SESSION 4: Rocky Mountain Power Clinic
Power Quality Event Demonstrator (PQED)

Officer's Club South
Session Chairman: Jason Wayment

12:25 **Stephen Manrique**
"PQED Solution Overview"

12:45 **Calvin Yan**
"FPGA"

1:05 **Lance Wayment**
"Mechanical System and Control"

1:25 **Jack Dam**
"Solid-State Relay"

1:45 **Jason Wayment**
"Satellite Modules and Safety"

Industrial Liaison: Steve Lathrop

Faculty Advisor: Behrouz Farhang

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PQED SOLUTION OVERVIEW

Stephen Manrique, Calvin Yan, Lance Wayment, Jack Dam, Jason Wayment (Behrouz Farhang, Arn Stolp, Department of Electrical and Computer Engineering; Dennis Hansen, Steve Lathrop, Rocky Mountain Power, Salt Lake City, UT 84115; Philip T. Krein, University of Illinois, Urbana, Illinois, 61801), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

To demonstrate a single, periodic, and motor start voltage sag event, the Rocky Mountain Power Clinic had to go through many preliminary ideas before coming to a viable solution. These preliminary solutions included motor driven variacs, multi-tapped transformers, resistor networks, and conversion of the voltage to DC for manipulation, then back to AC. The Clinic finally agreed upon a plausible solution by implementing a combination of a motor driven variac and a dual-tap autotransformer. As with the other solutions, there were some problems that had to be overcome. This will be discussed along with other considerations such as digital circuitry requirements, motor/controller requirements, and switching requirements between the two voltage outputs. With this setup, Rocky Mountain Power will be able to effectively simulate a voltage transient disturbance to their customers.

SESSION 4 12:25 p.m. Officer's Club Soutl

PQED SOLUTION OVERVIEW

Stephen Manrique, Calvin Yan, Lance Wayment, Jack Dam, Jasor Wayment (Behrouz Farhang, Arn Stolp, Department of Electrical an Computer Engineering; Dennis Hansen, Steve Lathrop, Rock Mountain Power, Salt Lake City, UT 84115; Philip T. Kreir University of Illinois, Urbana, Illinois, 61801), Department o Electrical and Computer Engineering, University of Utah, Salt Lak City, UT 84112

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SESSION 4 **12:45 p.m.** **Officer's Club South**

FPGA

Calvin Yan, Lance Wayment, Jack Dam, Jason Wayment, Stephen Manrique (Behrouz Farhang, Arn Stolp, Department of Electrical and Computer Engineering; Dennis Hansen, Steve Lathrop, Rocky Mountain Power, Salt Lake City, UT 84115; Philip T. Krein, University of Illinois, Urbana, Illinois, 61801), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

A field-programmablegate array (FPGA) acts as the head of the project. It communicates with the user to get the input information. By that, the FPGA generates the required waveform by controlling the motor and the electronic switches. The control system of the FPGA can break into three main parts: input interface, waveform information generation, and waveform generation. Input interface will get the input from the user. Waveform information generation will transform the input data to the useful data for the program. Waveform generationwill generate the waveform. The decision of the parts for FPGA will also be discussed.

SESSION 4 **12:45 p.m.** **Officer's Club Soutl**

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Calvin Yan, Lance Wayment, Jack Dam, Jason Wayment, Stephe Manrique (Behrouz Farhang, Arn Stolp, Department of Electrical an Computer Engineering; Dennis Hansen, Steve Lathrop, Rock Mountain Power, Salt Lake City, UT 84115; Philip T. Krein University of Illinois, Urbana, Illinois, 61801), Department o Electrical and Computer Engineering, University of Utah, Salt Lak City, UT 84112

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SESSION 4 **1:05 p.m.** **Officer's Club South**

