



Tektronix

先进的科学研究，尖端的测试测量

Advanced Measurement for Advanced Technology

CN FAE

8 JUNE 2016

KEITHLEY
A Tektronix Company

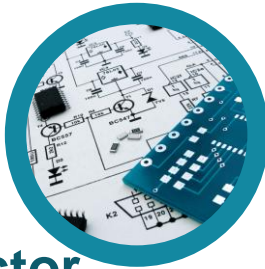
PART 1:
**New Material and
Nano-technology**



PART 4:
**Signal, Data
storage/sorting**



PART 2:
**Power
semiconductor
devices**



PART 5:
**Power
management**



PART 3:
**MEMS and
Semiconductor
Sensors**

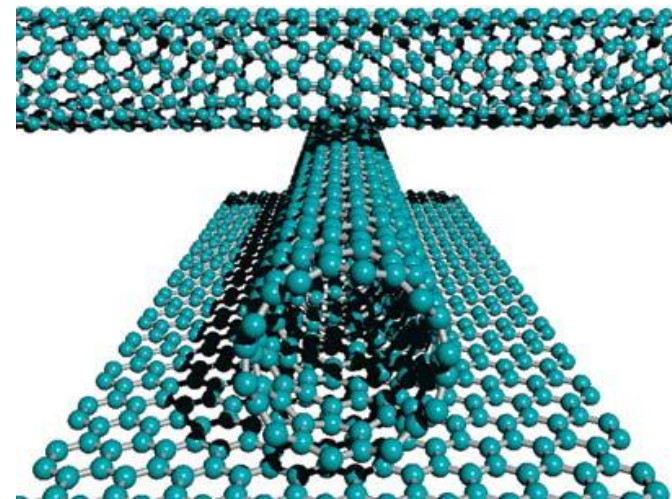
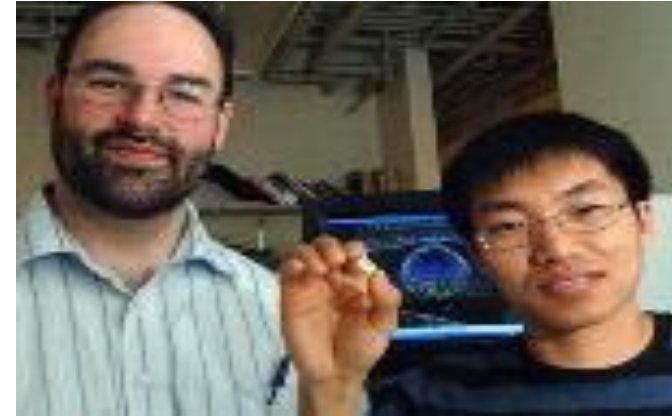


PART 6:
Opto-electronics



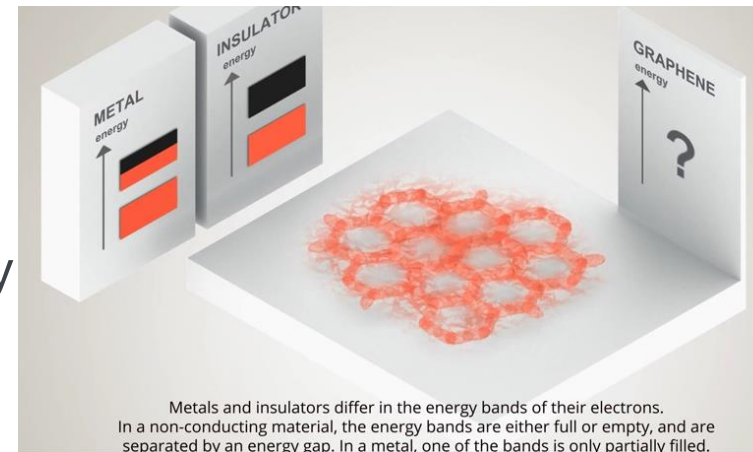
Nanoscale Materials & Devices

- Nanotechnology is science and engineering conducted at the nanoscale level
 - 1 to 100 nanometers
- Requires multiple disciplines:
 - Physics, material science, chemistry and measurement system design
- Nanoscale technologies have the potential to improve our quality of life
 - Medical delivery systems & detection
 - Faster electronics
 - Cheaper energy
 - Bio- and chemical detection systems



Nanoscale Materials & Devices

- Graphene:
 - 100 X stronger than the strongest steel
 - conducts heat and electricity efficiently
 - nearly transparent
 - And so on....



By Dexter Johnson

Posted 19 May 2016 | 20:00 GMT

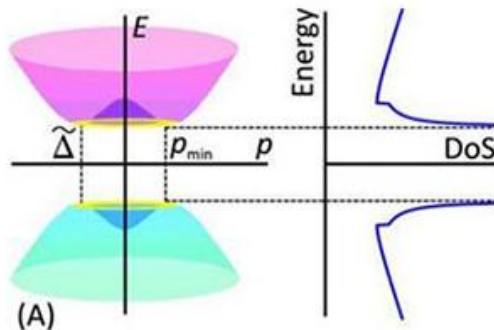
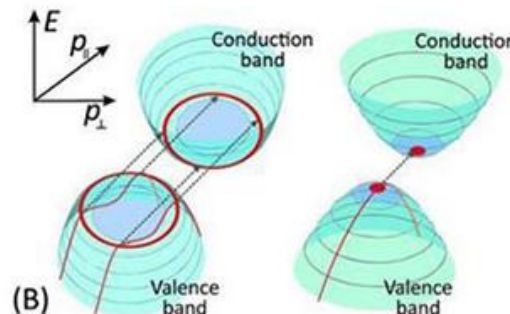


Illustration: Moscow Institute of Physics and Technology



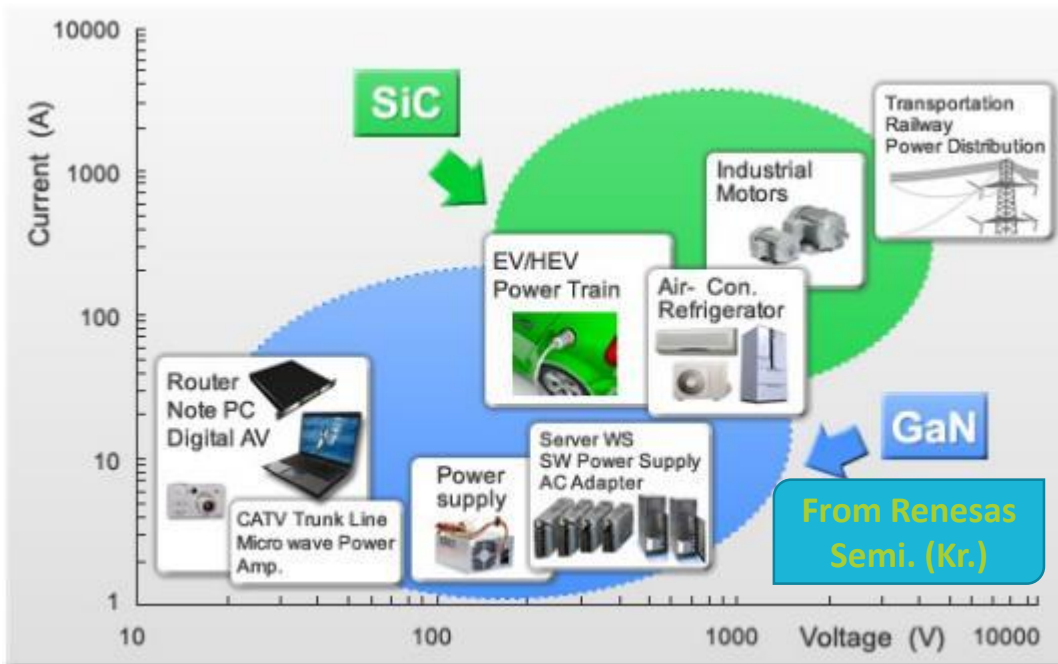
Researchers at the Moscow Institute of Physics and Technology (MIPT) [new tunnel transistor based on bilayer graphene](#)

- reduce its power consumption
- increase in processors' clock speeds (two orders of magnitude)

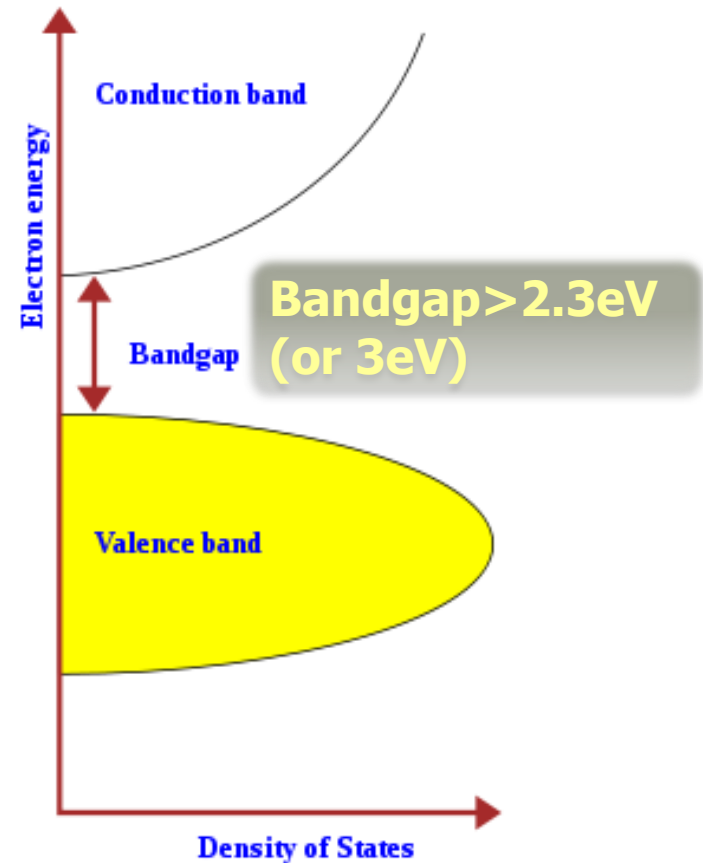
<http://spectrum.ieee.org/nanoclast/semiconductors/materials/bilayer-graphene-could-usher-in-new-tunnel-transistor>

Wideband Gap material : GaN, SiC

Wide bandgap materials are often utilized in applications in which high-temperature operation is important



WBG materials ?



WBG material: GaN, SiC

- Greater emphasis on *commercialization* of devices made from wide bandgap materials, especially SiC and GaN
 - Benefits of SiC and GaN:
 - Faster switching speed than Si → smaller passive components → smaller size and lower weight → higher efficiency
 - Lower switching losses than Si (especially lower recovery losses in diodes)
 - Lower leakage currents → better switch
 - Higher power density
 - Pack more power into smaller areas → higher efficiency
 - Higher operating temperature (especially SiC) → able to handle higher power with fewer parametric changes and without requiring cooling systems as extensive as silicon-based electronics → smaller size and higher efficiency



SiC



GaN

What is a Source Measure Unit (SMU)?

