Measuring Semiconductor Growth using Image Processing

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Introduction

Efforts to develop confined epitaxial lateral overgrowth as a procedure to enable Tunnel Field Effect Transistors (TFETs) has faced challenges because it is difficult to gather a statistically significant amount of data using a single person to manually record data. It is thus necessary to automate measurements in order to accelerate data collection and analysis to better direct future growth efforts. The code written will measure and record facets of semiconductor material grown in a Metal Organic Chemical Vapor Decomposition (MOCVD) process. Figure 1 an example of an expected input for this code.

Object Detection

Object Detection in this code is done through the use of an Aggregated Channel Feature (ACF) Object Detector. For the purpose of time only vertically oriented transistors are detected. Figure 2 shows an example of labeling transistors, from which a database is created to train the ACF detector. Figure 3 shows the transistors detected by the ACF detector.

Edge Detection

The very first step of edge detection is to create a binary image from the original image. A binary image has only black and white squares, and the white squares are where the computer has determined an edge exists. There are multiple methods for doing this, but the only one that worked for this project is the Canny method of binary image creation. Figure 4 is one of the transistors detected in Figure 1 and Figure 5 is the binary version of that image. The outer most prominent line is considered the edge of the box where figure 6 shows the corners of the box denoted by a large x and a green line where the center is. The interior of the box is cropped, seen in figure 7, and the edges are detected here using the Hough transform, a mathematical process that detects multiple lines with varying lengths and angles. The Hough Transform of this particular sample is plotted in figure 9. The brightest spots of the transform are the parameters of a detected line. The lines are matched to the facets and highlighted in green in figure 8 with a blue line representing the lattice growth.

Output/User Interface

For consistent accuracy, there is a high degree of user input in the program. The resolution of the images are not always consistent therefore, there has to be a way to convert pixel lengths to actual measurements. This is done through the user inputting the measurement of the scale bar in real world dimensions and measuring the length of the scale bar in pixels, as seen in figure 11. Each transistor is displayed with its outline box and detected lattices shown in figure 10. In the event of an error occurring, the user can choose to delete an entry to prevent any errors in the data. Angles for the facets are considered zero degrees when horizontal and based on the zinc blende crystal structure the other angles possible are 35.26 degrees, 45 degrees, and 54.7 degrees. Both facet lengths and lattice growth lengths are recorded in micrometers.