MECHANICAL SYSTEM AND CONTROL

Lance Wayment, Jack Dam, Jason Wayment, Stephen Manrique, Calvin Yan (Behrouz Farhang, Arn Stolp, Department of Electrical and Computer Engineering; Dennis Hansen, Steve Lathrop, Rocky Mountain Power, Salt Lake City, UT 84115; Philip T. Krein, University of Illinois, Urbana, Illinois, 61801), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

The Power Quality Event Demonstrator (PQED) uses two voltage outputs to simulate poor power quality. One of these outputs is mechanically controlled by a stepper motor. This motor must operate quickly and precisely to accurately simulate a motor start event. Direct coupling the motor to the PQED variac's shaft results in a fast and precise solution. The motor controller consists of two inputs, J-K fliplops, and xor gates to control the four motor phases. The inputs indicate motor direction and step frequency. The controller is implemented with a field programmable gate array (FPGA). The PQED motor and controller require a calibration procedure upon startup, which is performed by using feedback switches at key locations along the variac's sweeping-arm path. A DC power supply is used to power both the motor and FPGA.

SESSION 4 **1:05 p.m.** **Officer's Club Sout**

MECHANICAL SYSTEM AND CONTROL

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SESSION 4 1:25 p.m. Officer's Club South

SOLID-STATE RELAY

Jack Dam, Jason Wayment, Stephen Manrique, Calvin Yan, Lance Wayment (Behrouz Farhang, Arn Stolp, Department of Electrical and Computer Engineering; Dennis Hansen, Steve Lathrop, Rocky Mountain Power, Salt Lake City, UT 84115; Philip T. Krein, University of Illinois, Urbana, Illinois, 61801), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

With our decision to tap two different points on the Vari-AC, we will need a way to switch between those different voltages. The problem arises when turning on or turning off a switch at any point other than the zero-volt crossing, with the extreme cases occurring at the peaks of the AC sinusoidal wave. Keeping in mind that current through an inductor does not change instantaneously, when the switch changes states other than at the zero-volt crossing, voltage spikes and surge currents result. If one can imagine instantaneously removing 120VAC from a load, current will increase instantaneously before settling to zero. Because of the inherent transients associated with applying AC power to a load, we decided to utilize a switch with silicon controlled rectifier (SCR) thyristor outputs. Two switches of this type were found from two different manufacturers, Teledyne and Clare. The two switches are solid-state relays which will allow control of the switching with a DC voltage that is optically controlled to allow for isolation from the load circuit, thus minimizing noise.

SESSION 4 1:25 p.m. Officer's Club Soutl

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SESSION 4 1:45 p.m. Officer's Club South

SATELLITE MODULES AND SAFETY

Jason Wayment, Stephen Manrique, Calvin Yan, Lance Wayment, Jack Dam (Behrouz Farhang, Arn Stolp, Department of Electrical and Computer Engineering; Dennis Hansen, Steve Lathrop, Rocky Mountain Power, Salt Lake City, UT 84115; Philip T. Krein, University of Illinois, Urbana, Illinois, 61801), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

In order for a Power Quality Event Demonstrator(PQED) to be useful, there needs to be some method of demonstrating power quality. The control unit produces the power quality disturbances, but two additional satellite modules are needed to demonstrate what effects these disturbances have on power equipment. Therefore, test benches were designed and constructed to demonstrate how lights and ice-cube style relays respond to voltage deviations. The light test module has three light receptacles that allow for side-by-side comparison of three separate bulbs, such as incandescent, compact florescent, and LEDs. The relay test module contains a receptacle for a typical double pole, double throw ice cube style relay, where one throw controls power to a normally open duplex power outlet, and the other throw controls a set of Form C dry jacks.

This project involves manipulating potentially dangerous voltages, so protection considerations and adherence to industry standards is necessary. The control unit is protected with fuses coordinated to protect the internal components, as well as any external equipment plugged into it. It is the intent that this product will be manufactured, so relevant National Electric Code® articles are complied with.

