先进的科学研究，尖端的测试测量

Advanced Measurement for Advanced Technology

CN FAE

30 SEPTEMBER 2016

A Tektronix Company

Advanced Measurement for Advanced Technology

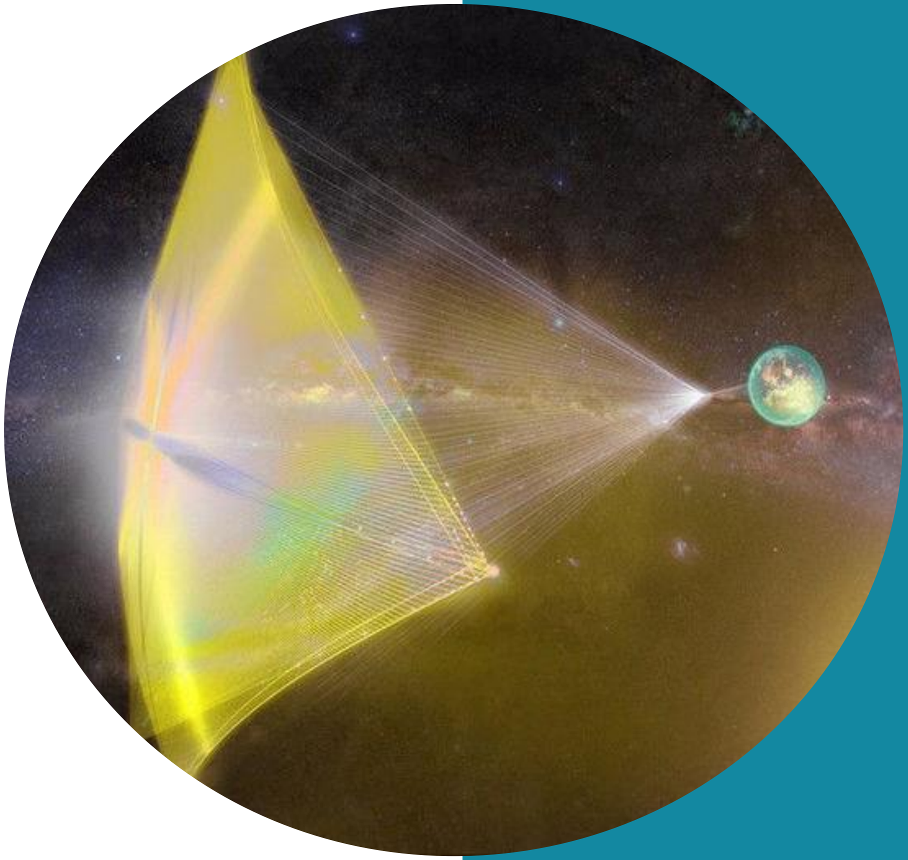
BREAKTHROUGH
STARSHOT

http://breakthroughinitiatives.org/

Advanced Measurement for Advanced Technology

http://breakthroughinitiatives.org/

To achieve this, what's the challenge there?

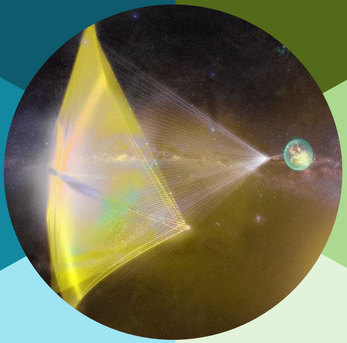


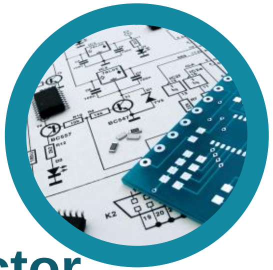
PART 1:

New Material and Nano-technology

PART 4:

Signal, Data storage/sorting





PART 2:

Power semiconductor devices

PART 5:

Power management

PART 3:

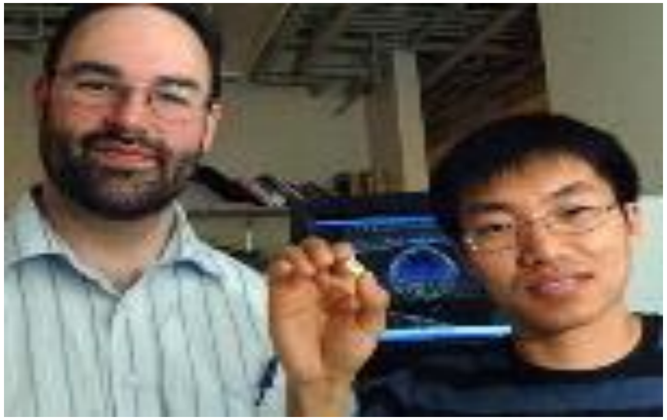
MEMS and Semiconductor Sensors

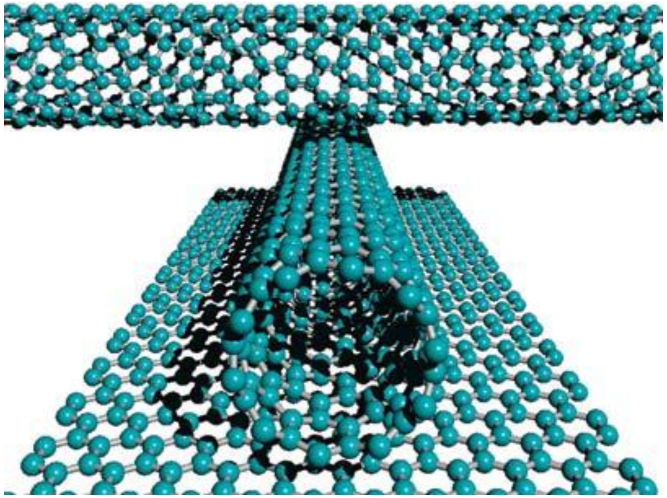
PART 6:

Opto-electronics

Nanoscale Materials & Devices

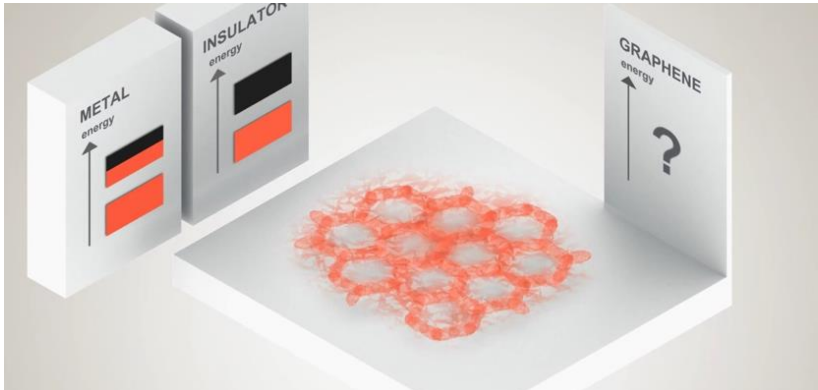
- Nanotechnology is science and engineering conducted at the nanoscale level
  - 1 to 100 nanometers
- Requires multiple disciplines:
  - Physics, material science, chemistry and measurement system design
- Nanoscale technologies have the potential to improve our quality of life
  - Medical delivery 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….



Metals and insulators differ in the energy bands of their electrons.
In a non-conducting material, the energy bands are either full or empty, and are separated by an energy gap. In a metal, one of the bands is only partially filled.

By Dexter Johnson
Posted 19 May 2016 | 20:00 GMT

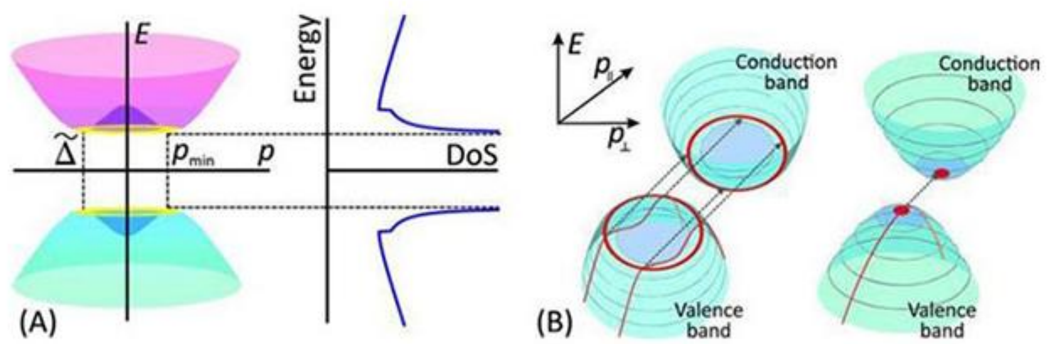


Illustration: Moscow Institute of Physics and Technology

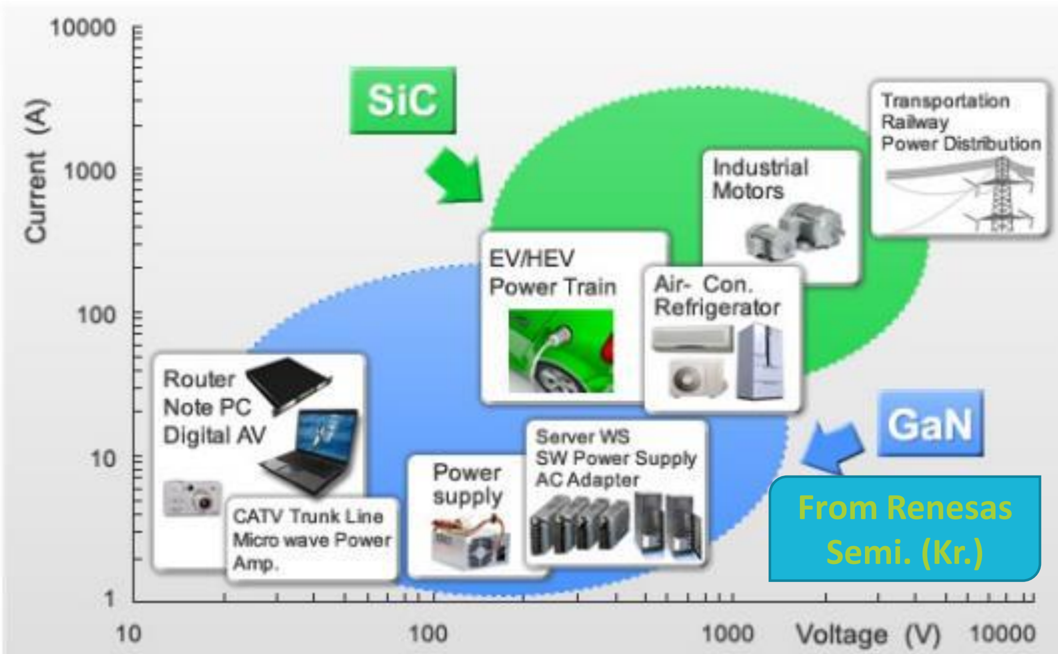
Researchers at the Moscow Institute of Physics and Technology (MIPT) new tunnel transistor based on bilayer graphene