- Simultaneously source and measure voltage and/or current
- Perform resistance measurements



Precision DMM



Precision Power Supply



True Current Source

Source Measure Unit (SMU)



Electronic Load

Keithley SMU Family - Instruments



2400 SourceMeter SMU Instruments

- Family of single-channel models with I-V capability from 1100V to 100nV and 10.5A pulse to 1pA
- Smart alternative to separate Power Supplies and Digital Multimeters (DMMs)
- Convenient DMM-like user interface



2450 & 2460 Touchscreen SourceMeter SMU Instruments

- Industry-first 5" color capacitive touchscreen GUI
- Test up to 200V and 1A (**2450**) or up to 100 V and 7A (**2460**)
- Sub pA and sub μ V resolution



2600B System SourceMeter SMU Instruments

- Family of dual- or single-channel models with I-V capability from 10A pulse to 0.1fA and 200V to 100nV
- TSP® (Test Script Processor) technology for best-in-class throughput and lowest cost of test
- Browser-based GUI enables testing on any PC from anywhere in the world



2650A Hi-Power System SourceMeter SMU Instruments

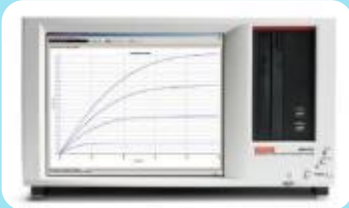
- Source and measure up to 3kV or 50A pulse, with best-in-class low current resolution
- Up to 2000W pulse or 200W DC power
- Optimized for characterizing and testing high power semiconductors, electronics, and materials

Keithley SMU Family - Systems



Parametric Curve Tracers

- Power device characterization up to 3kV and 100A including high quality instruments, cables, test fixturing, and software
- ACS Basic Edition software features real-time curve tracing and full parametric characterization modes
- Easily re-configurable to meet changing test needs



4200-SCS Semiconductor Parameter Analyzer

- An integrated analyzer for complete and precise characterization: I-V, C-V, Ultra-Fast I-V, and Pulse measurements
- Characterize devices, materials, and semiconductor processes with sub-fA resolution
- Easy-to-use Windows® GUI, modular architecture, and over 450 user-modifiable test applications simplify complex measurement



S530 Parametric Test Systems

- High-speed semiconductor parametric testing with low cost of ownership
- Designed for production and lab environments managing a broad range of devices and product wafers
- Proven SMU instrumentation technology ensures high measurement accuracy and repeatability



S500 Parametric Test Systems

- Highly configurable and scalable SMU instrument-based system
- Semiconductor device testing along with Automated Characterization Suite (ACS) at the device, wafer, or cassette level
- Ideal for SMU-per-pin Wafer Level Reliability (WLR) testing, high speed parallel test, die sort, and Process Control Monitoring (PCM)



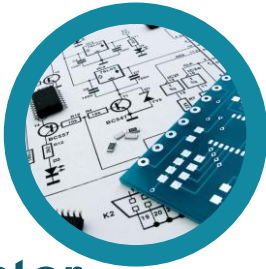
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Power semiconductor device:

- A power semiconductor device is a semiconductor device used as a switch or rectifier in power electronics; a switch-mode power supply is an example. Such a device is also called a power device or, when used in an integrated circuit, a power IC.
- **Typical device** : GTO / GTR / power MOSFET / IGBT

						
UPSs	High-End Power Supplies, Servers, etc.	HEVEV	Solar Panel Inverters	Industrial Motors and Drives	Wind Turbines	Electronic Transmission, Rail Traction, Ships
FETs, IGBTs, Diodes, GTOs	FETs, Diodes, GTOs	FETs, IGBTs, Diodes, GTRs	FETs, IGBTs, Diodes	FETs, IGBTs, Diodes, GTOs	IGBTs, Diodes	IGBTs, Diodes
2A-100A	0.5A-10A	50A-200A	75A	3A-100A	>150A	>200A
600V-1200V	600V	650V-2000V	600V-1200V	600V-1200V	690V (3kV~4kV in future)	>5kV

Characterization of power semiconductor device:

Characterization	Test Category	Devices and Parameters		
		IGBT	Power MOSFET	GTR
Static	ON-state	V_{CE-I_C} V_{GE-I_C}	V_{DS-I_D} V_{TH} V_{GS-I_D} $R_{DS(on)}$	V_{CE-I_C} Gummel plot
	OFF-state	I_{CEO} I_{CES} BV_{CES} BV_{CEO} BV_{CBS}	I_{GSS} I_{DSS} BV_{DSS} BV_{DG}	I_{CEO} I_{CES} BV_{CES} BV_{CEO}
Dynamic	Charge	Q_G	Q_G	NA
	Capacitance	C_{iss} (a.k.a. C_{ies}) C_{oss} (a.k.a. C_{oes}) C_{rss} (a.k.a. C_{res})	C_{iss} (a.k.a. C_{ies}) C_{oss} (a.k.a. C_{oes}) C_{rss} (a.k.a. C_{res})	
Switching	Timing	$T_{d(on)}$ T_r $T_{d(off)}$ T_f	$T_{d(on)}$ T_r $T_{d(off)}$ T_f	T_s T_f

Static Characterization directly describes DC performance and the quality of the devices, and the test is easy to perform.

Keithley Power Semi Test Solutions

MEET A WIDE RANGE OF CURRENT-VOLTAGE TESTING NEEDS

Up to 100A pulse for ON-State tests



Up to 3kV for OFF-State tests



Up to 10kV for breakdown voltage testing



Complete solution for ON-State, Off-State and C-V tests



NEW!! *Up to 7A DC, 10A pulse for interactive ON-State testing*

Keithley Power Semi Test Solutions

CONFIGURABLE SOLUTIONS

Single- or Dual-Channel
SMU Instruments



Options available:

- Software: ACS Basic Edition with built-in test libraries and real-time and parametric test modes
- Accessories: Test fixtures, protection modules, high voltage triaxial cables

COMPLETE SOLUTIONS

Parametric Curve Tracers



A complete bench top system that includes a variety of SMU instruments, cables, test fixtures, and software for characterizing power devices



Power Semi Test Accessories

SUPPORT A VARIETY OF MEASUREMENT TYPES AND SIMPLIFY SYSTEM INTEGRATION



Specialized Cabling



High Power Test Fixtures



High Voltage Bias Tee kits



Overvoltage Protection Modules

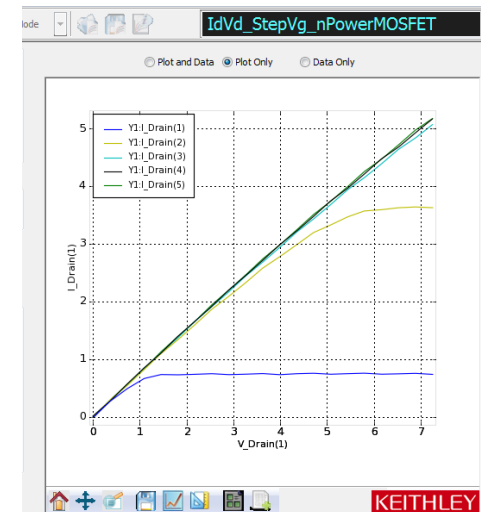
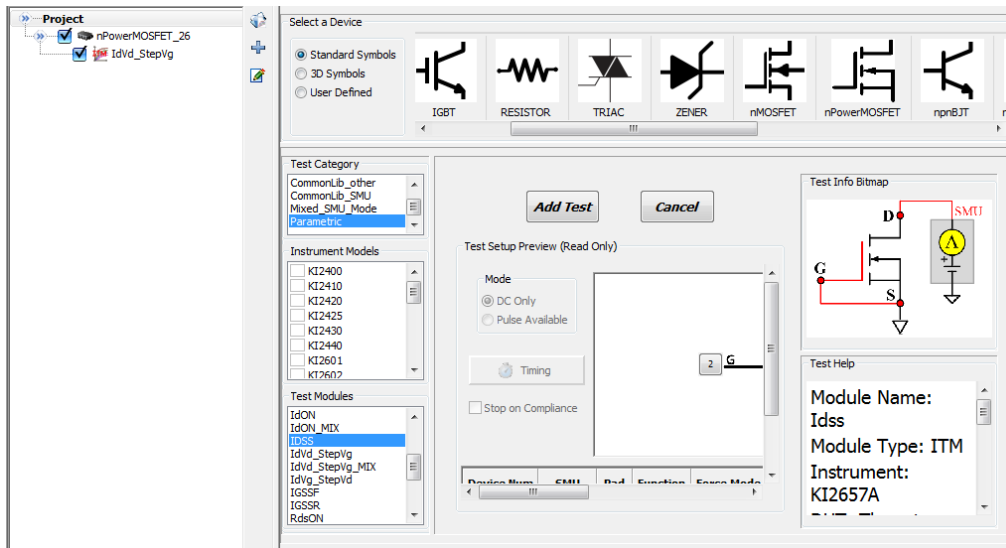


Power Semi Test Software

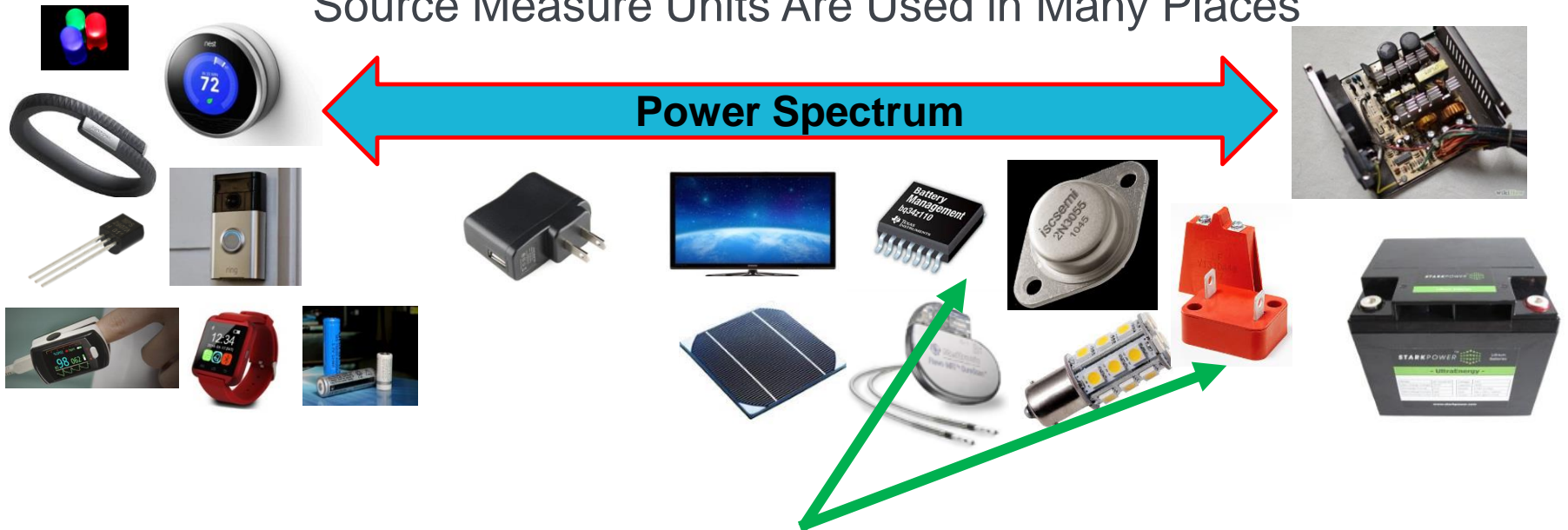
ACS BASIC, ACS



- ACS Software is the “glue” that brings all of the instruments together to make a solution
 - Supports Series 2400, 2600, and 4200 SMUs
- Includes hundreds of built-in device test libraries



Source Measure Units Are Used in Many Places



For designers/researchers of lighting, power management, power conversion & control circuits and related devices

- Power transistor forward characteristics
- Battery Load Curves
- Charger simulation
- Dynamic load simulation
- 7A DC, 10A pulsed
- **2460/2461 SMU**



Model 2461 SourceMeter SMU

KEITHLEY CONTINUES TO INVEST IN ITS LINE OF GRAPHICAL SOURCE MEASURE UNITS

new 10A @ 100V 1000W Pulse version of the Model 2460

- 1000W Pulse Source/Sink, 100W DC Source/Sink
- Pulses as fast as 150 μ S. Dedicated pulse screen and commands

new Dual 18-Bit 1MS/s Digitizers for simultaneous I&V. Store up to 5 million rdgs.

new Contact Check

- Succeeds the Model 2430, 2420-C, 2425-C, 2430-C, 2440-C SourceMeter SMUs. Opportunity to upsell to the 2461.