Figures

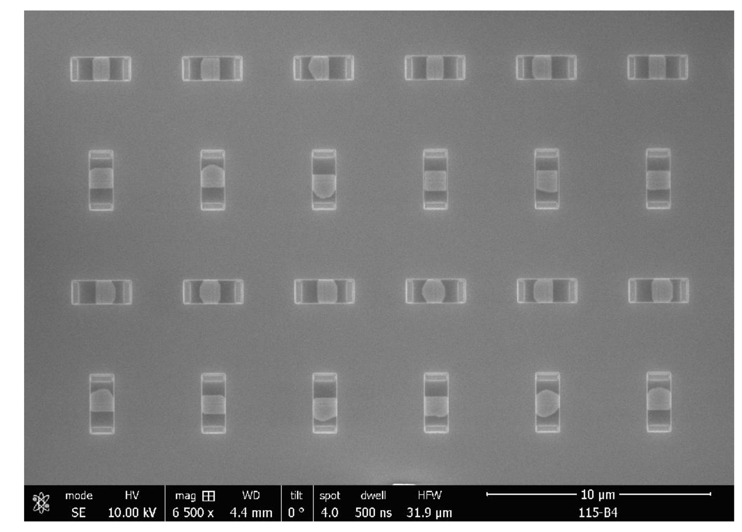

Figure 1
Input photo

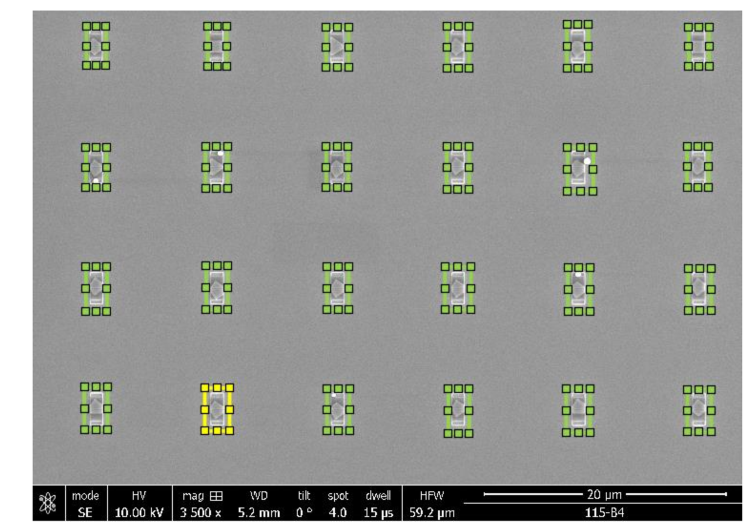

Figure 2
Labeled Transistors

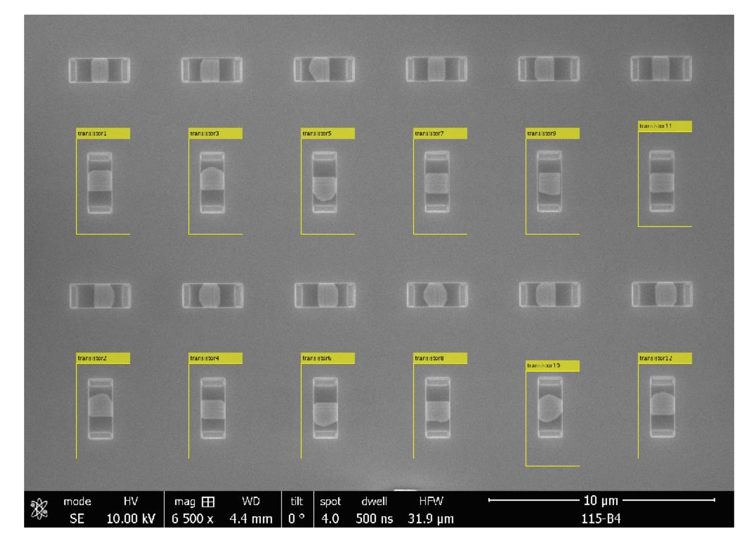

Figure 3
Detected Transistors

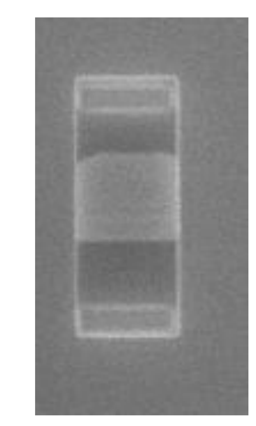

Figure 4
Cropped image of detected transistor

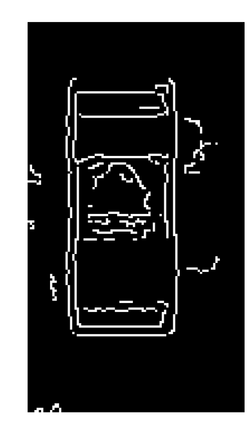

Figure 5
Binary image of transistor

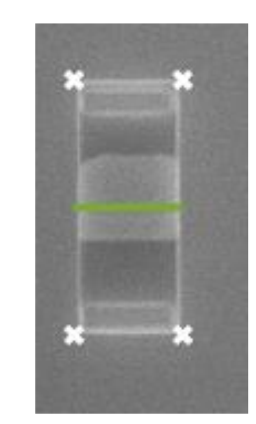

Figure 6
Outlined box of transistor

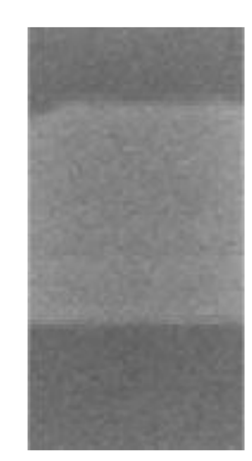

Figure 7
Interior of transistor

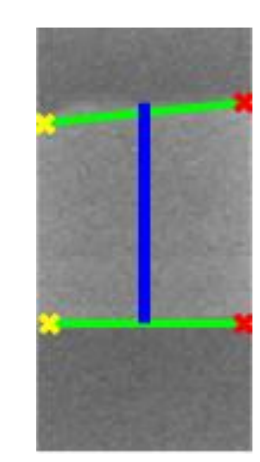

Figure 8
Detected facets

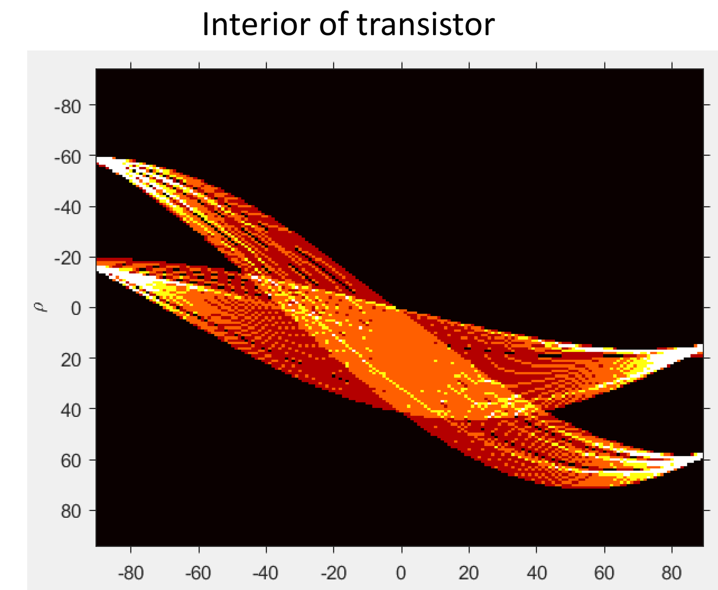

Figure 9
Hough transform of interior

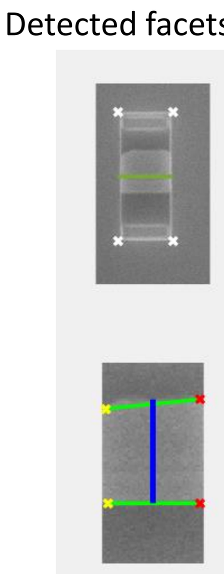

Figure 10
Example output of program

Figure 11
Scale bar from original image

Conclusions

Current version of code is capable of detecting vertically oriented transistors and approximately calculate angles and individual facet lengths along with the length of the entire growth. No significant amount data has been gathered but, the current version of this code will allow for a significant improvement to gathering and analyzing data for future TFET device fabrications.

Acknowledgments

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