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

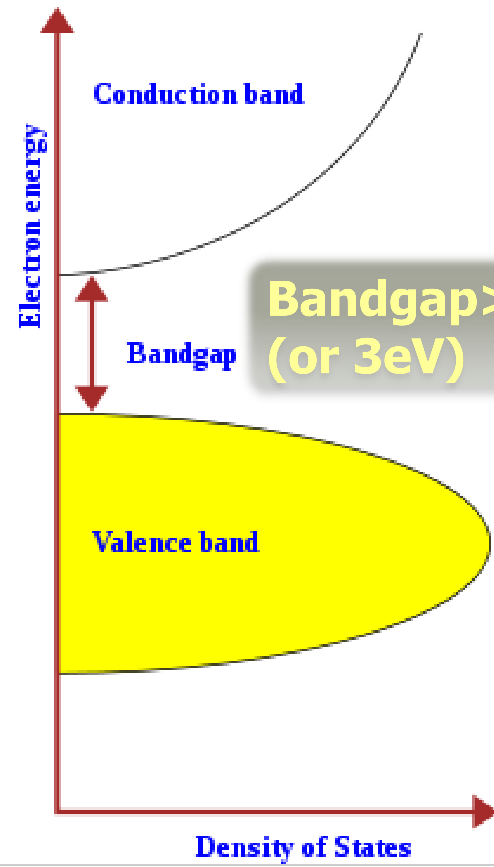
http://spectrum.ieee.org/nanoclast/semiconductors/materials/bilayer-graphene-could-usher-in-new-tunnel-transistor

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

Source Measure Unit (**SMU)**

Precision Power Supply

True Current Source

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 µV 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

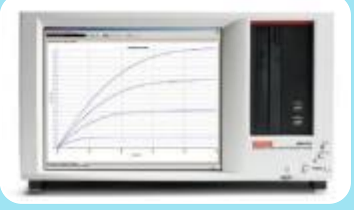
2650A Hi-Power System SourceMeter SMU Instruments

- 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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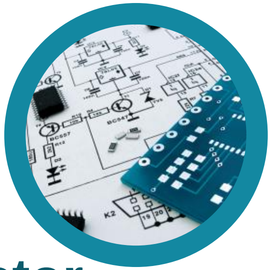
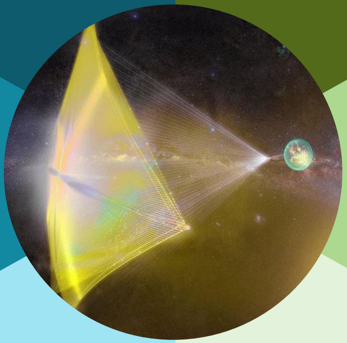


Power semiconductor devices



PART 5:

Power management

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MEMS and Semiconductor Sensors

PART 6:

Opto-electronics

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 VTH 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 descripts DC performance and the quality of the devices, and the test is easy to perform.

KEITHLEY A Tektronix Company

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

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

Up to 10kV for breakdown voltage testing

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

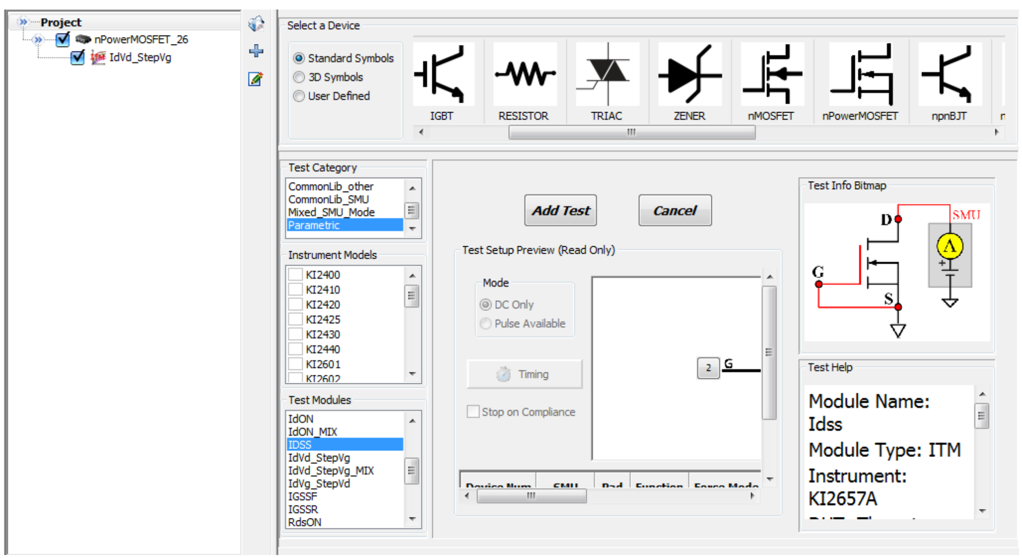
Overvoltage Protection Modules

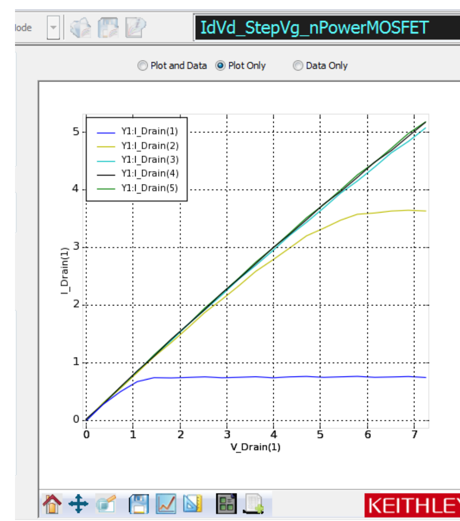
Power Semi Test Software

ACS BASIC, ACS

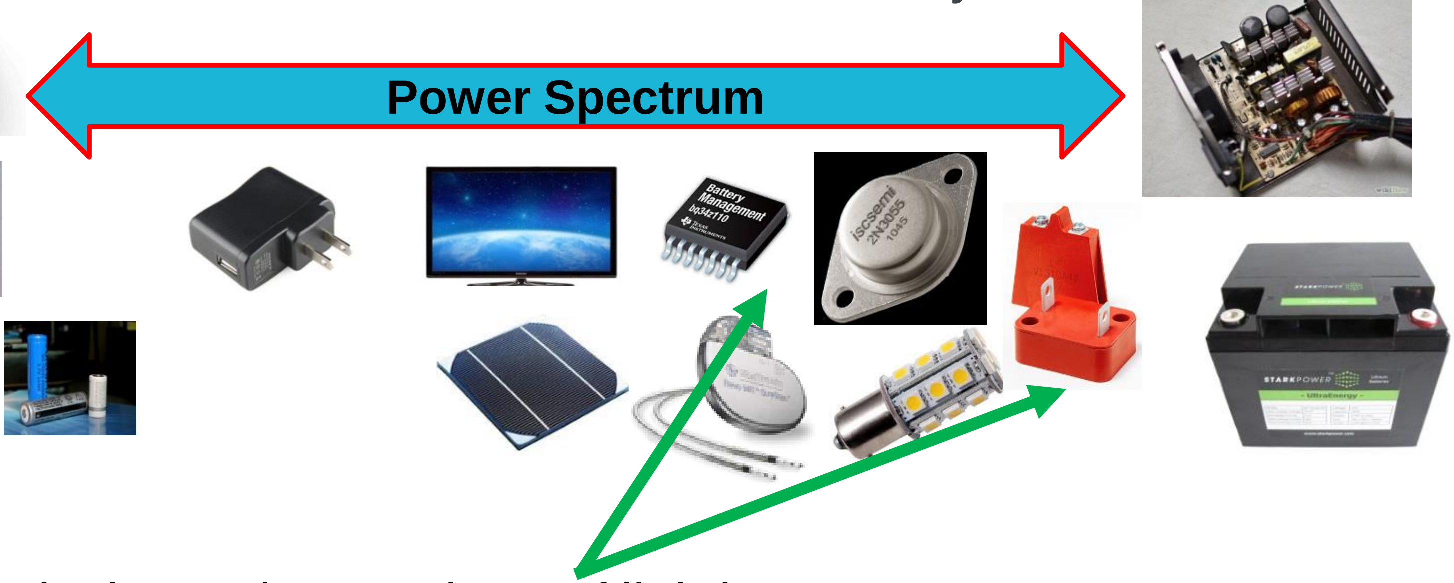
- ACS Software is the “glue” that brings all of the instruments together to make a solution
  - Supports Series 2400, 2600, and 4200 SMUs

- 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

- 10A @ 100V 1000W Pulse version of the Model 2460
  - 1000W Pulse Source/Sink, 100W DC Source/Sink
  - Pulses as fast as 150µS. Dedicated pulse screen and commands

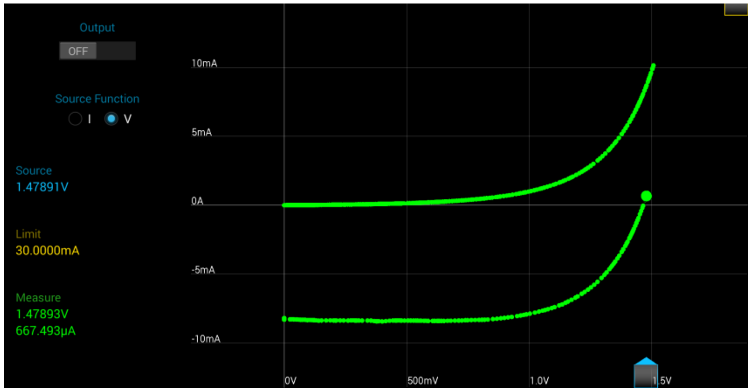
- Dual 18-Bit 1MS/s Digitizers for simultaneous I&V. Store up to 5 million rdgs.
- Contact Check

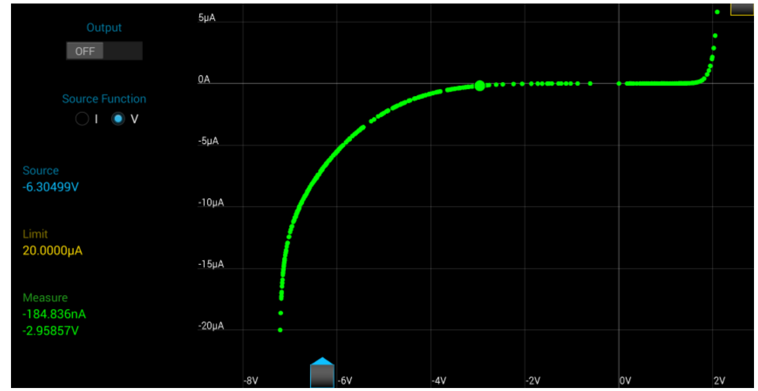
- Succeeds the Model 2430, 2420-C, 2425-C, 2430-C, 2440-C SourceMeter SMUs. Opportunity to upsell to the 2461.