Ivy Android/iOS App – Visualize, Interact, Share For Series 2600B SourceMeter SMU Instruments



- **Visualize Instant Responses**

- Swipe to change the source value and instantly see your device's response

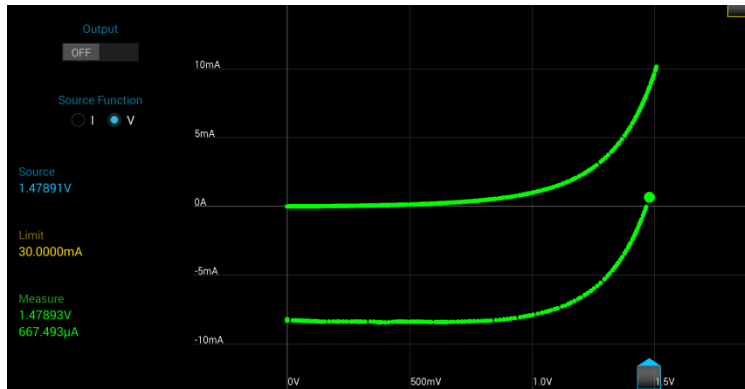
- **Interact for Better Understanding**

- Pinch and zoom to gain deeper insight into your device's performance

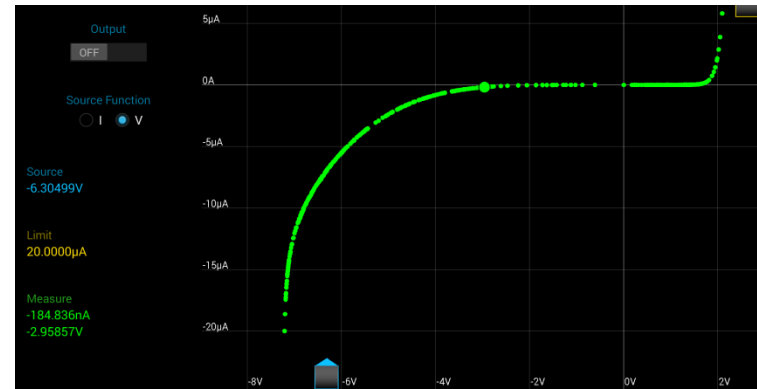
- **Share Your Results**

- Share screen shots and CSV files instantly using built-in Android tools

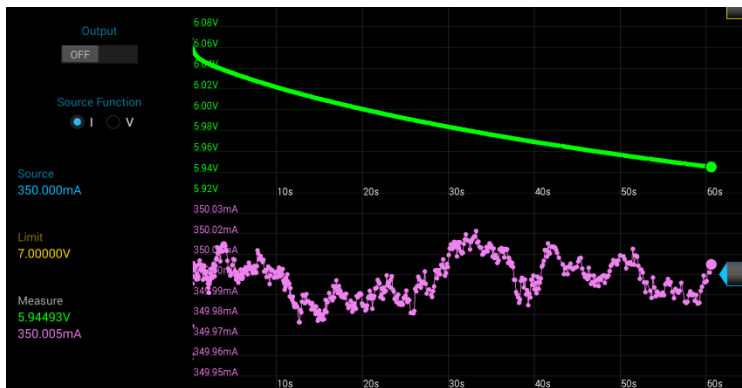
IVy Application Examples



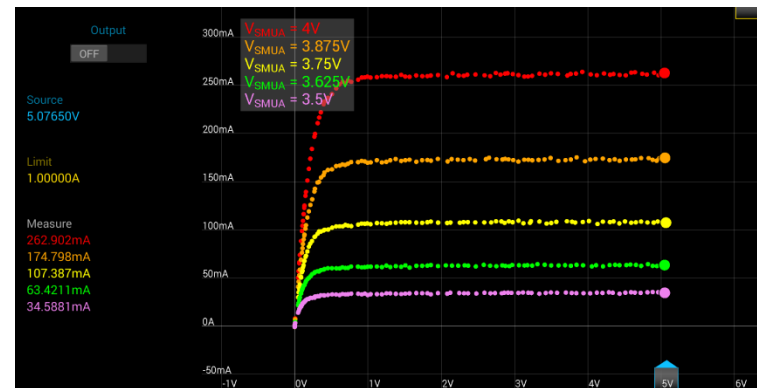
- DUT comparison



- Diode Reverse Bias



- LED Vf vs. Time



- MOSFET Family of Curves

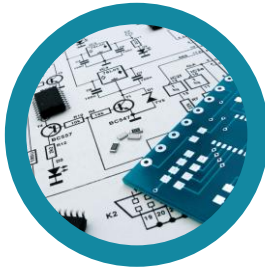
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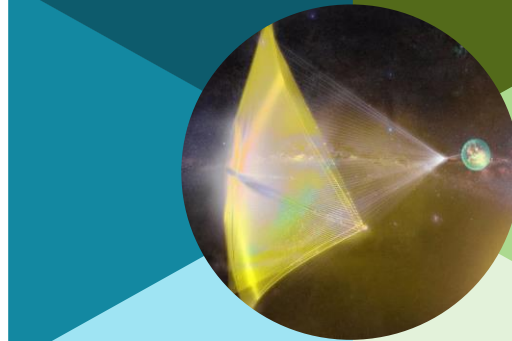
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**PART 6:
Opto-electronics**



MEMS Background



MEMS (Micro-electro-mechanical Systems)

The technology of fabricating **Micro** mechanical structures(devices), Usually in Silicon wafers

Sensors: turn non-electro-signal into electrical signal

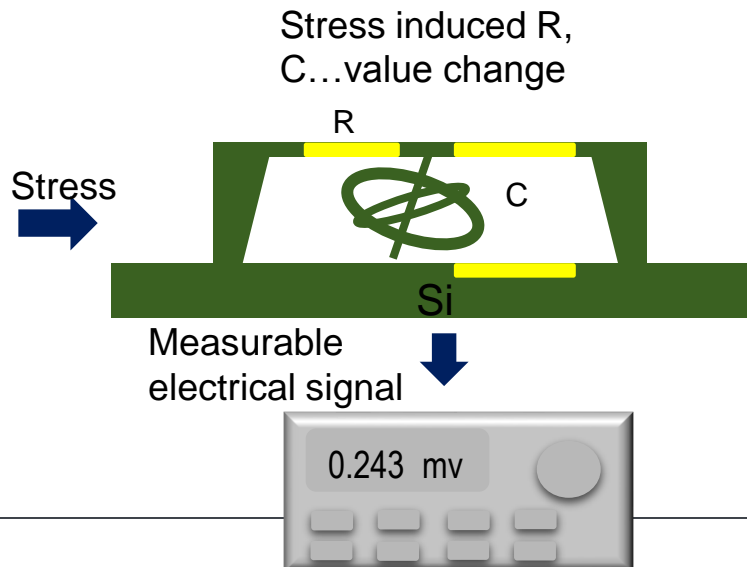
Widely Used

- ◆ Pressure/Force
- ◆ Light
- ◆ Vibration/ acoustic wave
- ◆ Fluidics
- ◆ Temperature
- ...

Actuator: Micro-motor moving or controlling a mechanism or system

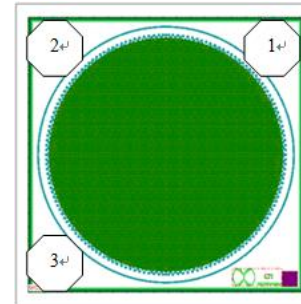
Structures: delicate structures for special use (silicon pump, e.g.)

- Classical application:
 - Accelerometers, MEMS gyroscopes (used in Wii, smart phone...)
 - Silicon pressure sensors (car tire, blood pressure)
 - Bio-MEMS (biosensor, chemosensor)
 - Optical switching (for data communication)

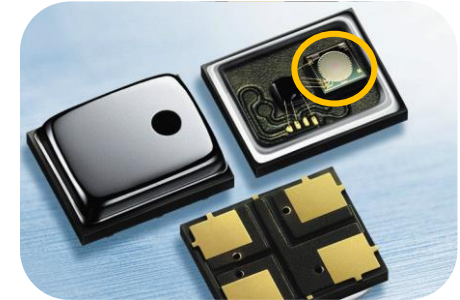


Keithley Solution for MEMS device test

- Customer application:
 - Test with sensor structure for its intrinsic characteristic without stress (pressure, vibration etc.)
 - To verify if fabricating process are within control.
 - **Micro-phone:**
 - Voice \rightarrow airflow \rightarrow Capacitance change in MEMS sensor \rightarrow electrical signal ---C test
 - **Pressure sensor:**
 - Pressure \rightarrow R change in MEMS sensor \rightarrow electrical signal ---R test
- Test requirement:
 - I-V:
 - R test: Force V measure I
 - $V < 10V$
 - $R \sim K\Omega$
 - C-V:
 - Capacitance test
 - $f = 100KHz$ $DCV < 30V$
 - $C \sim 10pF$ (0.1pF accu.)
 - wafer level with auto-prober

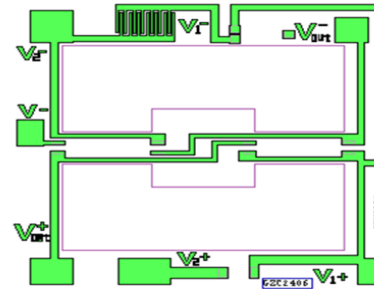


Customer Design



Product

Micro-phone



Customer Design



Product

Pressure sensor

Keithley Test Solution:

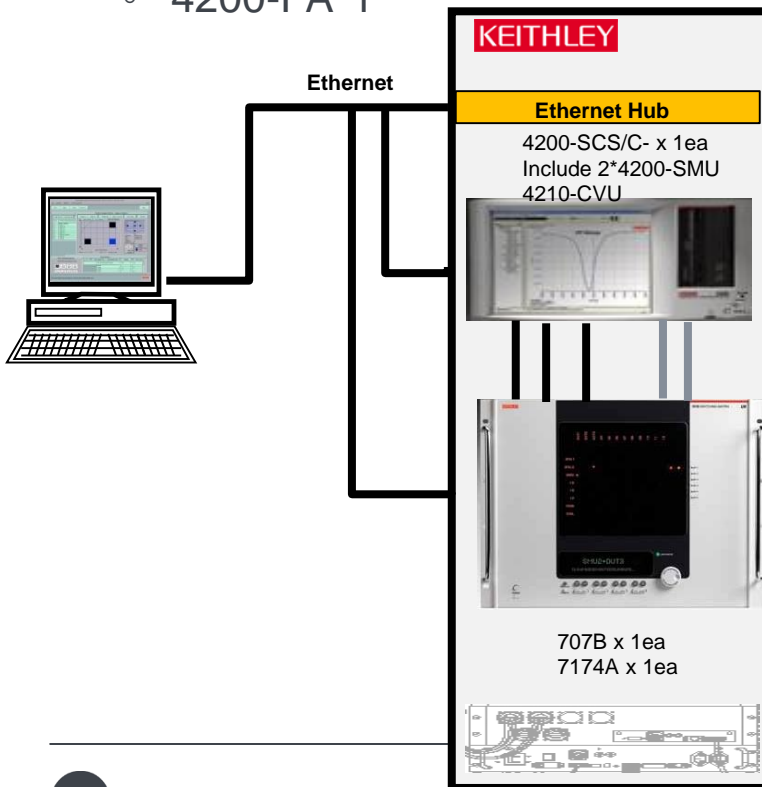
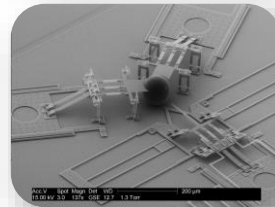
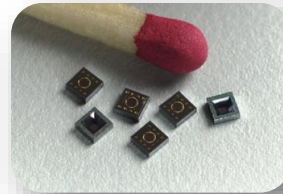
- Configuration:

- 4200-SCS/C x 1ea
- 4210-CVU*1
- 4200-SMU*2
- 4200-PA*1

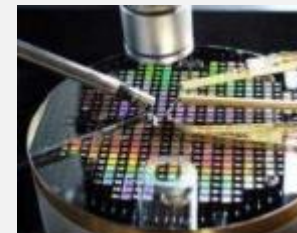
- 707B x 1ea
- 7174A x 1ea



S500 system



Prober station



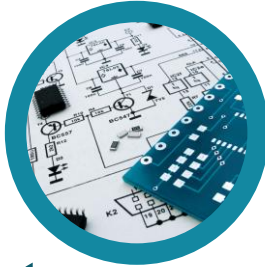
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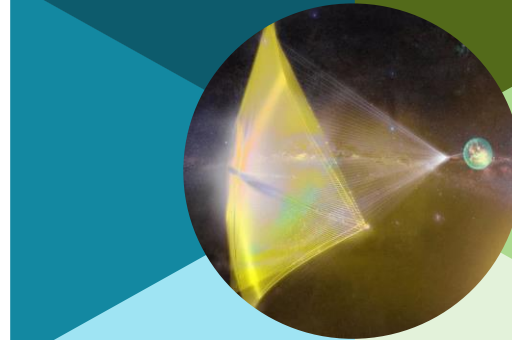
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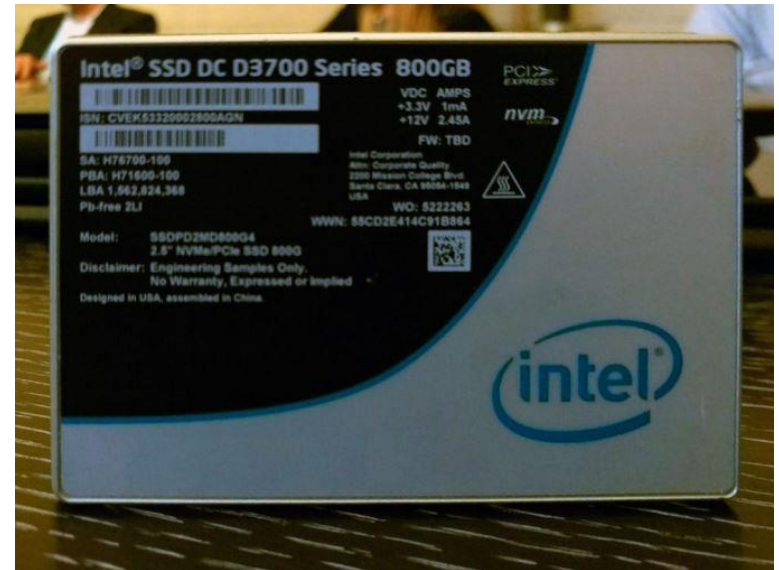
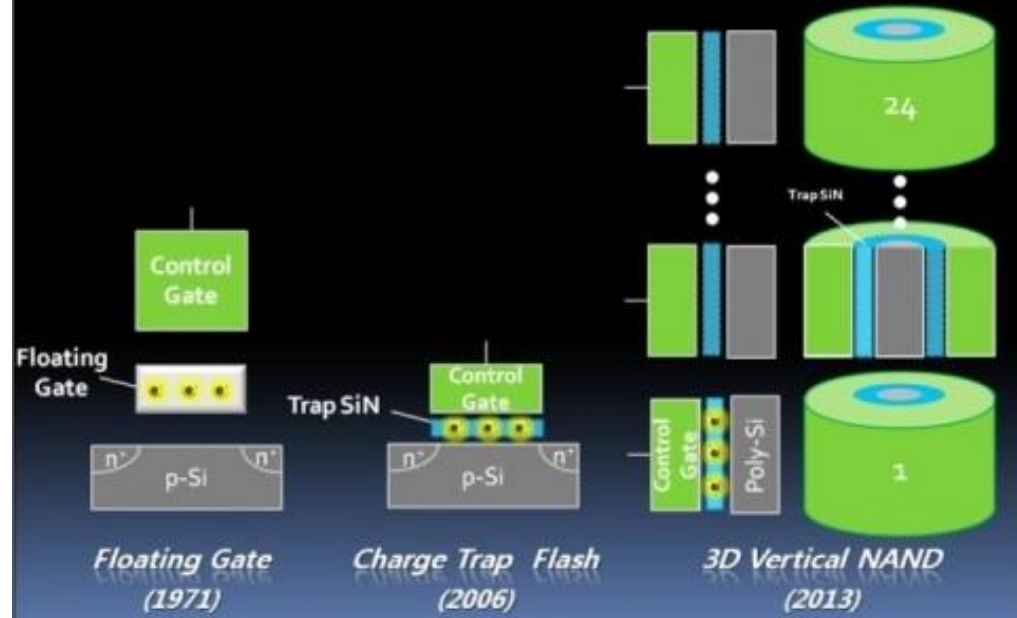


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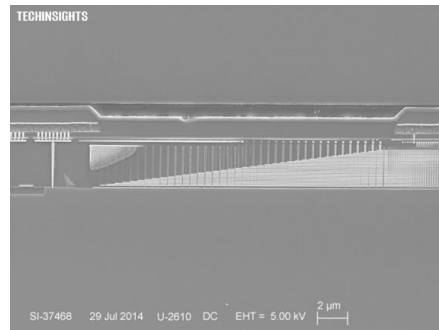


New Flash Memory, bigger and faster.

3D V-NAND Structure Innovation (Floating Gate → CTF → 3D V-NAND)

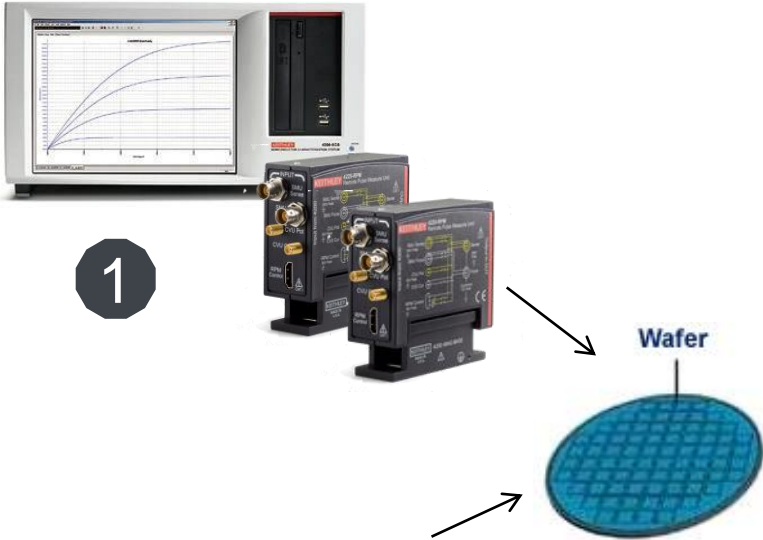


3D Nand Flash tech. makes the massive data store more easier and faster.

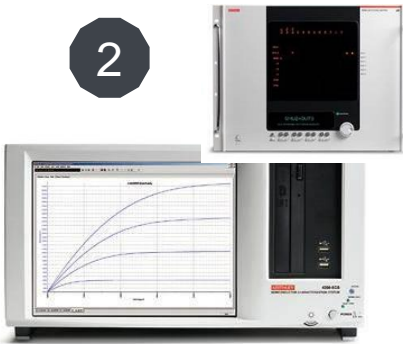


From How Samsung connects to the wordlines in the array (courtesy Technisights)

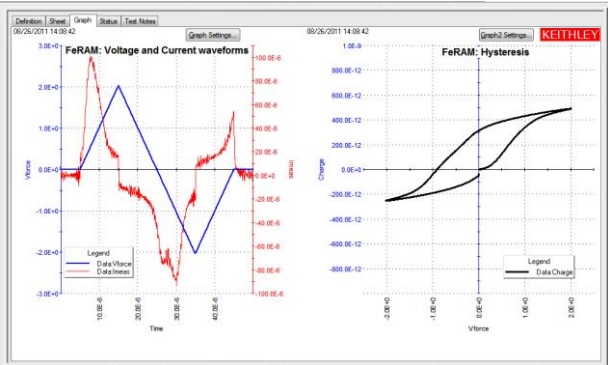
Non-volatile Memory Product Solutions



1

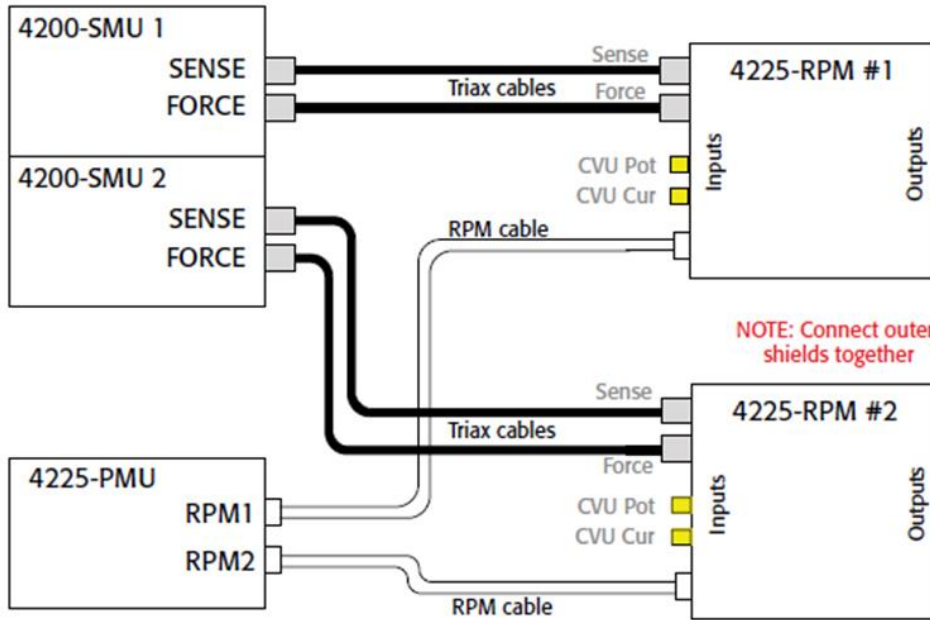


2



Configuration of Solution2 for 3D Nand Flash reliability test in one of our customer.

