Alignment, Stepping, Control and Measurements of Micro/Nanoscale Junctions with Automated Micropositioners

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Abstract

With the evolution of technology, the automation of repetitive processes has helped free up human capabilities to do activities of greater value. Similar was the goal in automating micropositioners used in probe stations to test micro and nanoscale junctions. Manually positioning the probe arm from terminal to terminal on the device under test was both tedious and time consuming. In order to eliminate this extraneous work, the 3-axis movement of the micropositioner was achieved through servo motors which allowed a digital override to the manually controlled analog system. All the continuous rotation servo motors were connected to a microcontroller which communicated to personal computer (PC) workstation. The PC was used to record the measurements from the device under test through universal asynchronous receiver/transmitter protocol. The driver software allowed the servo motors to position the probe arm at the required position for each test terminal without consuming precious time and wasting needless effort. This system can also be evolved to do remote monitoring of the devices as well.

Introduction

Many micro and nanoscale devices need to be probed one device at a time. The probing often requires making two or three terminal contacts to the device under test (DUT). The

characteristics of DUT are then measured before probe tips are manually moved to the next DUT. The probe is moved manually to make connections and to measure properties of DUT. This requires a lot of human time as the user has to peer through the microscope while trying to fiddle with the dials and knobs on micropositioner to move the probe arm so the it can be placed at the desired location. The automation of micropositioners of the probe arm has allowed a great increase in the efficiency of the test procedures.

Figure 1. Singatone H150 probe station modified with automated probes.

Setup

A typical probe station houses a stage with a microscope that allows magnified viewing of the DUT. For this setup, a Singatone H150 Probe Station was used, as shown in Fig. 1.[1] The micropositioner was placed on the steel plate around the stage. It was used to position the probe to make connections and to measure properties of DUT. A Singatone S-725 micropositioner was automated in this setup. An unmodified micropositioner is shown in Fig. 2.[2]

There were three basic controls on the micropositioner to control the position of the probe in three dimensions as highlighted with arrowed lines in Figure 2. The first control, *X*, was for the lateral position of the probe tips. This was a linear control which moved the tip directly proportional to the amount of turns of the knob attached to it. The other two controls for the position, *Y* and *Z*, were not linear. These moved the probe tip in a circular manner following an arc path. The arc radii for the movements were related to the lateral position of the probe arm's tip.

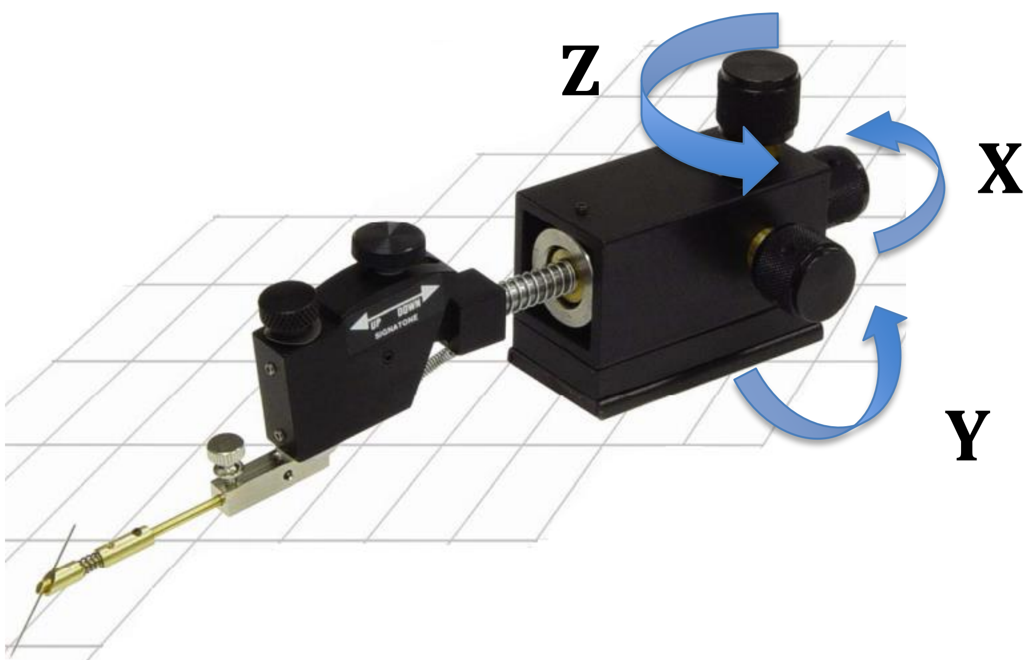

Figure 2. Unmodified Singatone S-725 micropositioner

For complete automation, each of the three control knobs was directly connected to a continuous rotating servo motor. Hitec robotics continuous rotation servos, HSR-1425CR, were used that allowed easy control of the rate of turn through pulse-width modulation (PWM).[3] All the servo motors were connected to a microcontroller which was programmed to communicate via universal asynchronous receiver/transmitter (UART) protocol. The microcontroller was connected via USB to a PC workstation which had the driver software installed to control the probe arm via the servo motors and microcontroller.