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

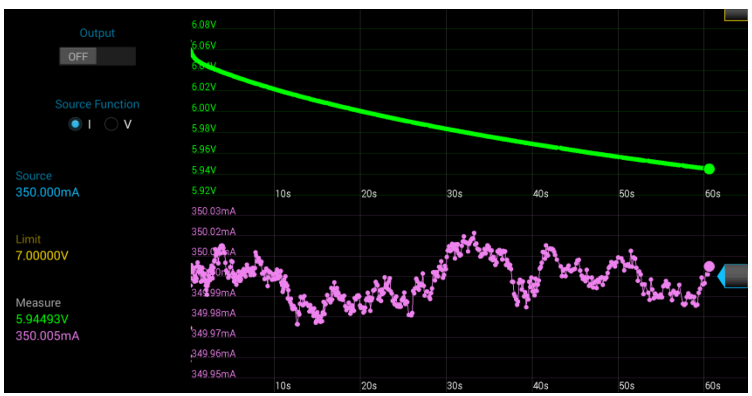
- **Visualize Instant Responses**
  - Swipe to change the source value and instantly see your device’s response
- **Interact for Better Understanding**
  - Pinch and zoom to gain deeper insight into your device’s performance
- **Share Your Results**
  - Share screen shots and CSV files instantly using built-in Android tools

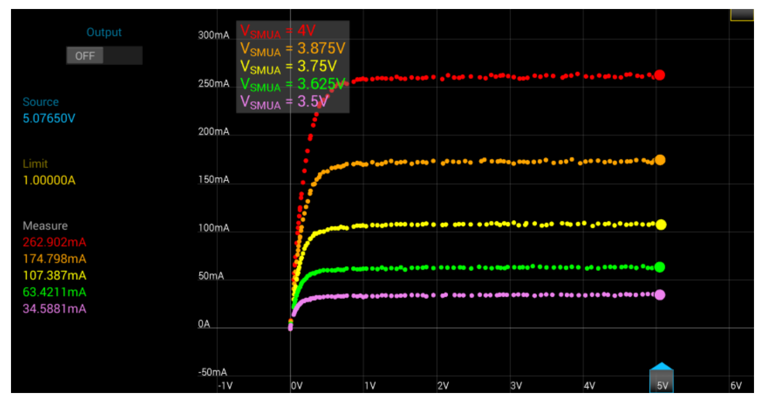
IVy Application Examples





- DUT comparison
- Diode Reverse Bias





- LED Vf vs. Time
- MOSFET Family of Curves

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New Material and Nano-technology

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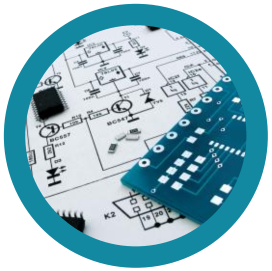


PART 2:

Power semiconductor devices

PART 5:

Power management

PART 3:

MEMS and Semiconductor Sensors

PART 6:

Opto-electronics

MEMS Background

MEMS (**M**icro-**e**lectro-**m**echanical **S**ystems)

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

Sensors: **turn non-electro-signal into electrical signal**

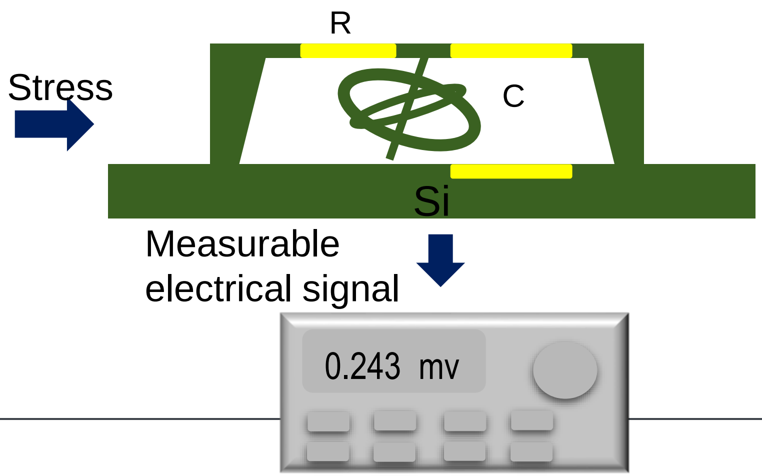
Widely Used

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

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

- Pressure/Force
- Light
- Vibration/ acoustic wave
- Fluidics
- Temperature
- …

Stress induced R, C…value change



- 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)
  - …

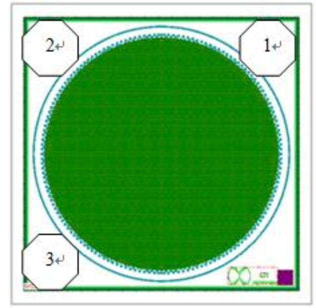
MEMS (**M**icro-**e**lectro**m**echanical **S**ystems)

Keithley Solution for MEMS device test

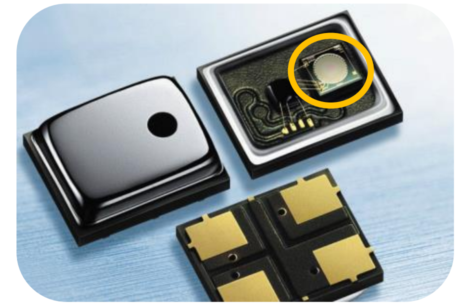
- Customer application:
  - Test with sensor structure for its intrinsic characteristic without stress (pressure, vibration etc.)
  - To verify if fabricating process are within control.
  - **Micro-phone:**

    Voice → airflow → Capacitance change in MEMS sensor → electrical signal ---C test
  - **Pressure sensor:**

    Pressure→ R change in MEMS sensor → electrical signal ---R test
- Test requirement:
  - I-V:
    - R test: Force V measure I
    - V<10V
    - R~KΩ
  - C-V:
    - Capacitance test
    - f=100KHz DCV<30V
    - C~10pF (0.1pF accu.)
  - wafer level with auto-prober

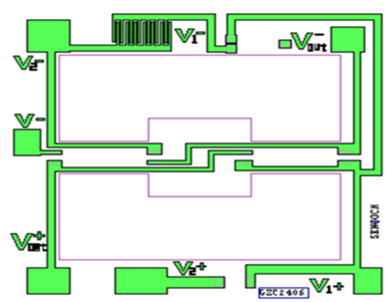


Customer Design



Product

Micro-phone



Customer Design

Product

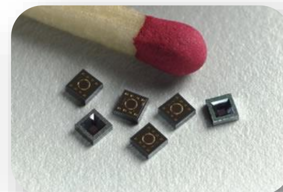
Pressure sensor

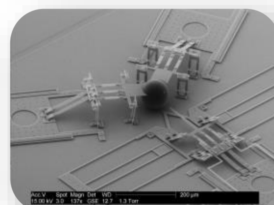
Keithley Test Solution:

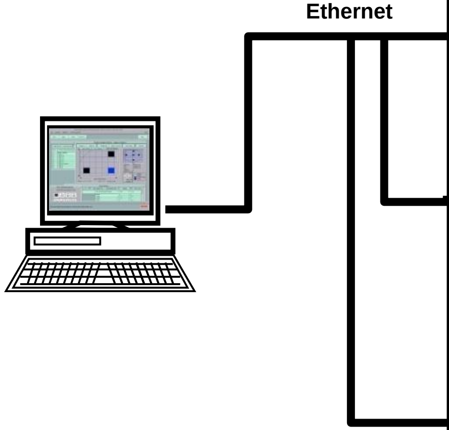
- Configuration:
  - 4200-SCS/C x 1ea
    4210-CVU*1
  - 4200-SMU*2
  - 4200-PA*1

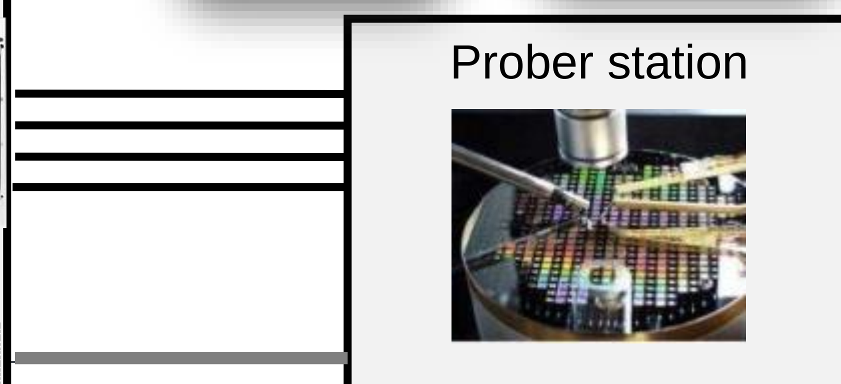
– 707B x 1ea
  7174A x 1ea

S500 system









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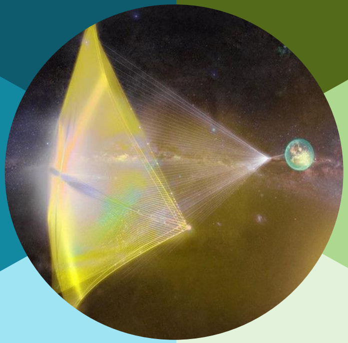