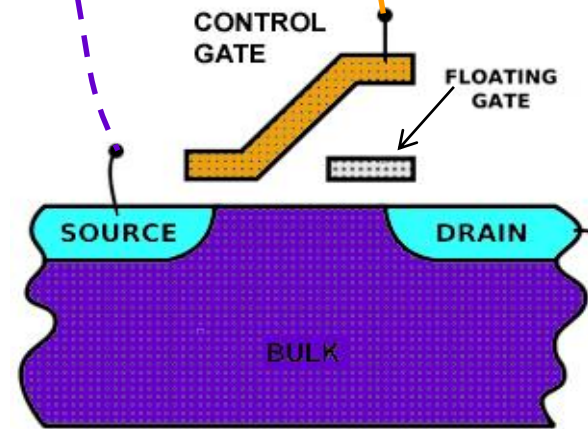
Example of Flash Memory Cell Test Setup



All connections made via the probe station



- SMUs are used to accurately measure V_t and I_D
- PMU and RPM are used to generate program/erase segments



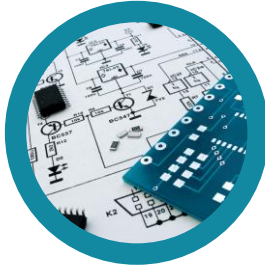
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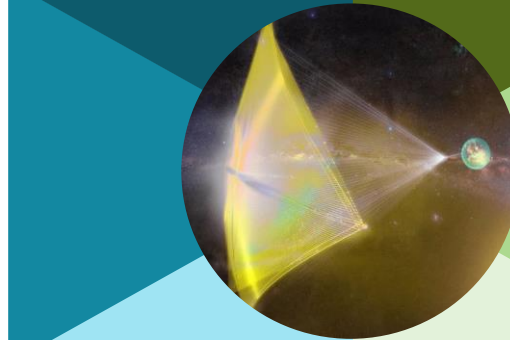
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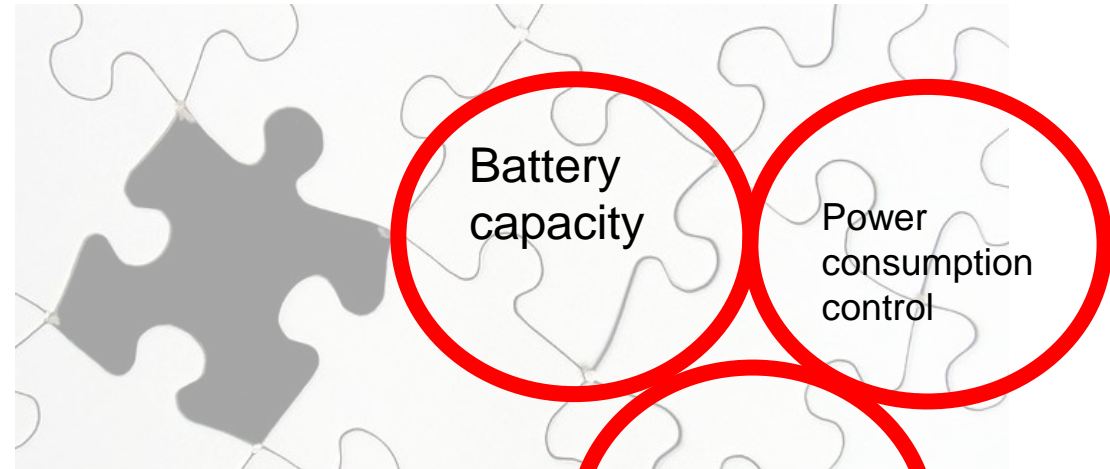


**PART 6:
Optical energy and
device**



More power and wisely use them

- Increase the Capacity of battery
 - **Ultra capacitor**: Need of Public transportation
 - **Electrochemistry** research for new battery
- Decrease the power consumption.
 - More accurate Power measurement for different mode.



“The limitation to the number of sensors and amount of generated data is the battery life of the Wearable.”

Power Management...is crucial in wearable technology because poor power management translates into battery drain...Battery life has a direct impact on a product’s real usefulness... Characterizing a usage profile is a non-trivial design activity.

**Measure
ment**

Mitch Maiman,
president and co-
founder of Intelligent
Product Solutions

Credit Suisse

Using SMU for Ultra-capacitor test

- Test Instrument:

- Keithley 2612/36B* for $C \leq 20F$
- Keithley 2651A for $C \geq 350F$



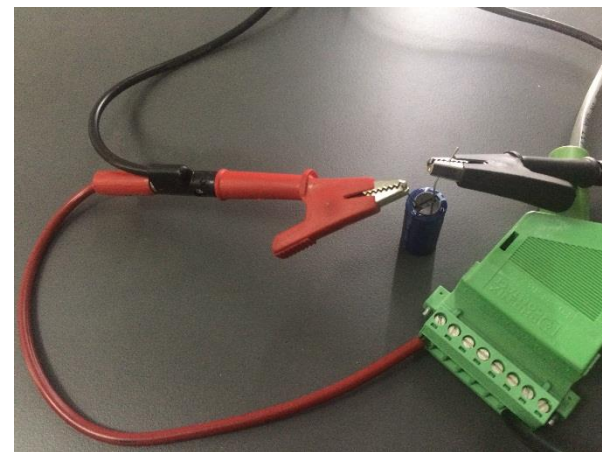
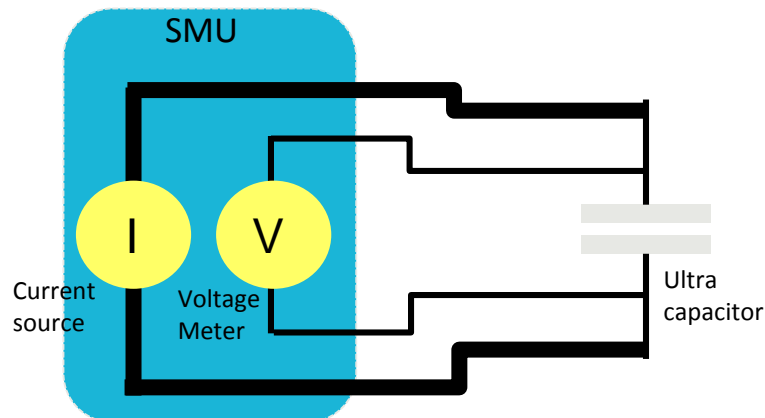
- Test Sample:

- KAMCAP 10F Urate=2.7V
- Maxwell 350F/3000F Urate=2.7V



- Connection:

- 4-wires connection (remote sense)



* The test instrument can be anyone of SMUs family as long as the current can fulfill the requirement.

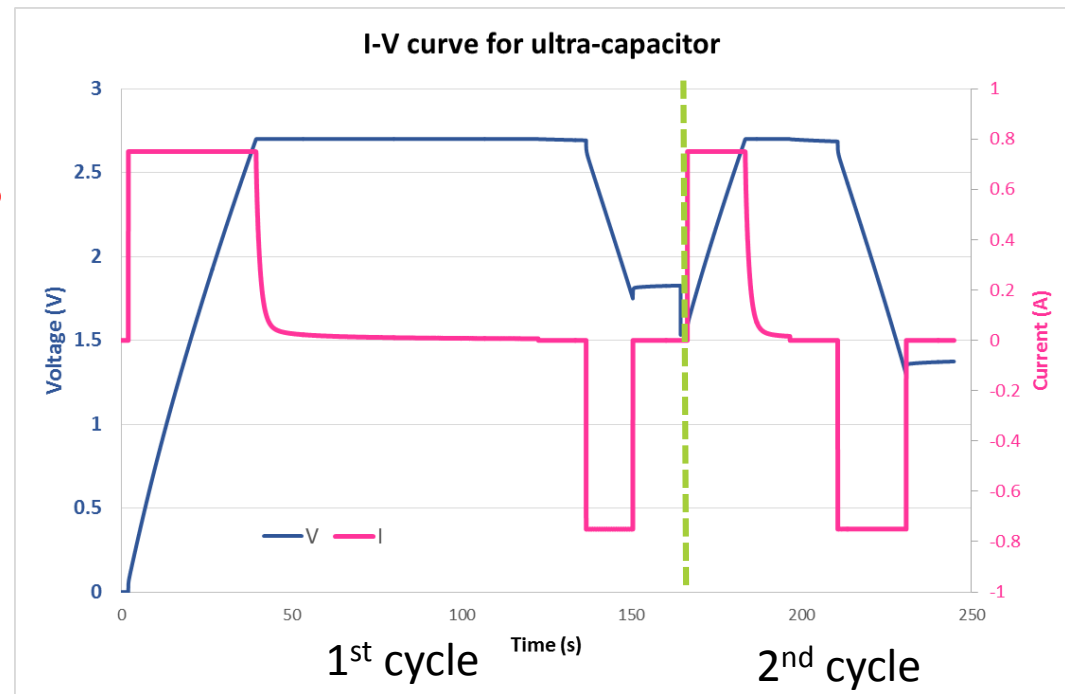
Experiment – Result

for **10F** capacitor with **2636B**

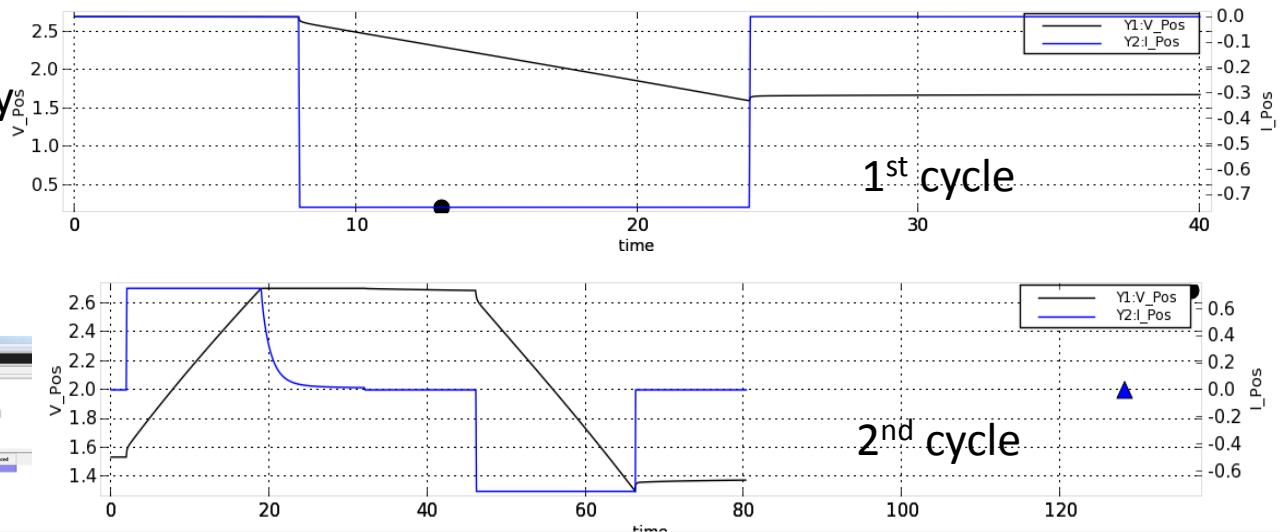
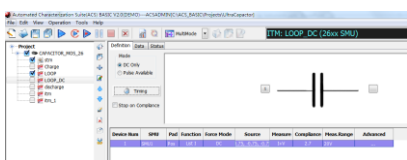
- Test result:
 - 2 cycles are tested

$$C_{ch} = I2 \times (t2 - t1) / (V2 - V1) = 10.93 \text{ F}$$

$$C_{dch} = I5 \times (t5 - t4) / (V5 - V4) = 10.88 \text{ F}$$

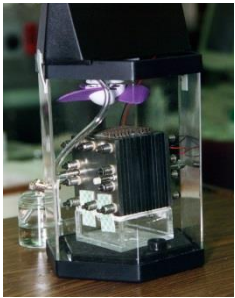


Test result chart by Keithley test software: ACS Basic



Programmable, sensitive, fast, accurate TEST.