SESSION 4 1:45 p.m. Officer's Club Soutl

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SESSION 5: Sandia National Laboratories Clinic

Low-Power, Context-Aware Global Positioning System

Officer's Club North

Session Chairman: Chris Chadwick

3:05 **Rashin Bolkameh**
"Introduction to GPS Tracking System and Project History"

3:25 **Chris Chadwick**
"Hardware Design"

3:45 **Michael B. Stevens**
"Board Design"

4:05 **Daniel Rolfe**
"Programming the Utah GPS Stack"

4:25 **Eric Hsu**
"Testing and Results"

Industrial Liaison: Steven Paradise

Faculty Advisor: Cameron Charles

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SESSION 5 **3:05 p.m.** **Officer's Club North**

INTRODUCTION TO GPS TRACKING SYSTEM AND PROJECT HISTORY

Rashin Bolkameh, Chris Chadwick, Michael B. Stevens, Daniel Rolfe, Eric Hsu (Cameron Charles), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

The Global Positioning System (GPS) is a fully functional Global Navigation Satellite System (GNSS). The goal of this project is to build a low-power device, utilizing a GPS Front-End Module on the Sandia stack, to capture and store that data, and transfer it to the PC via serial. The design uses one low-power MSP micro controller from Texas Instrument. In order to limit the power consumption, the low-power GPS stack is now able to capture a short sample of the GPS satellite signal and store these data into the flash memory (128 Mbit). We have also used an accelerometer in our design, which helps lower the power consumption by only activating the receiver when the stack is moving. Most GPS receivers require a full signal from the satellites (about 30-40s); our goal with this project was to calculate a position with less than one second of data.

SESSION 5 **3:05 p.m.** **Officer's Club Nortl**

INTRODUCTION TO GPS TRACKING SYSTEM ANI PROJECT HISTORY

Rashin Bolkameh, Chris Chadwick, Michael B. Stevens, Daniel Rolfe Eric Hsu (Cameron Charles), Department of Electrical and Compute Engineering, University of Utah, Salt Lake City, UT 84112

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SESSION 5 **3:25 p.m.** **Officer's Club North**

HARDWARE DESIGN

Chris Chadwick, Michael B. Stevens, Daniel Rolfe, Eric Hsu, Rashin Bolkameh (Cameron Charles), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

The process of designing an embedded system is not a short one. In designing an embedded system, one must first come up with a hardware solution to the problem; in our case, capturing GPS signal. Second, components must be found; third, read the data sheets for the components; and forth, figure out how all the components will work together. If it is found along the way that something is not going to work, go back to step one.

SESSION 5 **3:25 p.m.** **Officer's Club Nort**

HARDWARE DESIGN

Chris Chadwick, Michael B. Stevens, Daniel Rolfe, Eric Hsu, Rashi Bolkameh (Cameron Charles), Department of Electrical an Computer Engineering, University of Utah, Salt Lake City, UT 8411

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SESSION 5 3:45 p.m. Officer's Club North

BOARD DESIGN

Michael B. Stevens, Daniel Rolfe, Eric Hsu, Rashin Bolkameh, Chris Chadwick (Cameron Charles), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

The board schematic and layout were created with Cadsoft Eagle. The first step was to create each part in the Eagle software. This consists of creating a symbol used for the schematic and a package used for the layout. Then the schematic was drawn to make all electrical connections between the pins of the symbols. The schematic was checked using Eagle's Electrical Rule Check. Once the schematic was complete, the layout could then be generated. In the layout editor, the board was sized and all parts were placed. Then all connections between the pins on the packages had to be routed in the layout. As many connections as possible were done using Eagle's autorouter. A four-layer board was used with the two middle layers being ground and power. The layout was checked using Eagle's Design Rule Check. From the finished layout, the gerber files were created and sent to Sierra Proto Express for fabrication. After fabrication, the boards and parts were sent to PCB Solutions for assembly.