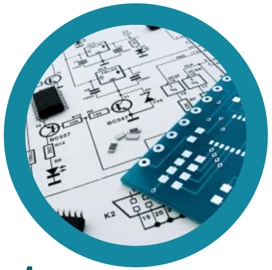

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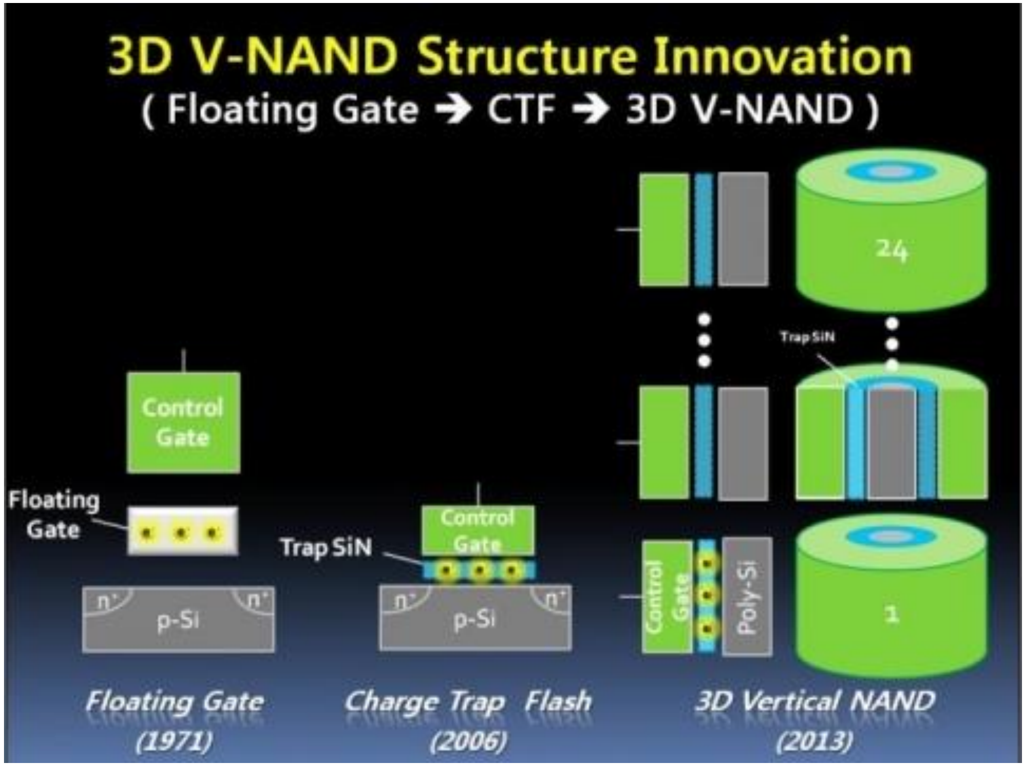
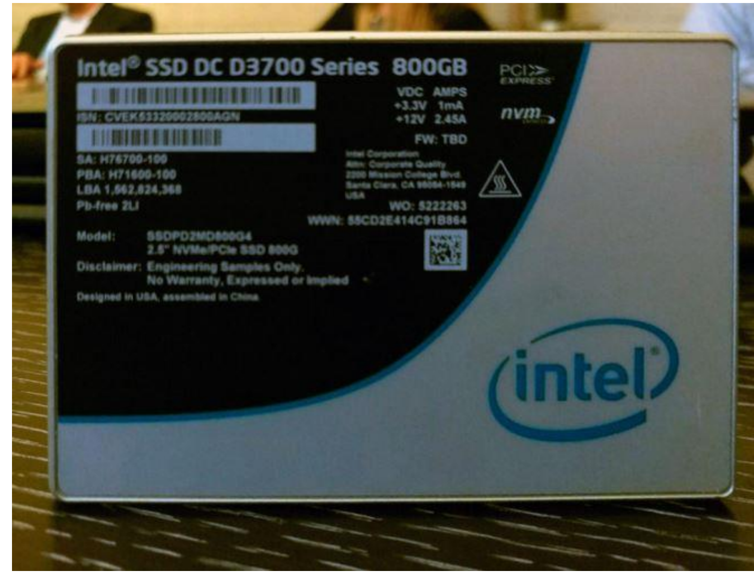
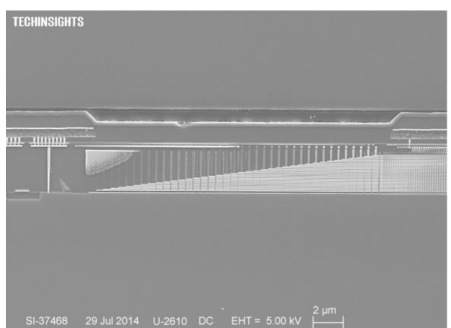
New Flash Memory, bigger and faster.





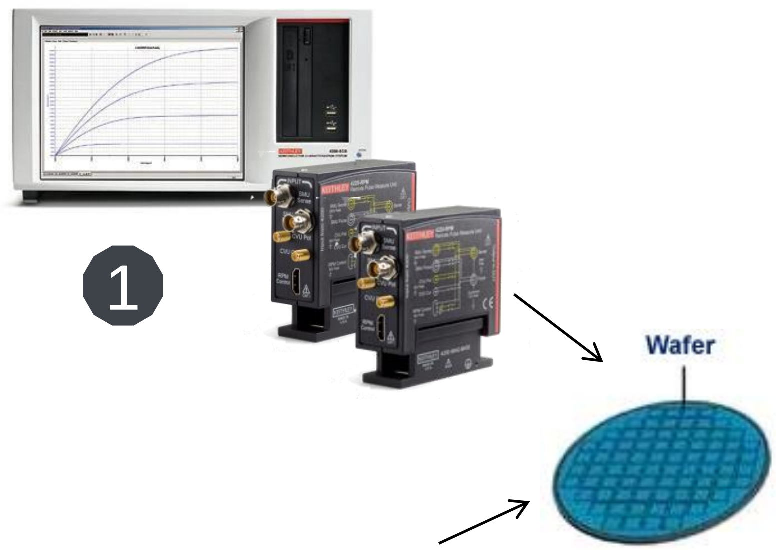
3D Nand Flash tech. makes the massive data store more easier and faster.

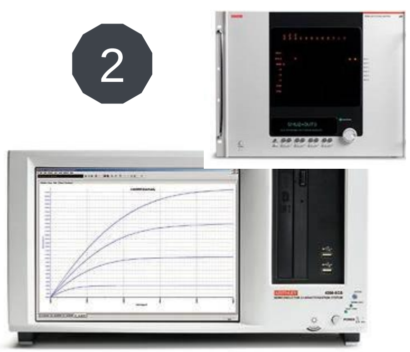


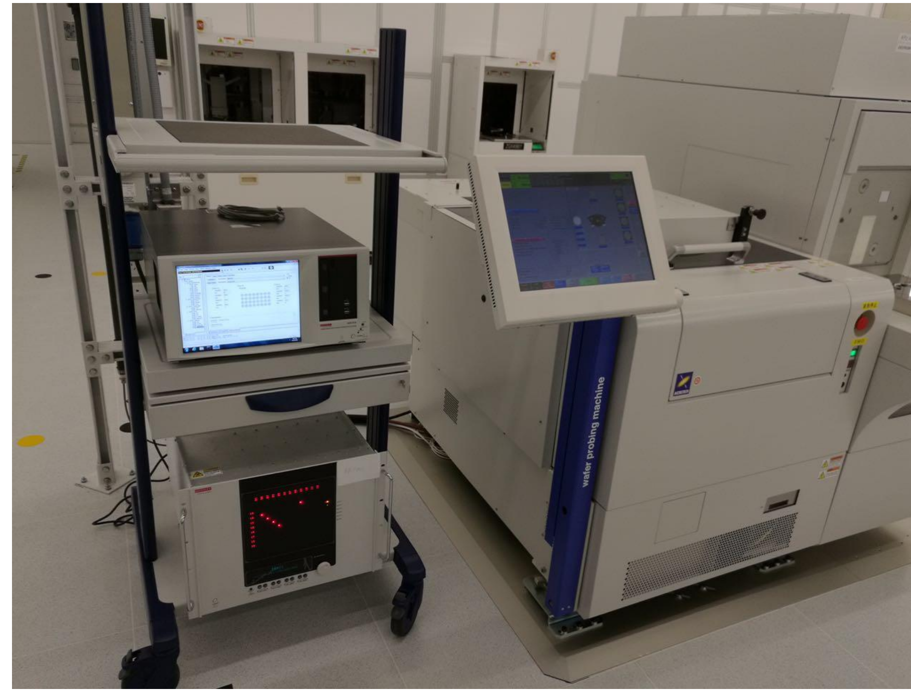
From How Samsung connects to the wordlines in the array (courtesy Techinsights)

