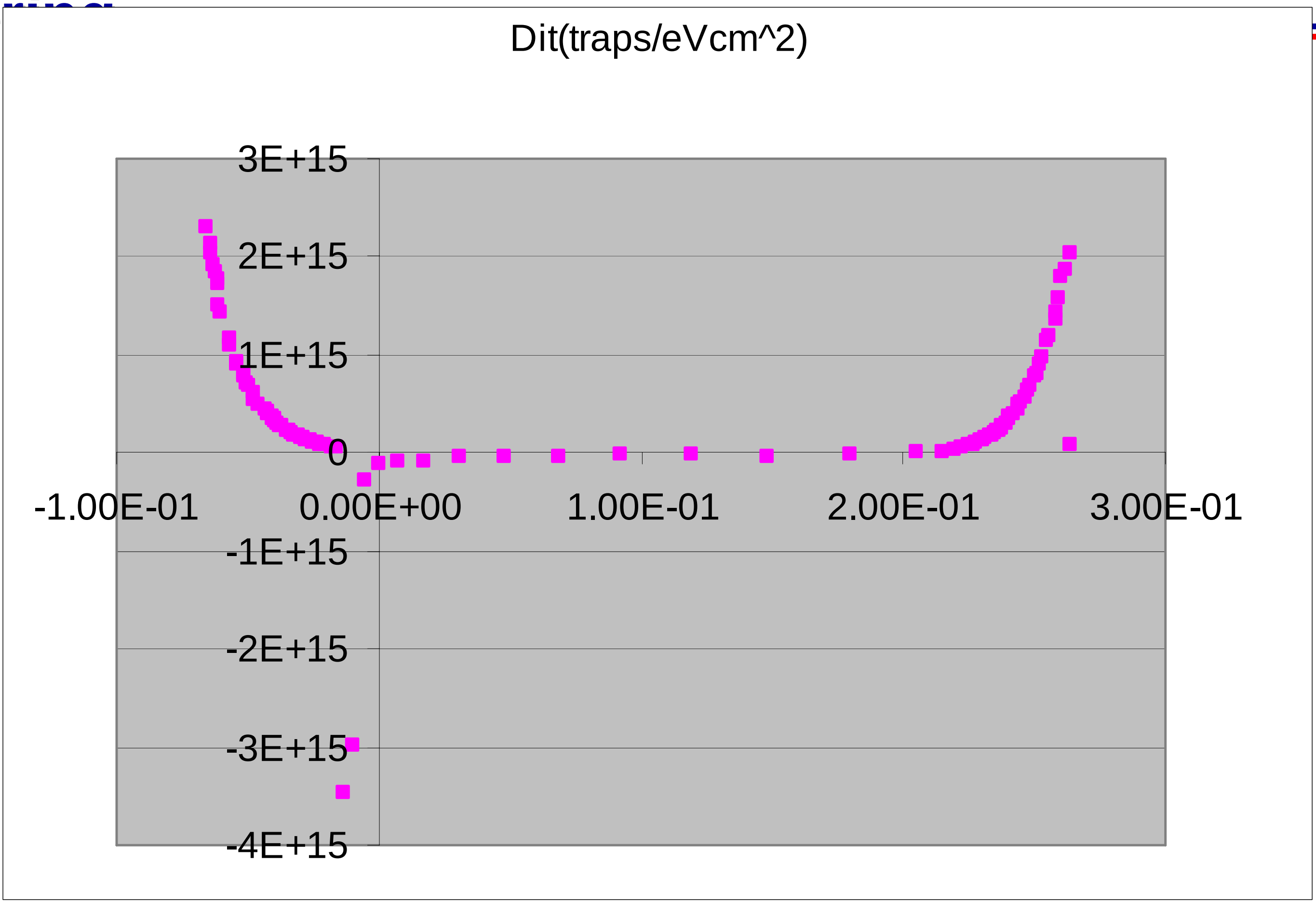


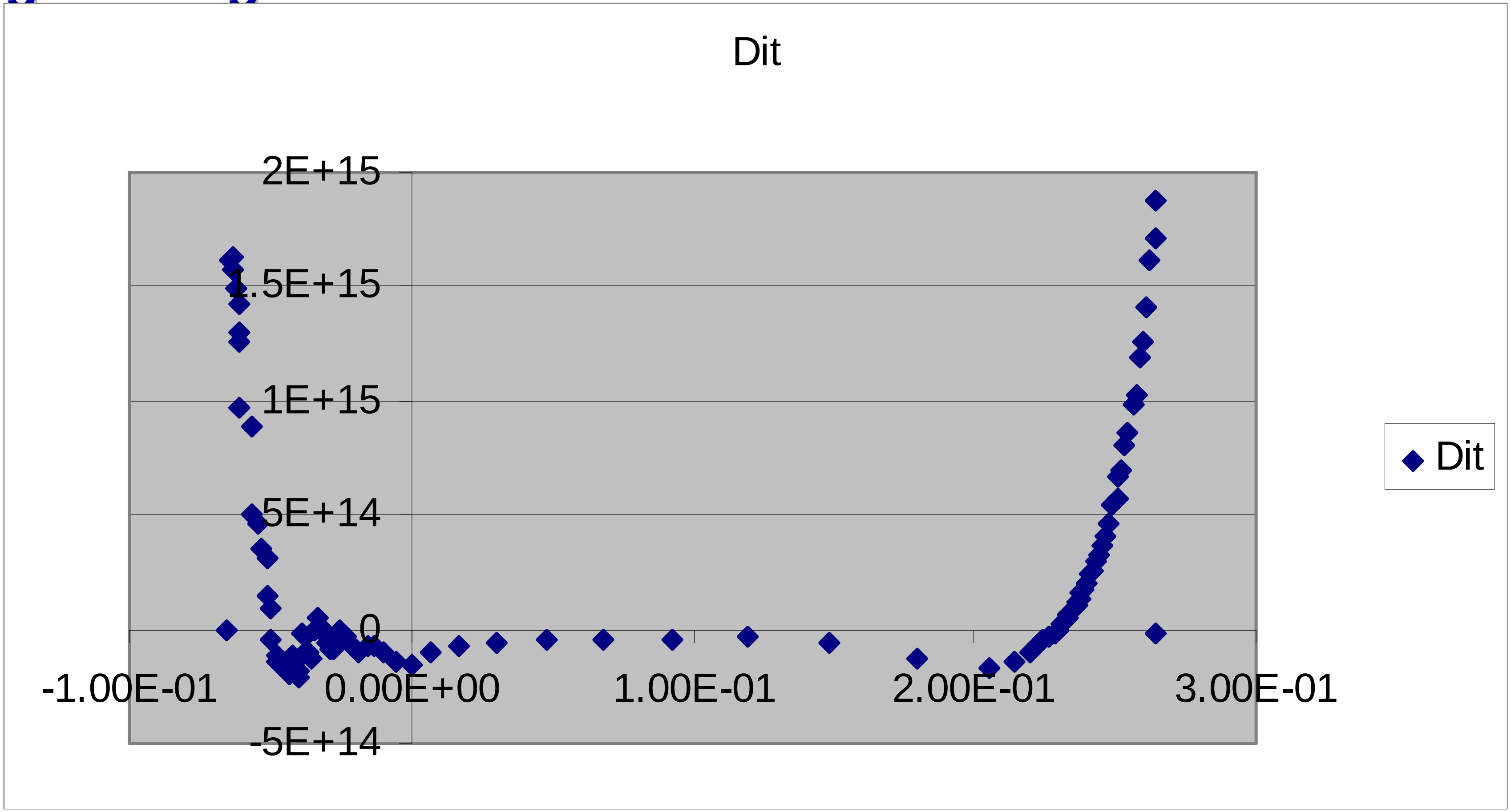
- ➢An ideal curve was constructed in order to use the Terman method

Results



- ➢The maximum trap density is about 2*10^15 traps/eVcm^2
- ➢The best results previously obtained on MCT gave 5*10^12 traps/eVcm^2. We have a long way to go
- ➢The density is still negative at some points, which does not make sense

Results



- Same set of data, reverse pass