SESSION 5 3:45 p.m. Officer's Club Nortl

BOARD DESIGN

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SESSION 5 **4:05 p.m.** **Officer's Club North**

PROGRAMMING THE UTAH GPS STACK

Daniel Rolfe, Eric Hsu, Rashin Bolkameh, Chris Chadwick, Michael B. Stevens (Cameron Charles), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

The heart of the GPS extension board for the Sandia Stack is a Texas Instruments MSP430F169 micro controller which required a custom embedded program. This microcontroller handles the operation and interactions between the devices on the GPS extension board. Program development was divided into several small pieces which could be developed mostly independently then combined into completed software. The main portions of the program are: connecting the SiGe GPS front end to the flash memory, reading data from the flash memory to the micro controller, passing information from the micro controller to a computer, and developing a timer to handle the timing between the sub parts in the GPS stack. Since the Sandia Stack runs off battery power, the software was written with power conservation in mind. The TI MSP430 will only turn on devices when they are needed, and it will run in the lowest power mode possible. Interrupts are utilized to signal when a GPS sample should be taken, and to know when the computer is ready to accept data from the GPS stack. Captured samples are transferred to a computer to be processed. When the processing of the GPS samples is completed, they can be used to determine previous whereabouts of the Sandia Stack.

SESSION 5 **4:05 p.m.** **Officer's Club Nortl**

PROGRAMMING THE UTAH GPS STACK

Daniel Rolfe, Eric Hsu, Rashin Bolkameh, Chris Chadwick, Michael E Stevens (Cameron Charles), Department of Electrical and Comput Engineering, University of Utah, Salt Lake City, UT 84112

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SESSION 5 4:25 p.m. Officer's Club North

TESTING AND RESULTS

Eric Hsu, Rashin Bolkameh, Chris Chadwick, Michael B. Stevens, Daniel Rolfe (Cameron Charles), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

The first step in our testing phase was to load small instruction sets to the micro controller to verify proper wiring of the board and test for certain operations such as power, saving data, and detecting movement. The testing involved verifying all individual components of our manufactured GPS stack to make sure it powered up correctly and individual paths were correct in the way we envisioned. Once that phase was completed, we moved into verification logic of the accelerometer code that enables and disables GPS data acquisition. One of the major aspects of our operational sequence was the transfer of data from the front-end GPS unit to our internal memory and finally outputting these data using serial interface. After we verified the individual modules to be working, we combined them together to ultimately build a single overall operational code for our GPS stack. Extended testing over the GPS stack with its associated results remains one of the primary objectives of this project.

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SESSION 6: ON Semiconductor Clinic

Characterization of Bonding Stress on Analog Integrated Circuit Performance

Officer's Club West

Session Chairman: Michael Bombardier

2:45 **Mike Bombardier**
"Bond Over Active Circuitry Project Overview"

3:05 **Nikhil Handa**
"Bond Over Active Circuitry Failure Analysis"

3:25 **Jay Walston**
"Bond Over Active Circuitry Data Analysis"

Industrial Liaison: Matt Tyler

Faculty Advisor: Ian Harvey

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Industrial Liaison: Matt Tyler

Faculty Advisor: Ian Harvey

SESSION 6 **2:45 p.m.** **Officer's Club West**

BOND OVER ACTIVE CIRCUITRY PROJECT OVERVIEW

Mike Bombardier, Nikhil Handa, Jay Walston (Ian Harvey), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

Due to the never-ending drive in the semiconductor industry to minimize integrated circuit (IC) size, ON Semiconductor teamed with the University of Utah to form the ON Semiconductor Bond Over Active Circuitry (BOAC) Clinic Project with the intent of determining design rules for placing bond pads over active circuitry. The ON Semiconductor BOAC Clinic Project began with the design and layout phase that allowed the fabrication of BOAC test chips. In the design and layout phase, the BOAC Clinic team modified the layouts of ON Semiconductor standard chip libraries to include BOAC structures. These modifications were performed on the test chip parts library, the electrostatic-discharge (ESD) combined structures library, and the scribe line monitor (SLM) library. The modified layouts were delivered from the BOAC Clinic team to ON Semiconductor to allow fabrication of BOAC test chips. This presentation will discuss the motivation for BOAC circuitry, provide a clinic project overview, and discuss the specific layout design modifications made.