Electrochemistry Applications



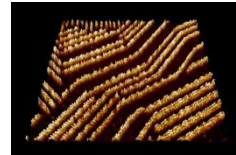
Basic Lab Research



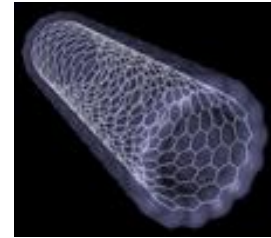
Electrode Development



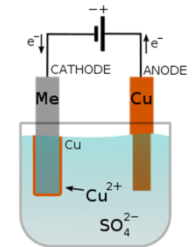
Electrolyte Research



Organic Semi



Nanomaterials



Electro-deposition



Dye-Sensitized Solar Cells



Health Care Sensors



Corrosion Resistance



Batteries



Fuel Cells



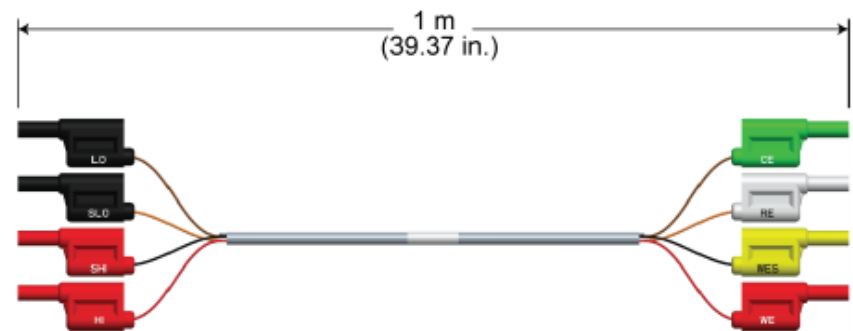
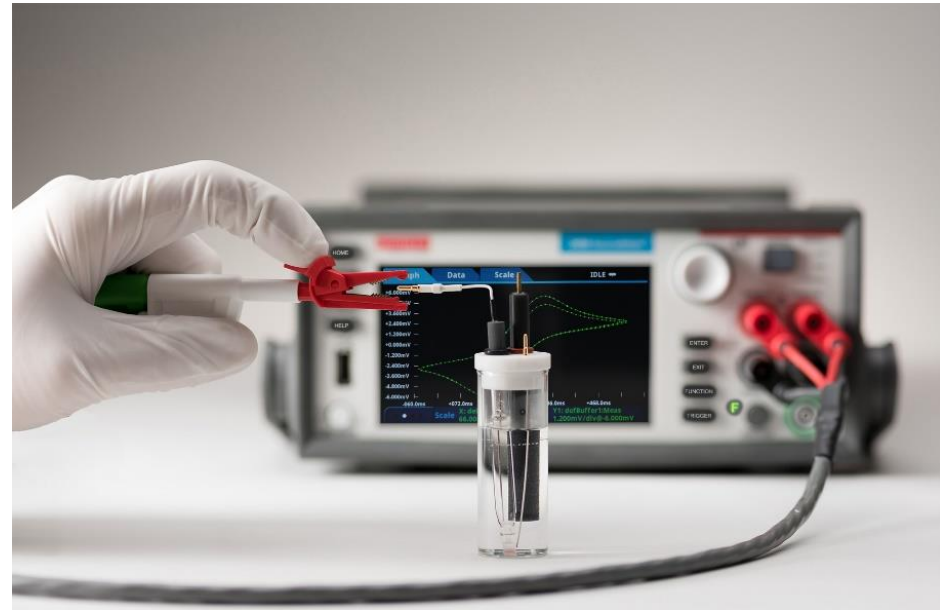
Super-capacitors

Electrochemistry is the cornerstone for many new products such as: batteries, glucose sensors, solar cells, coatings, medical devices etc.

Involving Research, Design, Characterization, Performance Testing

Keithley's Electrochemistry test solution

- 2450-EC: 1A, 200V, 20W Potentiostat/Galvanostat
- 2460-EC: 7A, 100V, 100W Potentiostat/Galvanostat
- Includes:
 - Potentiostat (SMU)
 - Cable for 2,3 or 4 electrodes
 - Built-in software with test techniques
 - Full documentation



Keithley SMU for Electrochemistry Applications

GROWING LIBRARY OF TECHNIQUES

- Cyclic Voltammetry
- Linear Sweep Voltammetry
- Open Circuit Potential
- Potential Pulse and Square Wave with Current Measure
- Current Pulse and Square Wave with Voltage Measure
- Chronoamperometry
- Chronopotentiometry

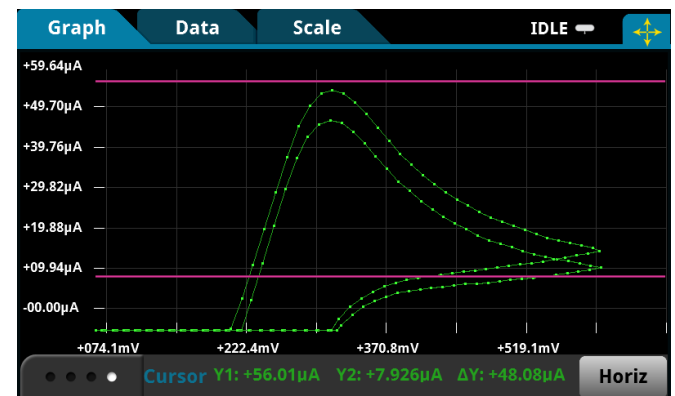
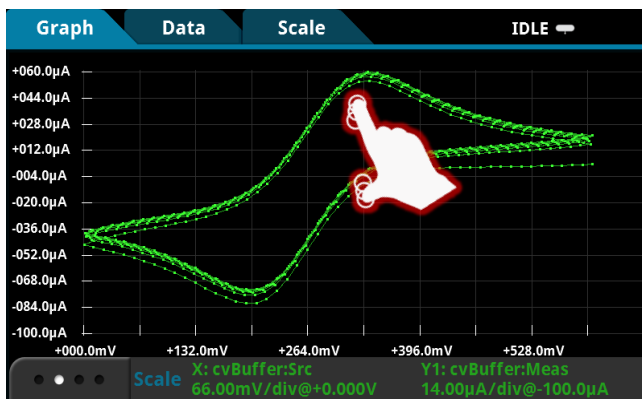
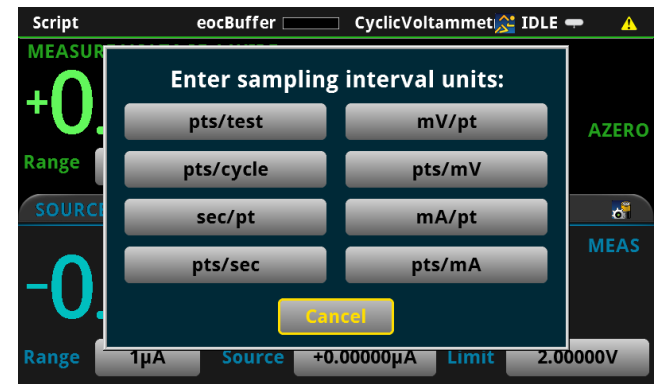
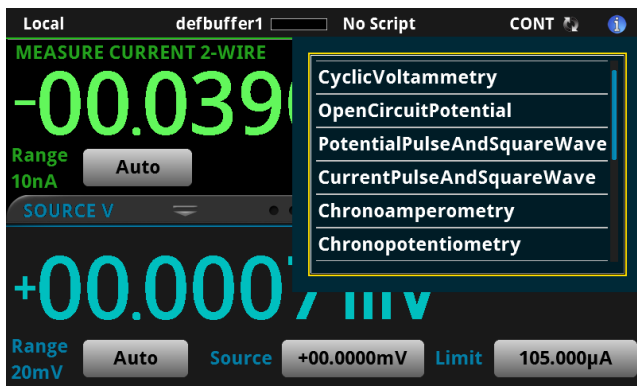


Distinctive differences

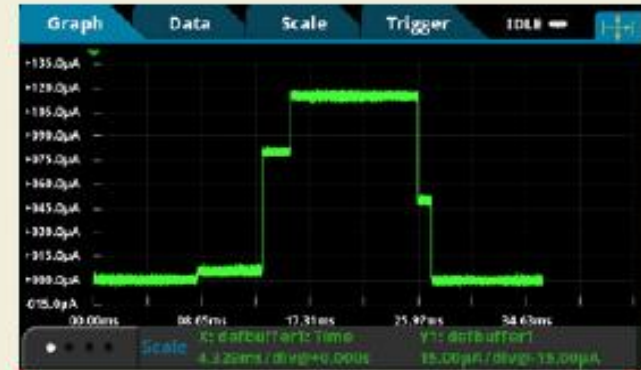
SIMPLICITY

Simplify learning
and test set-up

- Configure test, run experiment, generate voltammogram plot, analyze results



Solution for low power consumption measurement: DMM7510 + 2280S



DC power analysis using a
DMM7510 Graphical Sampling
Multimeter and 2280S High
Performance Power Supply.

Example Application

More Detailed Power Consumption Info with DMM7510



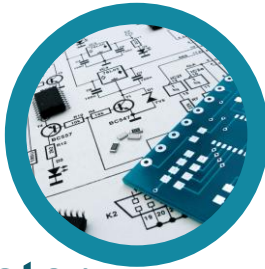
**PART 1:
New Material and
Nano-technology**