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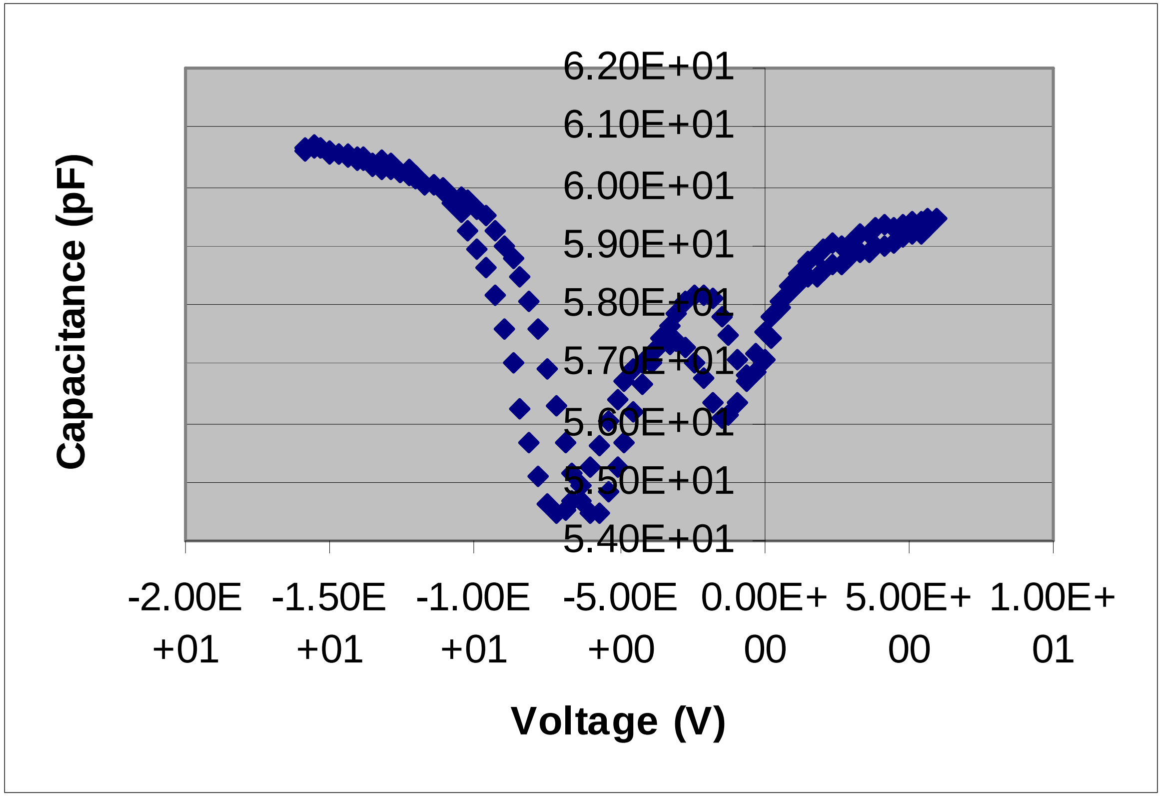
InAs/GaSb C-V Curve



- The capacitance grows again after reaching a minimum rather than saturating at a low value. This may indicate that the frequency is not high enough
- There is a bump on the C-V curve. The cause of this is unknown
- The Terman method can not be used on this data because it assumes high frequency

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