SESSION 6 **2:45 p.m.** **Officer's Club Wes**

BOND OVER ACTIVE CIRCUITRY PROJECT OVERVIEW

Mike Bombardier, Nikhil Handa, Jay Walston (Ian Harvey) Department of Electrical and Computer Engineering, University o Utah, Salt Lake City, UT 84112

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SESSION 6 3:05 p.m. Officer's Club West

BOND OVER ACTIVE CIRCUITRY FAILURE ANALYSIS

Nikhil Handa, Jay Walston, Mike Bombardier (Ian Harvey), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

The layouts modified by the ON Semiconductor Bond Over Active Circuitry (BOAC) Clinic were delivered from the Clinic team to ON Semiconductor to allow fabrication of BOAC test chips. ON Semiconductor returned packaged scribe line monitor (SLM) structures (a portion of the BOAC test chip) to the Clinic team for BOAC characterization and failure analysis (FA). The BOAC Clinic performed analysis of the SLM structures beginning with electrical characterization of the structures. Devices with non-characteristic curves were analyzed further using non-destructive and destructive FA techniques to identify failure modes and physical failure sites. Analyses of the other portions of the test chip were performed by ON Semiconductor. Results will be used to determine design rules for functional BOAC processes. This presentation contains a report on the methods used in performing the characterization and failure analysis of the SLM structures along with preliminary analysis results.

SESSION 6 3:05 p.m. Officer's Club Wes

BOND OVER ACTIVE CIRCUITRY FAILURE ANALYSIS

Nikhil Handa, Jay Walston, Mike Bombardier (Ian Harvey) Department of Electrical and Computer Engineering, University o Utah, Salt Lake City, UT 84112

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SESSION 6 3:25 p.m. Officer's Club West

BOND OVER ACTIVE CIRCUITRY DATA ANALYSIS

Jay Walston, Mike Bombardier, Nikhil Handa (Ian Harvey), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

It is common practice in industry to avoid placing bond pads over active circuitry. This is because bonding methods induce large amounts of stress that can potentially damage active circuitry. Bond pads are often the largest features on microchips and use up large amounts of wafer space. If methods were developed for active circuitry to be placed beneath bond pads, there is potential for a 15 percent reduction in die area in silicon controlled rectifier (SCR) based input/output (I/O) and a 60 percent reduction in die area for standard I/O. This reduction in die directly correlates to more die being included on a wafer, lower manufacturing cost per device, and increased profits. The ON Semiconductor Bond Over Active Circuitry (BOAC) Clinic Project targeted die reduction by performing an analysis on BOAC test chips. ON Semiconductor fabricated and delivered the scribe line monitor (SLM) portion of the BOAC test chips to the clinic team. This part of the presentation reports on the analysis of the data gathered from the SLM structures. The physical failure sites of the SLM structures will be shown and the recommendations of the Clinic team for functional BOAC processes will be reported on.

SESSION 6 3:25 p.m. Officer's Club Wes

BOND OVER ACTIVE CIRCUITRY DATA ANALYSIS

Jay Walston, Mike Bombardier, Nikhil Handa (Ian Harvey) Department of Electrical and Computer Engineering, University o Utah, Salt Lake City, UT 84112

It is common practice in industry to avoid placing bond pad over active circuitry. This is because bonding methods induce larg amounts of stress that can potentially damage active circuitry. Bon pads are often the largest features on microchips and use up larg amounts of wafer space. If methods were developed for activ circuitry to be placed beneath bond pads, there is potential for a 1 percent reduction in die area in silicon controlled rectifier (SCR) base input/output (I/O) and a 60 percent reduction in die area for standar I/O. This reduction in die directly correlates to more die bein included on a wafer, lower manufacturing cost per device, an increased profits. The ON Semiconductor Bond Over Activ Circuitry (BOAC) Clinic Project targeted die reduction by performin an analysis on BOAC test chips. ON Semiconductor fabricated an delivered the scribe line monitor (SLM) portion of the BOAC tes chips to the clinic team. This part of the presentation reports on th analysis of the data gathered from the SLM structures. The physica failure sites of the SLM structures will be shown and th recommendations of the Clinic team for functional BOAC processe will be reported on.