Microcontroller

The microcontroller used was an 8-bit ATmega640 microcontroller onboard an Axon II board (Figure 3).[4, 5] This processor allowed multiple PWM ports and UART through USB. It also had a series of analog inputs which could be used for tracking the position of the probe arm. There were twelve events that the microcontroller performed: four events for each servo. One commanded the motor to turn clockwise at a high speed while the other commanded a clockwise turn at low speed. The other two events turned the motor counter-clockwise. The speed allowed for fine and coarse tuning to optimize the time it took for the probe to position itself correctly.

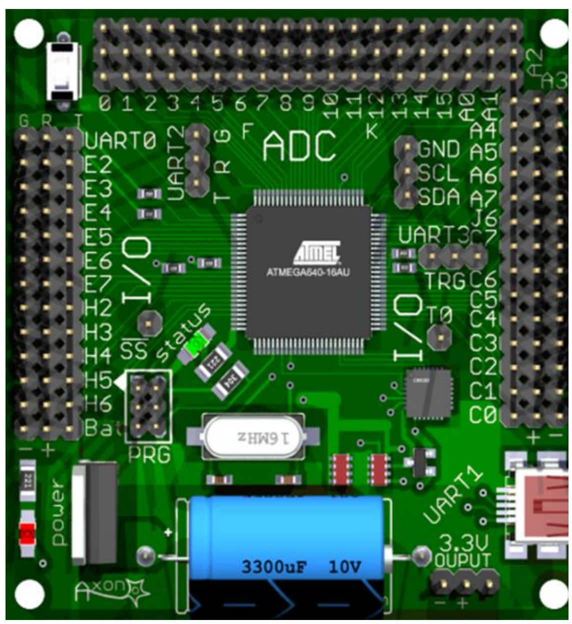

Figure 3. Axon II Board with
ATmega640 microcontroller

The microcontroller waited for inputs in a series of nine characters. The first character specified the commanded position as a relative or an absolute position. The characters 2-5 and

6-9 specified the desired location's coordinates in terms of X and Y position respectively. The characters 2 and 6 were direction indicators of positive or negative movement. The microcontroller divided the string of 9 characters to decipher what it needed to do. It ran an automated sequence from the twelve events to move the probe arm's tip to the desired location. First, the controller computed the amount of motion required. If the command was for relative position, then there was no computation required. However, if it was an absolute position, then the microcontroller used its tally of the current position of probe arm's tip to calculate the relative motion required to obtain the absolute position commanded. The motion sequences were then initiated. All the sequences started with lifting the probe arm in the Z-direction to avoid dragging the probe tip on the DUT. Depending on the amount of motion required, the microcontroller sent pulses of varying widths to rotate the servo motors at either a low or a high speed. This positioned the probe in the X and then the Y-direction. Finally, the probe tip was lowered in the Z-direction to make contact with the DUT and the microcontroller updated its tally of the current position of the tip.

Driver Software

The microcontroller was connected to a PC workstation. A driver software was written to operate the microcontroller to control micropositioner. A screenshot of the main screen graphical user interface (GUI) of the software is shown in Figure 4. The software allowed automated as well as manual positioning. The manual positioning part used either buttons of the screen or the number pad of the keyboard to move the probe arm in the desired location at either a fast or slow speed depending on coarse or fine tuning.