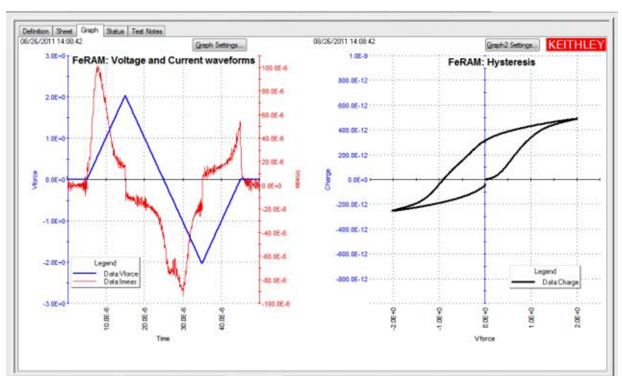
15.3TB SSD from Samsung

Non-volatile Memory Product Solutions



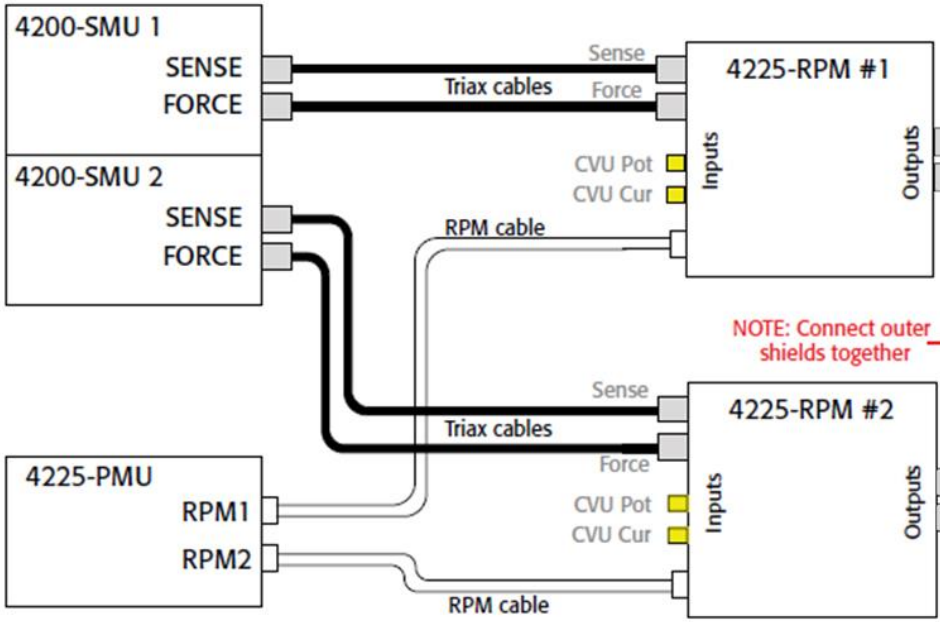


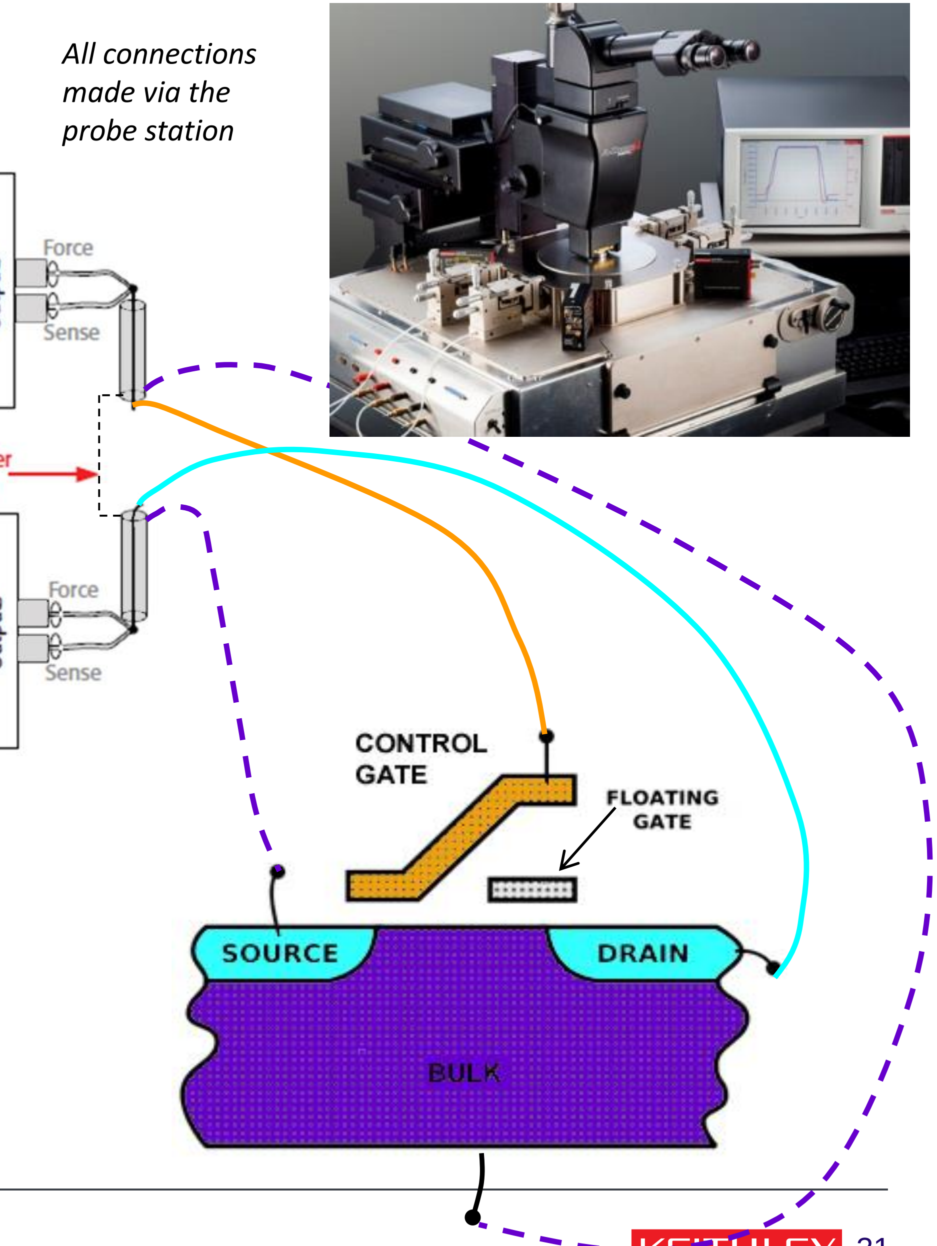




Configuration of Solution2 for 3D Nand Flash reliability test in one of our customer.

Example of Flash Memory Cell Test Setup





- 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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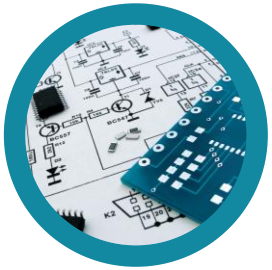
New power devices



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Power management

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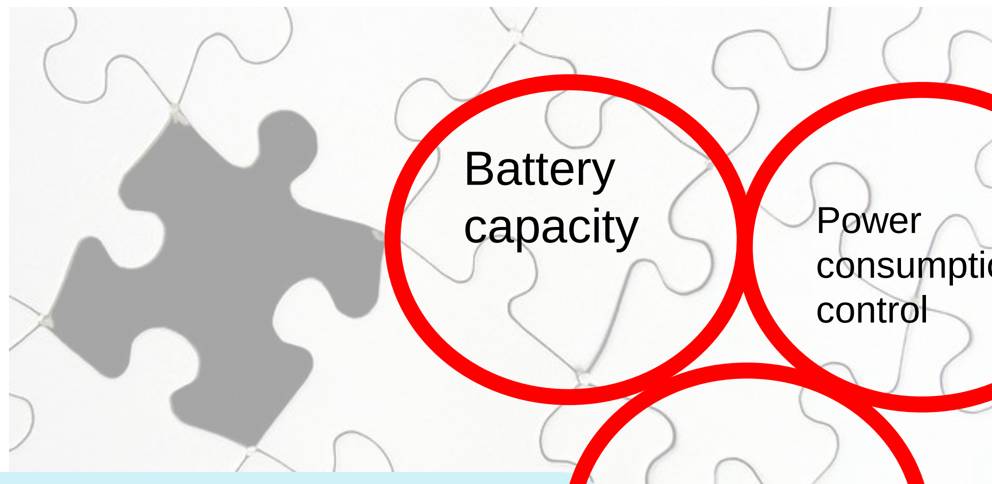
Optical energy and device

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.



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.

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

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

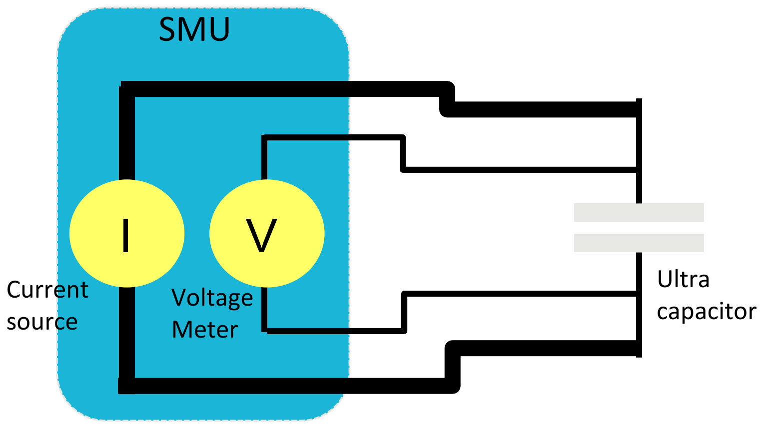
Credit Suisse

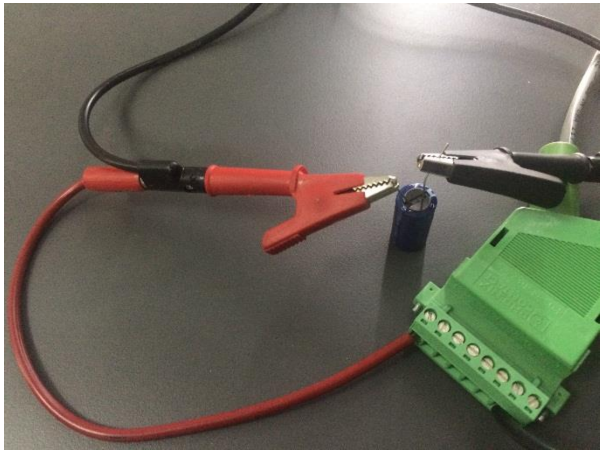
Using SMU for Ultra-capacitor test

- Test Instrument:
  - Keithley 2612/36B* for C<=20F
  - Keithley 2651A for C>=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.