SESSION 7: Richard W. Grow Project

A Study in Vacuum Tube Field Emission from a C_{60} Coated Cathode

Officer's Club West
Session Chairman: Seaver W. Cauch

4:05 **Seaver W. Cauch**
"Physics and Physical Description of C_{60} Coated Palladium Cathode"

4:25 **Paul Beard**
"Attaching C_{60} to a Cathode for Testing"

4:45 **Doug A. Tucker**
"Field Emission Characteristics of a C_{60} Cathode"

5:05 **Stephen Pendrey**
"Finding the Current"

Faculty Advisor: Richard W. Grow

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SESSION 7: Richard W. Grow Project

SESSION 7 **4:05 p.m.** **Officer's Club West**

PHYSICS AND PHYSICAL DESCRIPTION OF C_{60} COATED PALLADIUM CATHODE

Seaver W. Cauch, Paul Beard, Doug A. Tucker, Stephen Pendrey (Richard W. Grow, J. Mark Baird, Carl Turnblom), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

In order to negate the problems of carbon nanotube coated cathodes in vacuum tube devices, carbon 60 (C_{60}), a spherical molecule, was bonded to a palladium substrate on the emitting surface of these tubes and the devices were tested. Palladium, with its unique metallic properties and suitable work function along with the round carbon molecules, were chosen to increase current across a specially designed tube device. The cathode was designed using a high thread count bolt as an emitting surface to roughly approximate a saw tooth pattern that was chosen because of its efficient emitting geometry. The tube, both the mount and emitter surface, was designed and fabricated in-house, and was implemented along with a specially treated cathode substrate. The flashed palladium surface was painted with C_{60} molecules with the aid of benzene, a substance in which the carbon molecules are highly soluble. Increases in current density at high voltages in the tube were seen going from control materials to palladium due to the metal's special properties, and the C_{60} proved to be capable of significant electron emission.

SESSION 7 **4:05 p.m.** **Officer's Club Wes**

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SESSION 7 **4:25 p.m.** **Officer's Club West**

ATTACHING C_{60} TO A CATHODE FOR TESTING

Paul Beard, Doug A. Tucker, Stephen Pendrey, Seaver W. Cauch (Richard W. Grow, J. Mark Baird, Carl Turnblom), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

Carbon has been an important topic of research with respect to vacuum tubes. It is drawing attention because it exhibits good field emission properties. This would make carbon ideal for cathodes, as it will not require the extreme heat currently used to produce current. Carbon nanotubes are the most widely used form of carbon. They have an ideal cylindrical shape and can emit from the end. They tend to have problems, though, as they bend when an electric field is applied. In an effort to get a more stable form, we decided to use carbon 60 (C_{60}), which has a shape similar to a soccer ball. This spherical shape should prevent the field emission surface from bending. In doing so it was important to be able to choose the correct materials to bind the carbon to the cathode. Stainless steel screws coated in palladium were used. Palladium was ideal because its work function is lower than many other metals, and it draws its outermost two electrons to the inner valence shell, thus leaving an empty outer shell which allows many things to bond well with it. In order to bond C_{60}, however, it was important to study how carbon nanotubes and carbon in general have been bonded before in order to choose a process to use. After doing research on the web as to the numerous techniques to bond, it was decided to use a liquid solution. Palladium tends to absorb some hydrogen-based molecules, and as such, we decided benzene would be ideal. Using a benzene solution we were able to attach C_{60} to our palladium coated cathode.