**PART 4:
Signal, Data
storage/sorting**



**PART 2:
Power
semiconductor
devices**



**PART 5:
Power
management**



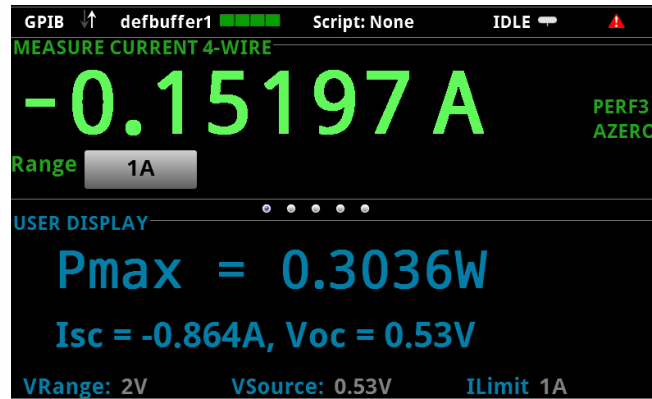
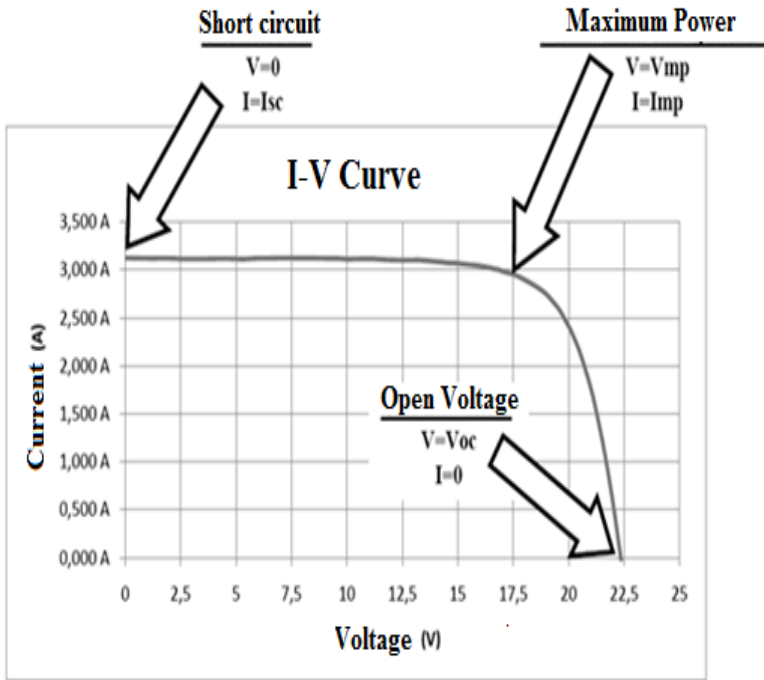
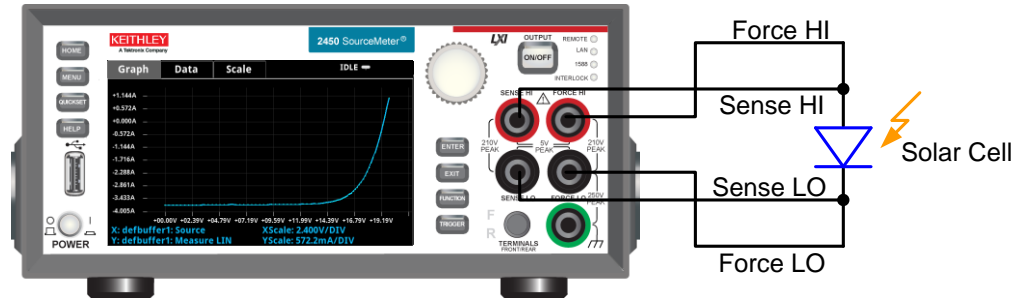
**PART 3:
MEMS and
Semiconductor
Sensors**



**PART 6:
Opto-electronics**



Optical energy: Solar cell



Better Solar Cell Testing: The Key to Faster Development and Production

James Niemann, Keithley Instruments, Inc.

Solar Energy Collection and Conversion

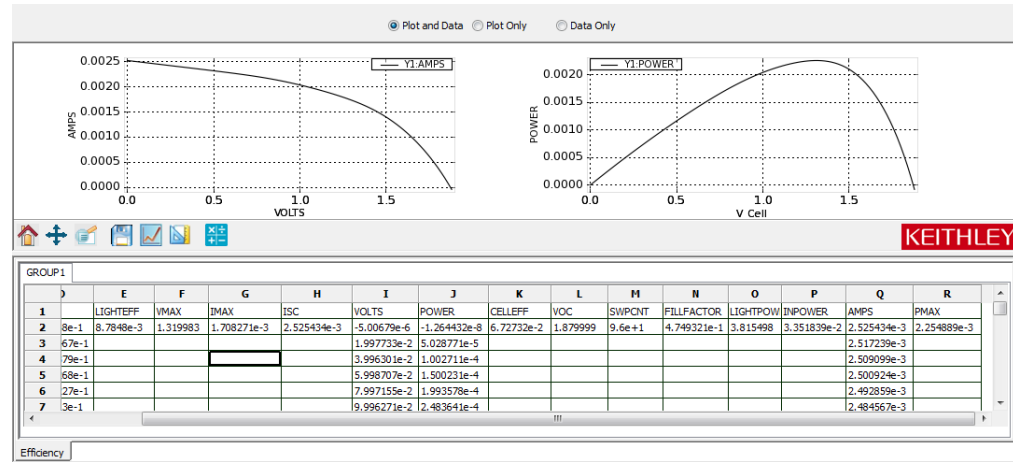
As more people seek ways to reduce their carbon footprint, solar energy is becoming a more popular option. In the United States, solar energy is projected to grow 25% in the next five years. A good deal of research is also being conducted in photovoltaic (PV) technology to improve efficiency and reduce the cost of solar energy. This research is being conducted in the form of solar cell testing. The solar cell testing process involves measuring the current and voltage of a solar cell under various conditions. This process is critical to the development and production of solar cells. Keithley Instruments provides a comprehensive solution for solar cell testing, including the Keithley 2450 SourceMeter. This instrument is designed to measure the current and voltage of a solar cell with high accuracy and precision. It also provides a variety of test modes and features that make it easy to use and integrate into a test system. The Keithley 2450 SourceMeter is a powerful tool for solar cell testing, and it is the key to faster development and production of solar cells.



Keithley provides solution from single cell research test and mass production test.



Solar cell test solution:

- Based on SMUs' powerful capability of I-V characterization, solar cell test engineers are able to test the cell or cells more efficiently along with ACS Basic solar cell suit.



		Max.Cur.	Max.Volt.	Min.Cur/Volt.	Software
SolarCell-24 	2450	±1.05A DC	±210V	10fA/10nV	ACS Basic
	2460	±7A DC	±100V	10fA/10nV	
SolarCell-26 	2601B	±3A DC/ ±10A Pulse	±40V	100fA/100nV	ACS Basic
	2611B	±1.5A DC/ ±10A Pulse	±200V	100fA/100nV	
	2635B	±1.5A DC/ ±10A Pulse	±200V	10fA/10nV	
	2651A	±20A DC/ ±50A Pulse	±40V	0.1fA/100nV	

符号	参数名称
Isc	短路电流
Voc	开路电压
Pmax	最大功率点
Imax	最大功率点处的电流
Vmax	最大功率点处的电压
FF	填充因子
η	转换效率
Rsh	并联电阻
Rs	串联电阻

太阳能电池测试参数



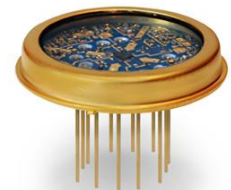
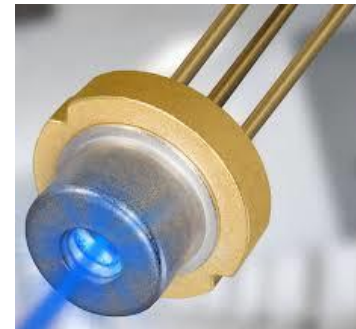
Standard Solar cell characterization test can be done in **ONE MINUTE!**

KEITHLEY

A Tektronix Company

Optical Module Components in Optical Communication

- Optical communication (a.k.a. optical telecommunication) is communication at a distance using light to carry information.
- Electrical signal (message) → optical signal → Electrical signal (information)
- “sender” and “receiver”
 - Laser diode
 - Photo detector



Keithley solution for Optical Module Components test

- Final DC test, Process control DC test, Coc parallel test, FA test for TOSA/ROSA, Tuneable, Coherent etc., telecom, Datacom products

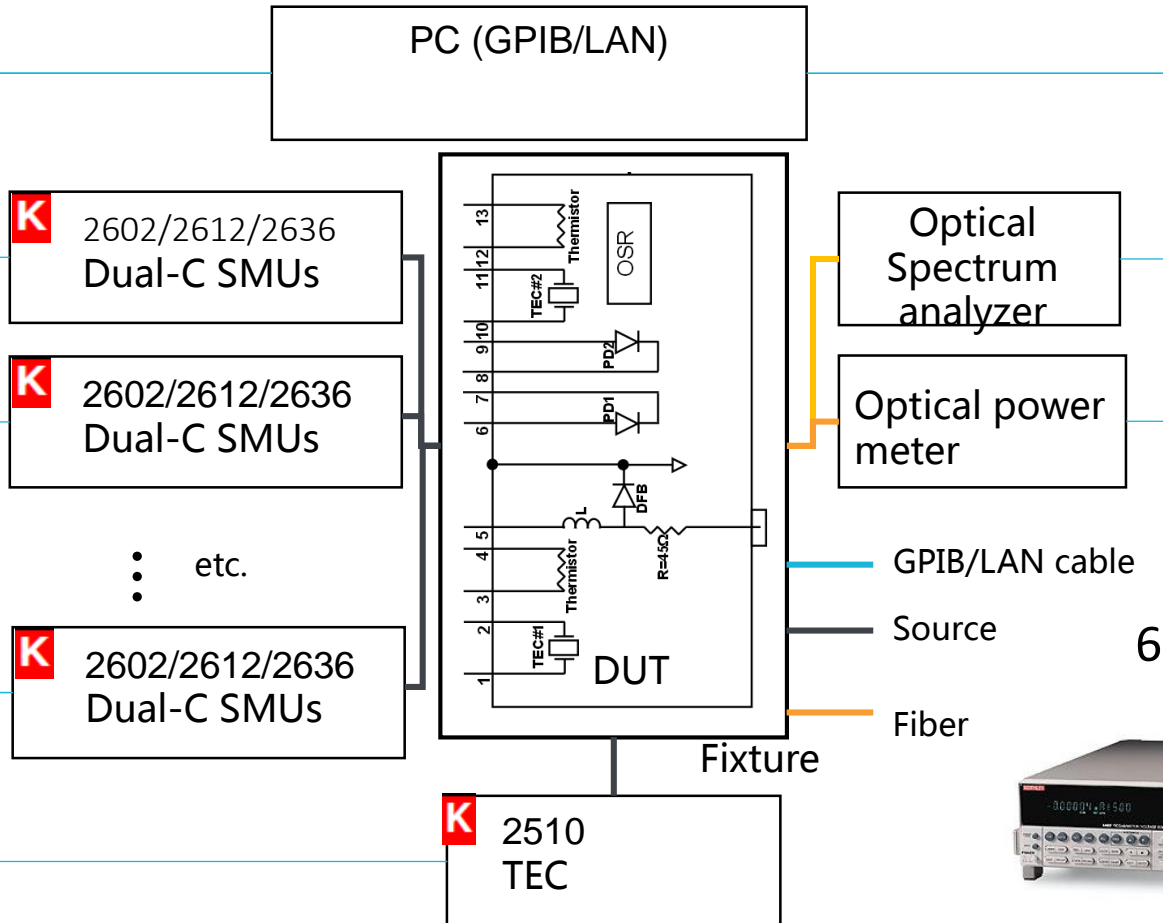
26** SMU:

- 4-quadrant voltage/current source and measure instruments
- 10A pulse to 0.1fA and 200V to 100nV
- TSP (Test Script Processing) technology



