Thesis work summery

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October 2022

1 The Problem

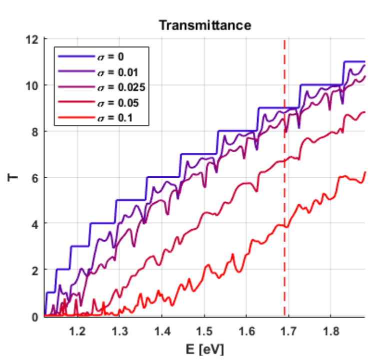
The cornerstone of all modern digital electronics is the transistor invented in 1947. In the 75 years since then, the dimensions of the transistor has been scaled down further and further reaching feature sizes of 7 nm recently. Making the transistor smaller has improved the performance in transistor allowing faster computers and higher speed wireless communication while at the same time reducing power consumption. In recent years the geometry of the transistor has changed with the introduction of the finFET which has allowed feature sizes of 7 nm with the drawback of exhibiting a higher leakage current resulting in higher power consumption. Nanowire transistors are the next step in the transistors development as they allow for better scalability than the finFET while also reducing leakage current. Producing nanowire transistors and nanowires introduces a new series of problems that needs to be solved. This master thesis will study how imperfections in a nanowire structure from production changes the behavior and electrical characteristics of the nanowire.

2 The Method

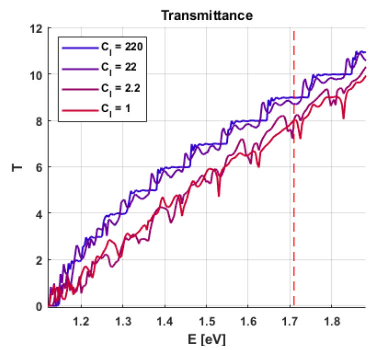
The nanowires were simulated instead of real samples being measured. This has the advantage that it allows for full control of the features and imperfections present in in the nanowires. Simulating nanowires can also be done much faster since the devices does not actually have to be produced while also reducing the cost of the study. To accurately study nanodevices quantum physics has to be accounted for. The method used for simulating the nanodevices is called the non-equilibrium greens function (NEGF) method. The imperfections in the nanowires were introduced by adding a noise floor to the conduction band of the nanowires. This noise was varied in amplitude and locality to study both of these effects. The data generated from the simulation becomes very large when simulations of higher accuracy are calculated so a compression algorithm was also implemented to reduce the size of the data. This compression algorithm was based on a recent image compression algorithm called QOI which has the advantage over PNG that it is orders of magnitude faster than PNG while reaching similar compression rates.

3 The Results

The nanowires showed a decrease in conductivity when noise was introduce as seen in figure 1. The amplitude of the noise had a bigger impact on the performance of a nanowire than how quickly the noise varied. In figure 2 the electron density in the wire is shown for different levels of noise marked by the red line in figure 1a.



(a) σ is the amplitude of the noise relative to the conduction band.



(b) C_l is the correlation length of the noise. Lower value means that the noise changes more rapidly.

Figure 1: The conductivity of simulated nanowires with applied noise.

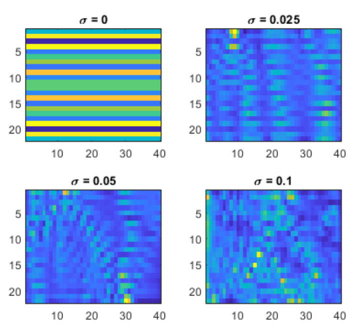


Figure 2: Local electron density in wire, yellow being a higher concentration and blue being lower. Electrons flow from left to right.

The compression algorithm showed a great reduction of required data size while only introducing a small error to calculations. The compression reduced the data-sizes by up to 98% while only introducing an error to calculations less than 0.1%, this is shown in figure 3.

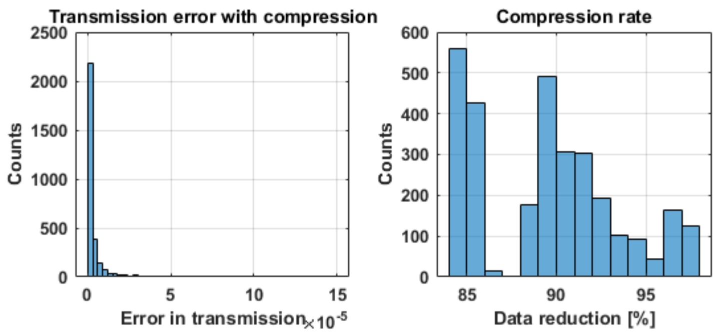


Figure 3: Performance of compression algorithm.

4 Discussion

The work shows that imperfections that have a small change in the conduction band won't change the performance of the wire much even if the imperfections are tightly packed. Larger fluctuations will however have a drastic impact on the performance of the wires and is more important to eliminate than keeping the device uniform. More importantly, the simulations act as a great tool to learn more about nanodevices and give an intuitive understanding of their inner workings. From figure 2 we can see that the paths electrons have to take through the devices become more restricted as the noise becomes larger. The compression algorithm was also able to greatly reduce data which will be of importance once larger systems are being simulated where the results could take up terabytes of data.