SESSION 7 **4:25 p.m.** **Officer's Club Wes**

ATTACHING C_{60} TO A CATHODE FOR TESTING

Paul Beard, Doug A. Tucker, Stephen Pendrey, Seaver W. Caucl (Richard W. Grow, J. Mark Baird, Carl Turnblom), Department o Electrical and Computer Engineering, University of Utah, Salt Lak City, UT 84112

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SESSION 7 4:45 p.m. Officer's Club West

FIELD EMISSION CHARACTERISTICS OF A C_{60} CATHODE

Doug A. Tucker, Stephen Pendrey, Seaver W. Cauch, Paul Beard (Richard W. Grow, J. Mark Baird, Carl Turnblom), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

Carbon has drawn a lot of attention in vacuum tubes because of its ideal field emission properties. Electrons can be easily pulled from the carbon using an electric field. Carbon nanotube molecules are the most commonly tested in microwave tubes and, in theory, the most significant. We wanted to put this theory to the test by using molecules of carbon 60 (C_{60}). In theory, these should work better than the carbon nanotubes because C_{60} is shaped like a soccer ball with hexagons and pentagons, forming a perfect ball. This will eliminate the problem of the nanotubes moving in the vacuum, which causes a lower field emission. Because this is an inventive test with C_{60}, we will be basing this study on the closely related carbon nanotube results. When applying these C_{60} molecules to a cathode, it is possible to obtain a considerably large amount of field emissions that could change the future for microwave tubes. When this is tested in a vacuum tube, it will exercise the Fowler Nordheim emission behavior. Current density is also deeply affected by the shape and size of the cathode. The cathode must be a clean metal which will produce no pollution in the vacuum. The cathode that was chosen is a stainless steel screw cut in half lengthwise, so we only have a half circle coated in palladium. Palladium is a very unique element because it is the only element that does not have any electrons in the outer shell, and as such, C_{60} will bond to palladium very easily. The threads on the screw have a fine point, which is desired to obtain higher field emissions. In order to understand these field emission properties we will be using a single thread point source. This study will be used to forecast the field emissions for the cathode as a whole.

SESSION 7 4:45 p.m. Officer's Club Wes

FIELD EMISSION CHARACTERISTICS OF A C_{60} CATHODE

Doug A. Tucker, Stephen Pendrey, Seaver W. Cauch, Paul Bear (Richard W. Grow, J. Mark Baird, Carl Turnblom), Department o Electrical and Computer Engineering, University of Utah, Salt Lak City, UT 84112

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SESSION 7 **5:05 p.m.** **Officer's Club West**

FINDING THE CURRENT

Stephen Pendrey, Seaver Cauch, Paul Beard, Doug Tucker (Richard W. Grow), Department of Electrical and Computer Engineering, University of Utah, Salt Lake City, UT 84112

Carbon 60 (C_{60}) has the capability to not only lower or eliminate the field fluctuations experienced on nanotube coated cathodes, but also help to reduce cathode wear and erosion. To obtain the highest quality and repeatable results, we will utilize a multi-tipped cathode coated with C_{60}. The cathode shape will appear as a saw tooth when observed from the side. This will provide a good average for multiple points of electron flow to the anode. To aid in the proper coating of the C_{60} we will plate our multi-tipped cathode with palladium. The chemical element Palladium with its empty outer shell will aid in attracting and distribution of the C_{60} evenly over the cathode. This paper will primarily focus on the diode problem. The diode problem is what we can expect from the current as we set up our C_{60} cathode. It will show that Child's Law was the obvious first step as we began. That was too limited so we moved onto the Child-Langmuir relation. While that provided a more accurate description through its equation, it was found that the Fowler Nordheim equation would be the most precise for our problem. This project may have wide-reaching effects as it has the capability of affecting just about every vacuum tube that will be made.

SESSION 7 **5:05 p.m.** **Officer's Club Wes**

FINDING THE CURRENT

Stephen Pendrey, Seaver Cauch, Paul Beard, Doug Tucker (Richar W. Grow), Department of Electrical and Computer Engineerin University of Utah, Salt Lake City, UT 84112

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