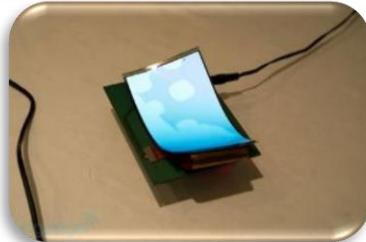
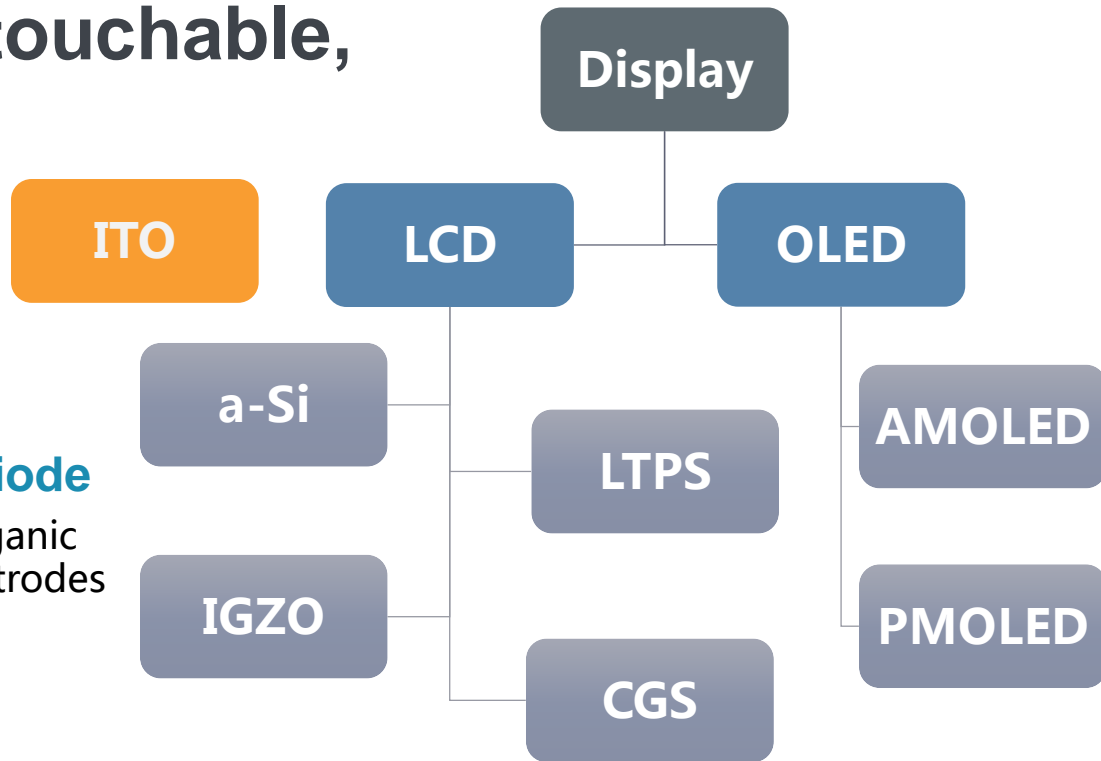
6485/6487 Picoammeter/Source

- 10fA (10x10-15A) sensitivity
- <200μV voltage burden
- Bipolar 500V floating source
- Displays resistance

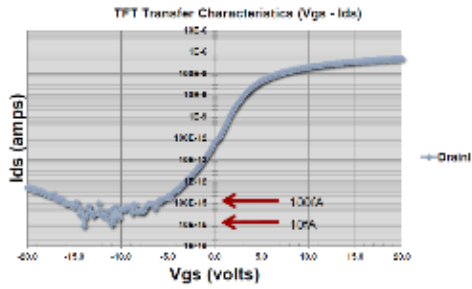
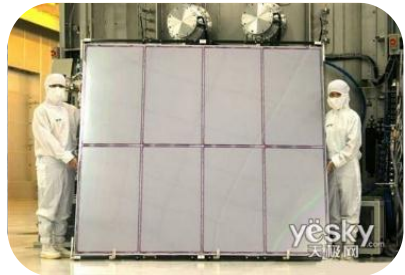


Display: wearable, touchable,

- LCD: Liquid crystal display
 - TFT: Thin film **Transistor**
 - liquid crystal molecular
 - Backlight (light source)
- OLED: Organic Light Emitting **Diode**
 - “Sandwich” structure: organic semiconductor between two electrodes
 - Each pixel is LED/LEDs



Keithley solution for Display



IV test

Switch Matrix

CV/IV test



S500/S530 system for TEG test in Display manufacture

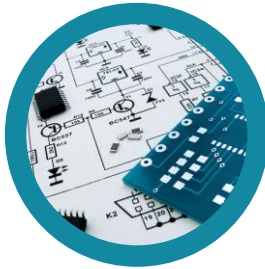
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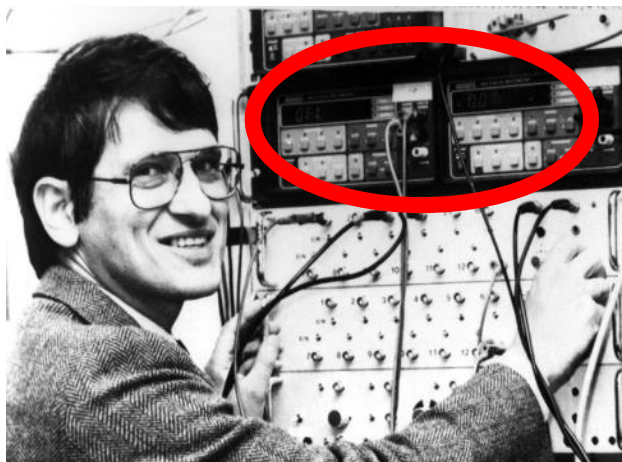
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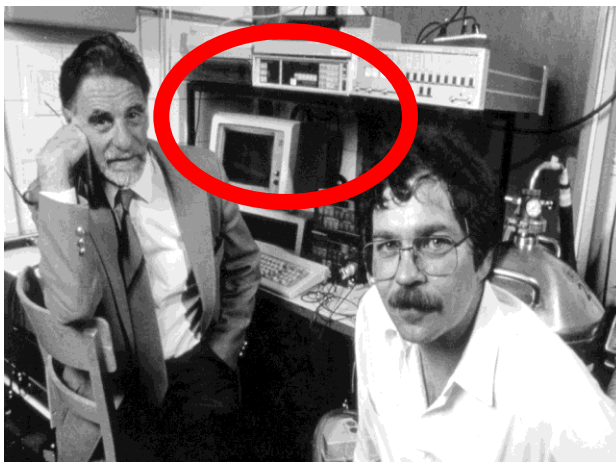
**PART 6:
Opto-electronics**



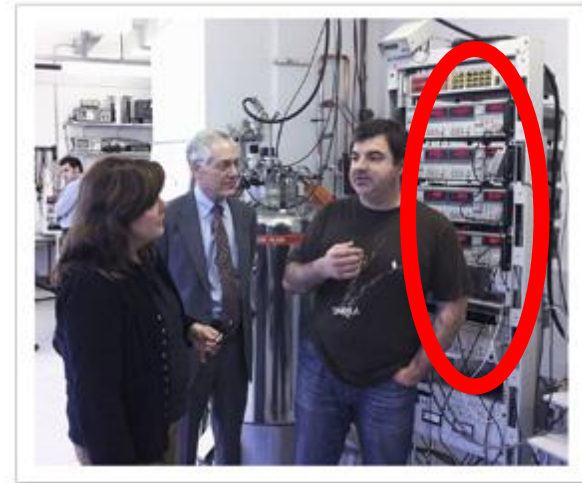
Researchers use Our Sensitive Instruments to Make Great Scientific Discoveries



Dr. Klaus von Klitzing
1985 Nobel Prize in Physics
Quantized Hall effect



Dr. K. Alexander Muller and
Dr. J. Georg Bednorz
1987 Nobel Prize in Physics
Superconductivity in ceramic
materials

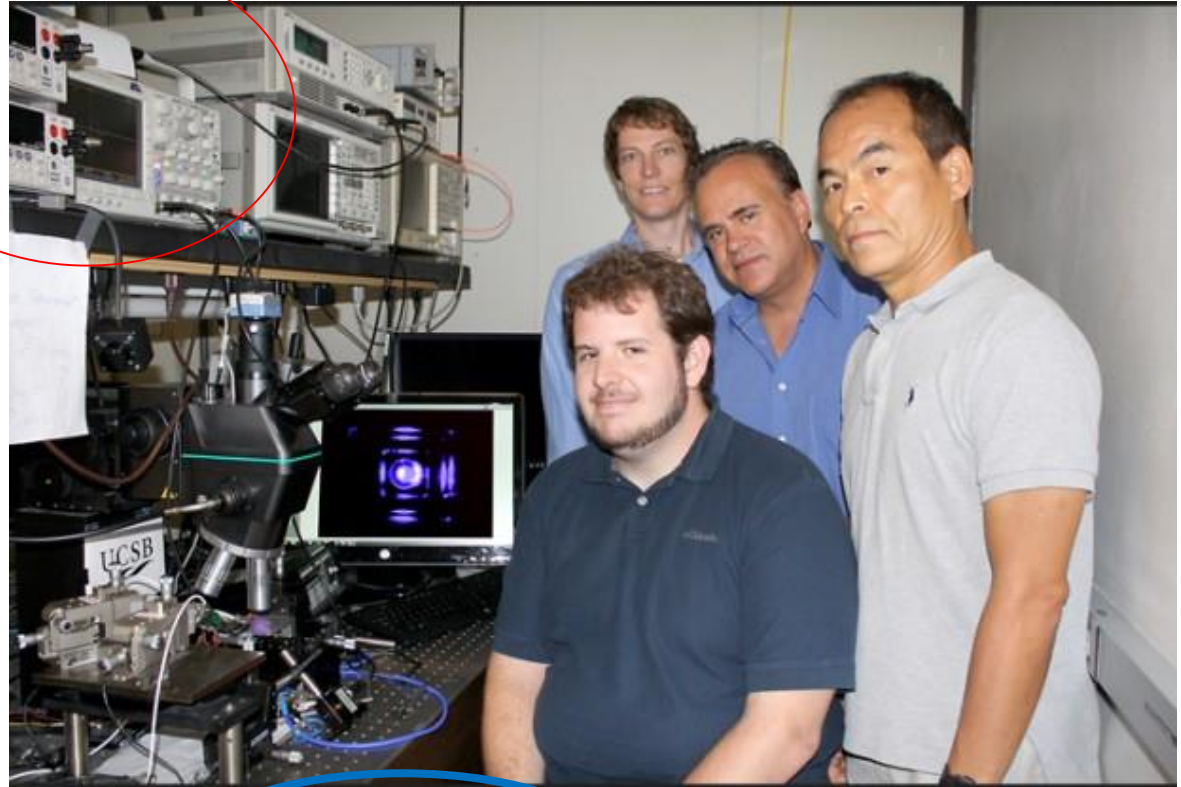


Dr. Konstantin Novoselov
2010 Nobel Prize in Physics
Graphene (two dimensional
material)

And They Need All Our of Equipment

Typical University/
Research Lab

- SourceMeters
- Scopes
- Power Supplies
- DMMs
- Other Equipment



2014 Physics Nobel
Laureate for the
development of the
Blue LED

Shuji Nakamura and his research group at UCSB.

Credit: UC Santa Barbara

**Team that invented Violet Nonpolar
Vertical-Cavity Laser Technology**

Need More Sensitivity: The Most World's Most Sensitive Meter

Sensitivity:

0.000000000000000000000001A (10^{-18} A, 1aA)
 = 6.241 electrons/second


Note: Q of $1e^- = 1.6 \times 10^{-19}$ C
 $1A = 6.2 \times 10^{18}$ electron/second



Our Key Advantage:

□ the world's most sensitive current measurement instrument





**Today, we commit to this next great leap
into the cosmos.
Because we are human.
And our nature is to fly.**

Tektronix[®]