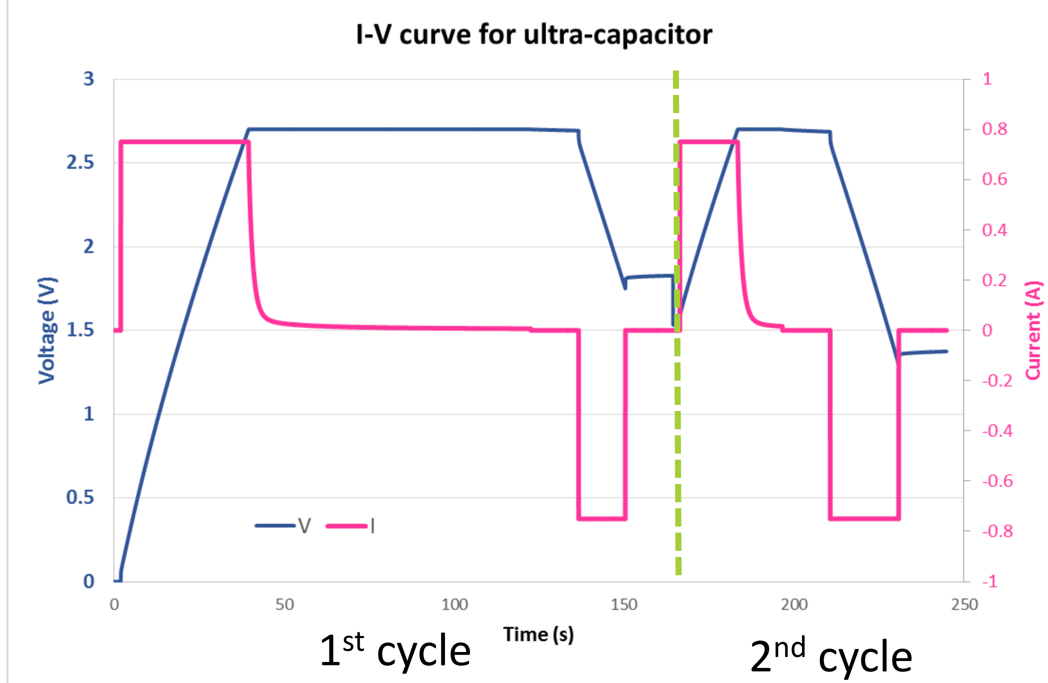
Experiment – Result

for 10F capacitor with 2636B

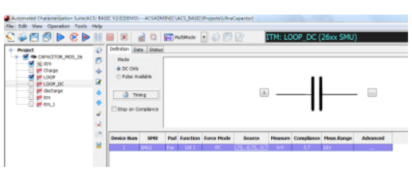
- Test result:
  - 2 cycles are tested

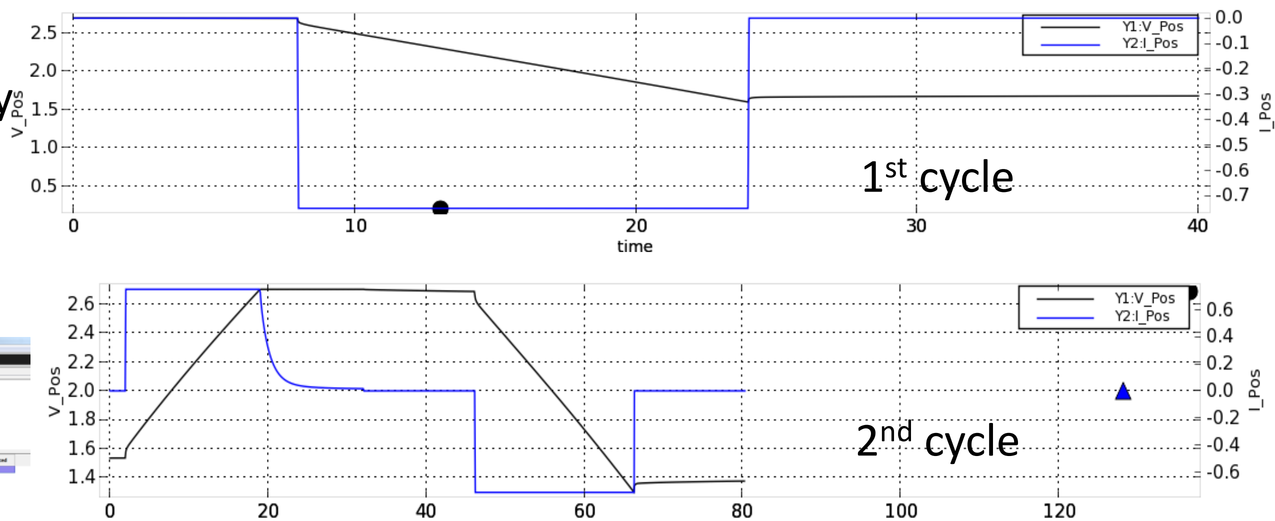
Cch = I2 ×(t2 –t1) / (V2 – V1)
=10.93 F

Cdch = I5 ×(t5 -t4) / (V5 – V4)
=10.88 F



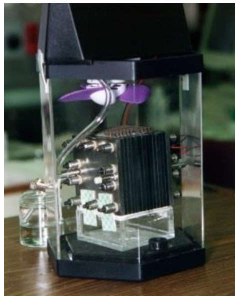
Test result chart by Keithley test software: ACS Basic





Programmable, sensitive, fast, accurate TEST.

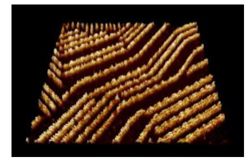
Electrochemistry Applications



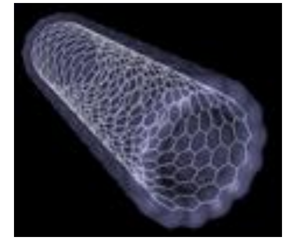
Basic Lab Research

Electrode Development

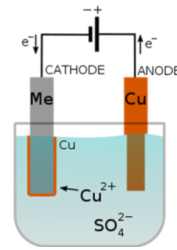
Electrolyte Research



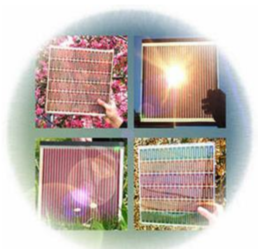
Organic Semi



Nanomaterials



Electro-deposition



Dye-Sensitized Solar Cells

Health Care Sensors

Corrosion Resistance

Batteries

Fuel Cells

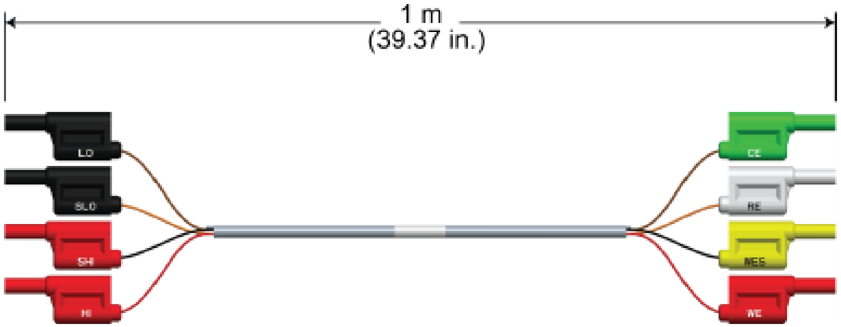
Super-capacitors

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

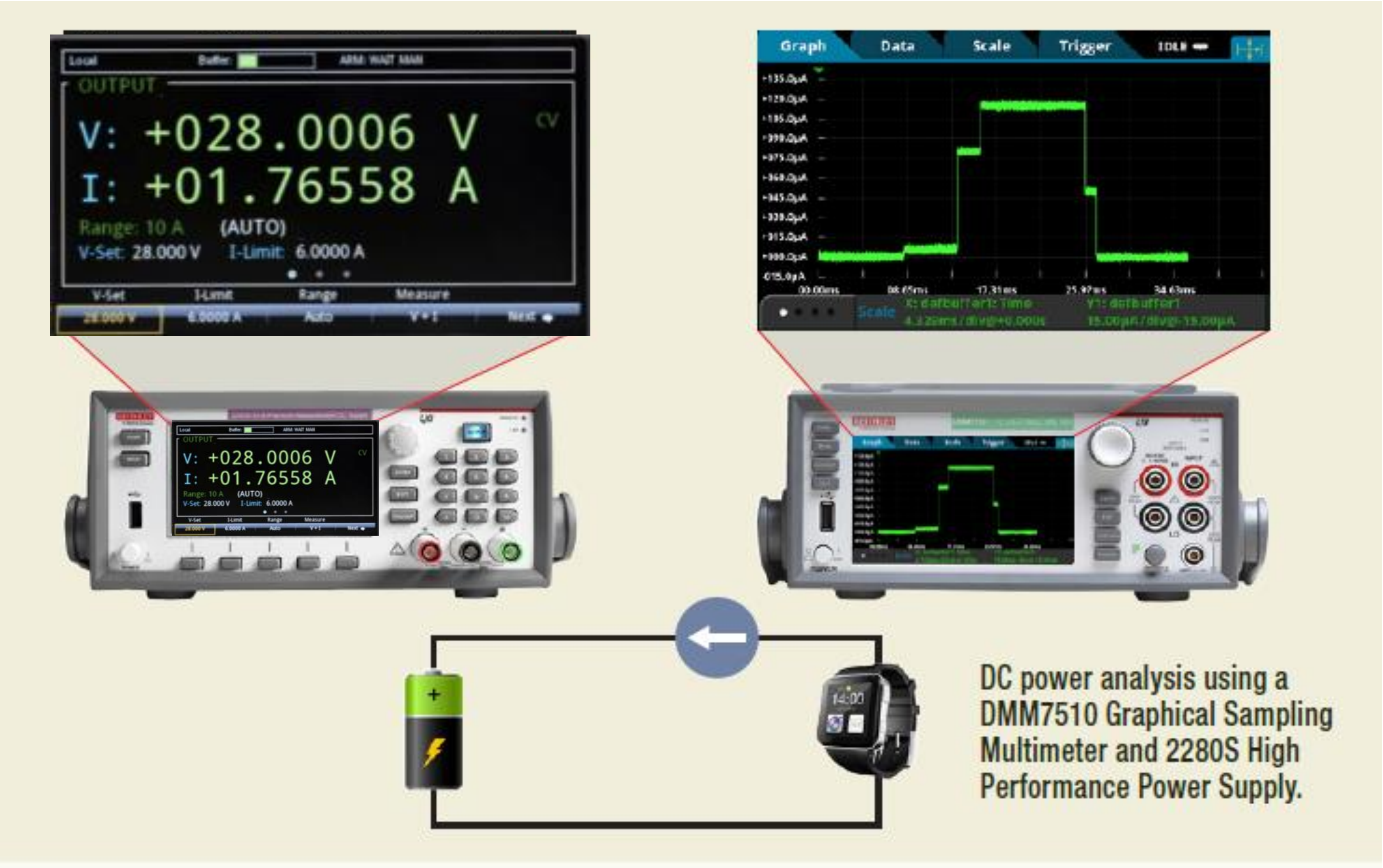
Distinctive differences

SIMPLICITY

Simplify learning and test set-up

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

Solution for low power consumption measurement: DMM7510 + 2280S



Example Application

More Detailed Power Consumption Info with DMM7510

KEITHLEY
A Tektronix Company

PART 1:

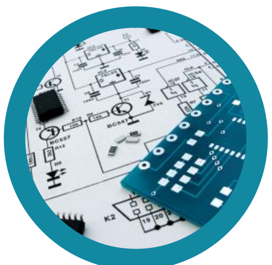
New Material and Nano-technology

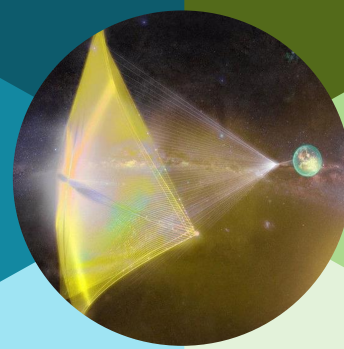
PART 4:

Signal, Data storage/sorting

PART 2:

Power semiconductor devices





PART 5:

Power management

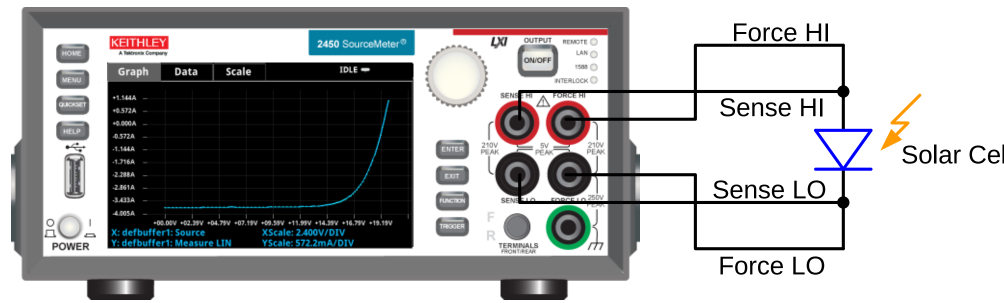
PART 3:

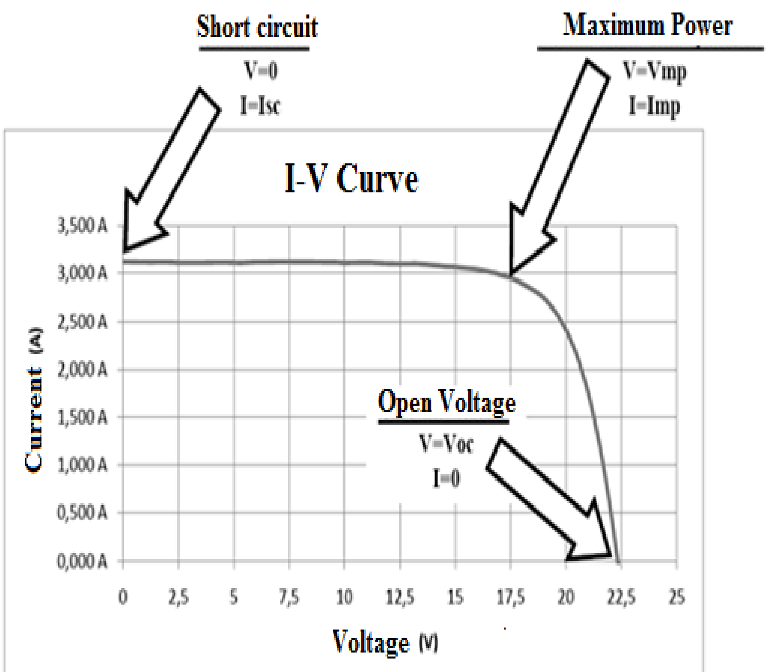
MEMS and Semiconductor Sensors

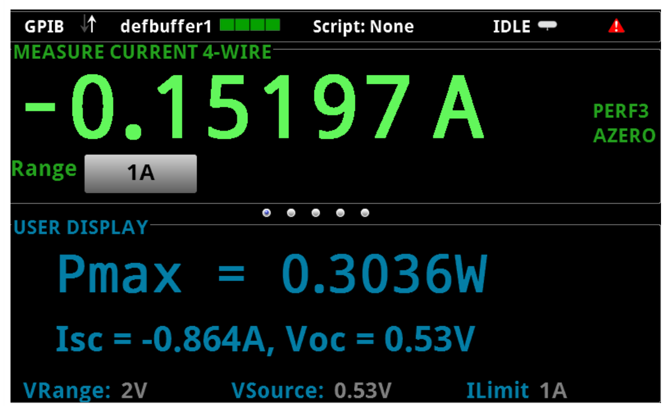
PART 6:

Opto-electronics

Optical energy: Solar cell








KEITHLEY

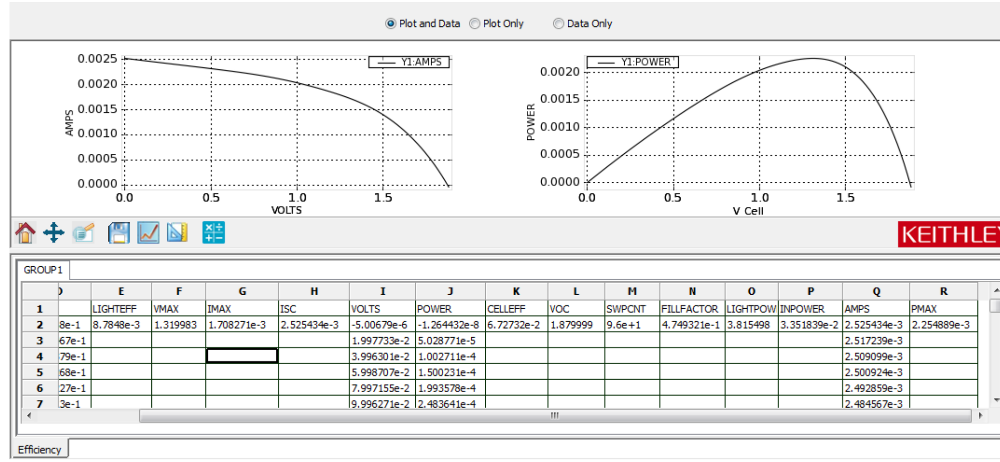
Better Solar Cell Testing: The Key to Faster Development and Production

James Niemann, Keithley Instruments, Inc.

Solar Energy Collection and Conversion

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

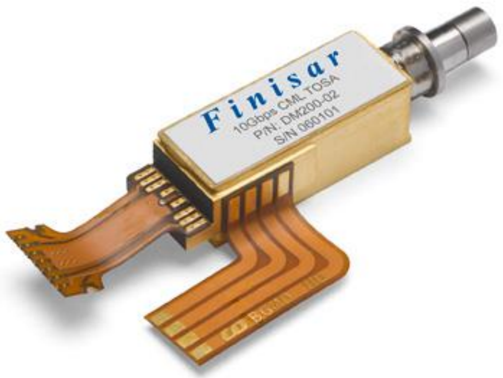
太阳能电池测试参数

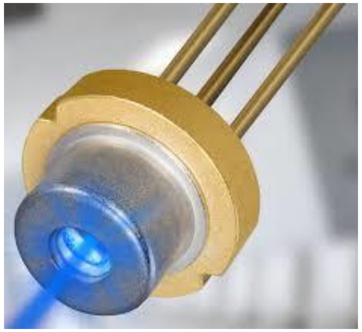
Standard Solar cell characterization test can be done in ONE MINUTE!