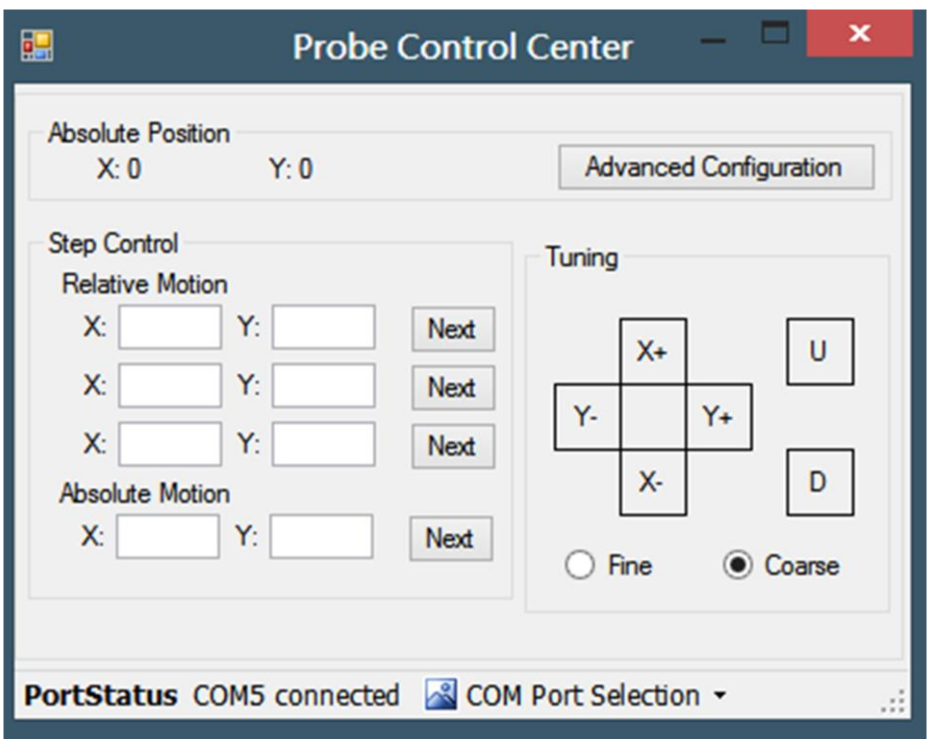

Figure 4. GUI for the micropositioner driver software.

The automatic positioning allowed an input for either a relative or an absolute X and Y coordinate for the probe to move to. Three relative motions could be stored, and with advanced configurations, a pattern could be assigned on how to execute these relative motions. A typical break-junction chip like the one in Figure 5 could have a "10-2-4" pattern configured. The first relative motion specifies the distance between two consecutive junctions. The second and third number specified the distance between each array set. In a "10-2-4" pattern, the 10 would then specify the number of junctions in each array while the 2 and 4 depict the number of rows and columns of the arrays. With this pattern specified along with the time to be spent at each DUT, the driver software generates all the locations the probe tip needs to move to and commands the microcontroller to move the servo motors to do so. The tip moves to all the locations and pause at each DUT long enough to record the readings.

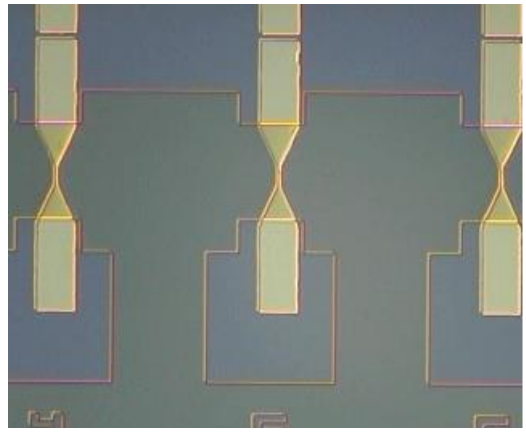

Figure 5 Break-junction chip with gold metal pads. The probe arm has to move from pad to pad for measurements.

Conclusions and Recommendations

The probe arm automation has been implemented successfully. It has been designed to be modular and allows expansion. The software and microcontroller board can control up to 3 different micropositioners and have the capability to take in analog inputs. The current version does not have any feedback. The microcontroller and the software have to track the actual location of the probe tip. In future versions, potentiometers can be used to gain analog input to measure and communicate the tip position in real-time. Also the driver software can be incorporated in LabVIEW to allow complete automation of measuring and logging of the DUT.

References

1. Singatone, "H150 Series," Gilroy, California, [Brochure].
2. Singatone, "S-700 Series," Gilroy, California, [Brochure].
3. Robot Shop, "HSR-1425CR Continuous Rotation Servo," URL: http://www.robotshop.com/productinfo.aspx?pc=RB-Hit-78&lang=en-US
4. Atmel, "8-bit Atmel Microcontroller with 64K/128K/256K Bytes In-System Programmable Flash," ATmega640 Datasheet, Oct. 2012.
5. Society of Robots, "Axon Datasheet," [Online]. Available: http://www.societyofrobots.com/axon/axon_datasheet.shtml. [Accessed Jan. 4, 2013].

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