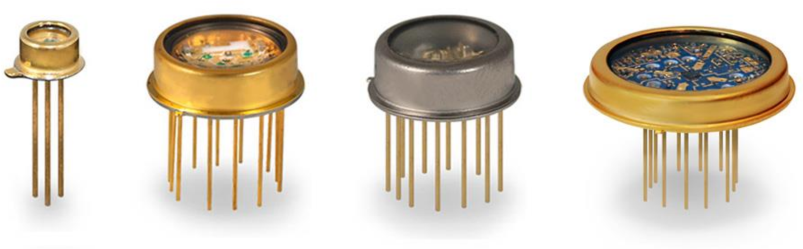
KEITHLEY
A Tektronix Company

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

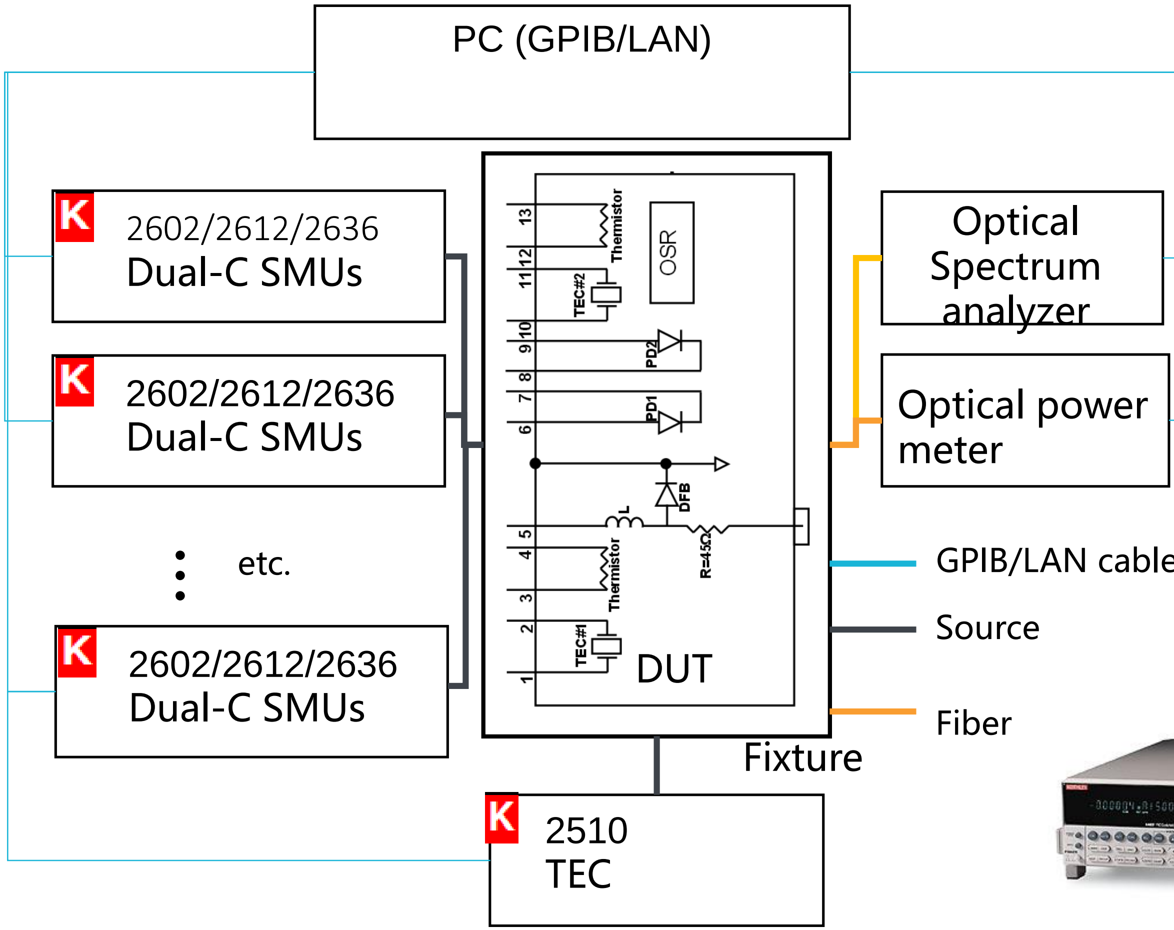






Keithley solution for Optical Module Components test

- 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

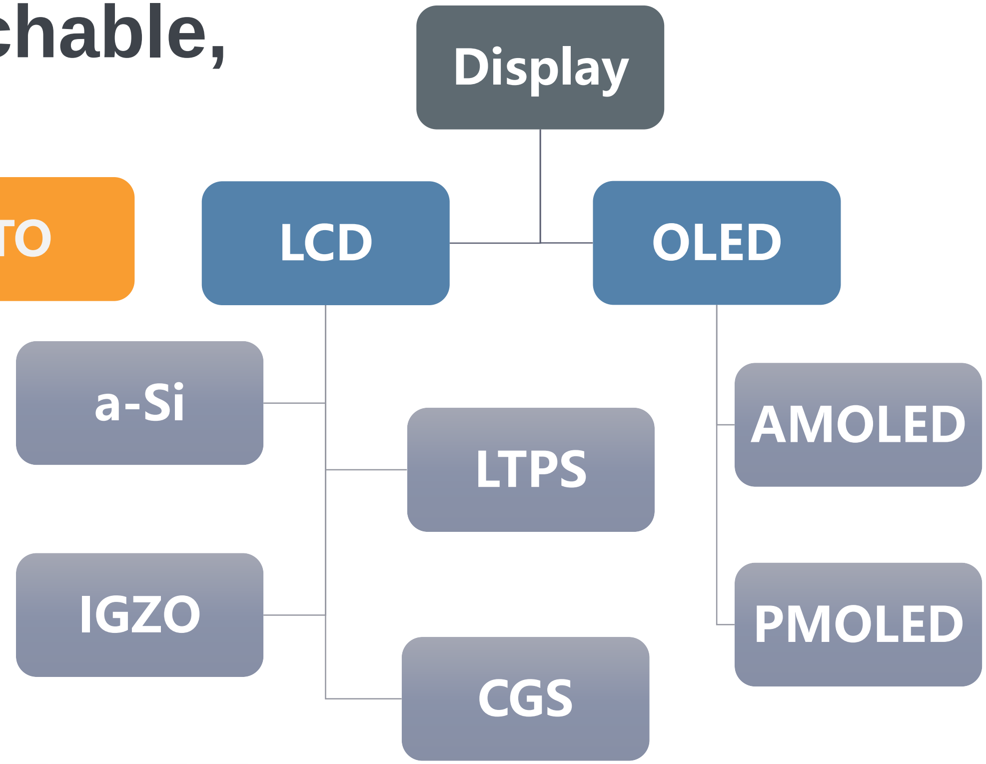
6485/6487 Picoammeter/Source

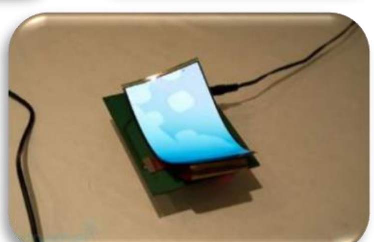
- 10fA (10x10-15A) sensitivity
- <200µV voltage burden
- Bipolar 500V floating source
- Displays resistance

Display: wearable, touchable,

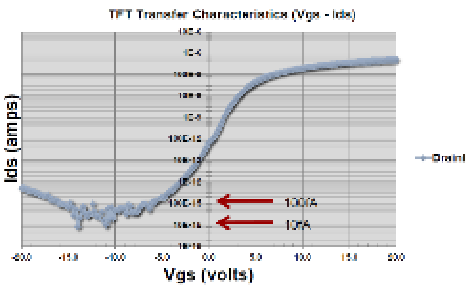
- LCD: Liquid crystal display
  - TFT: Thing film **Transistor**
  - liquid crystal molecular
  - Backlight (light source)
- OLED: Organic Light Emitting **Diode**
  - "Sandwich" structure: organic semiconductor between two electrodes
  - Each pixel is LED/LEDs

ITO





Keithley solution for Display



IV test

Switch Matrix

CV/IV test

S500/S530:

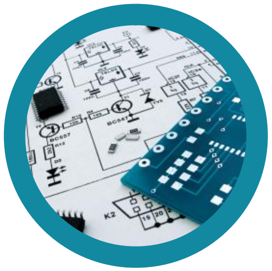
S500/S530 system for TEG test in Display manufacture

PART 1:

New Material and Nano-technology

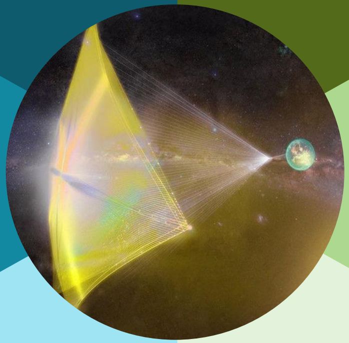
PART 4:

Signal, Data storage/sorting



PART 2:

Power semiconductor devices



PART 5:

Power management

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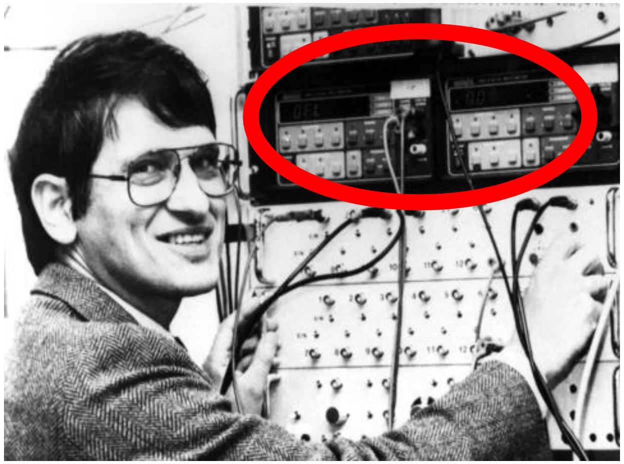
Opto-electronics

Researchers use Our Sensitive Instruments to Make Great Scientific Discoveries



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

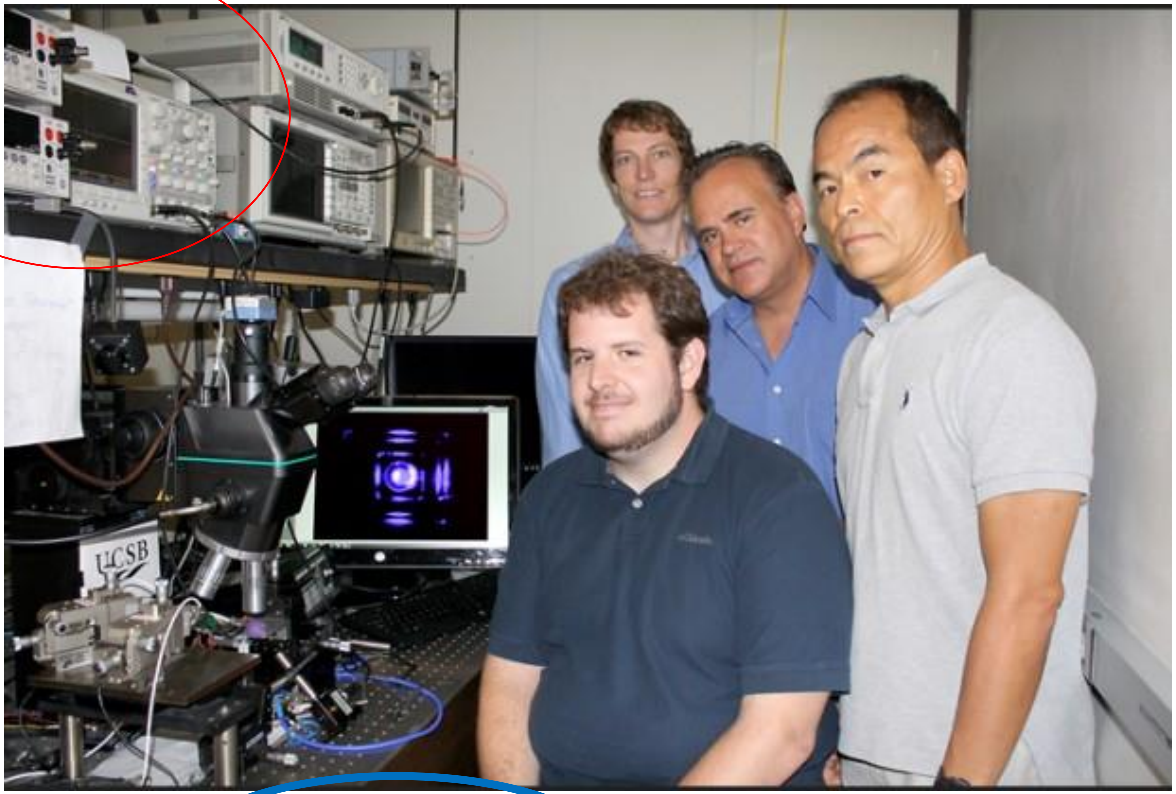
Dr. K. Alexander Muller and
Dr. J. Georg Bednorz
1987 Nobel Prize in Physics
Superconductivity in ceramic materials

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:

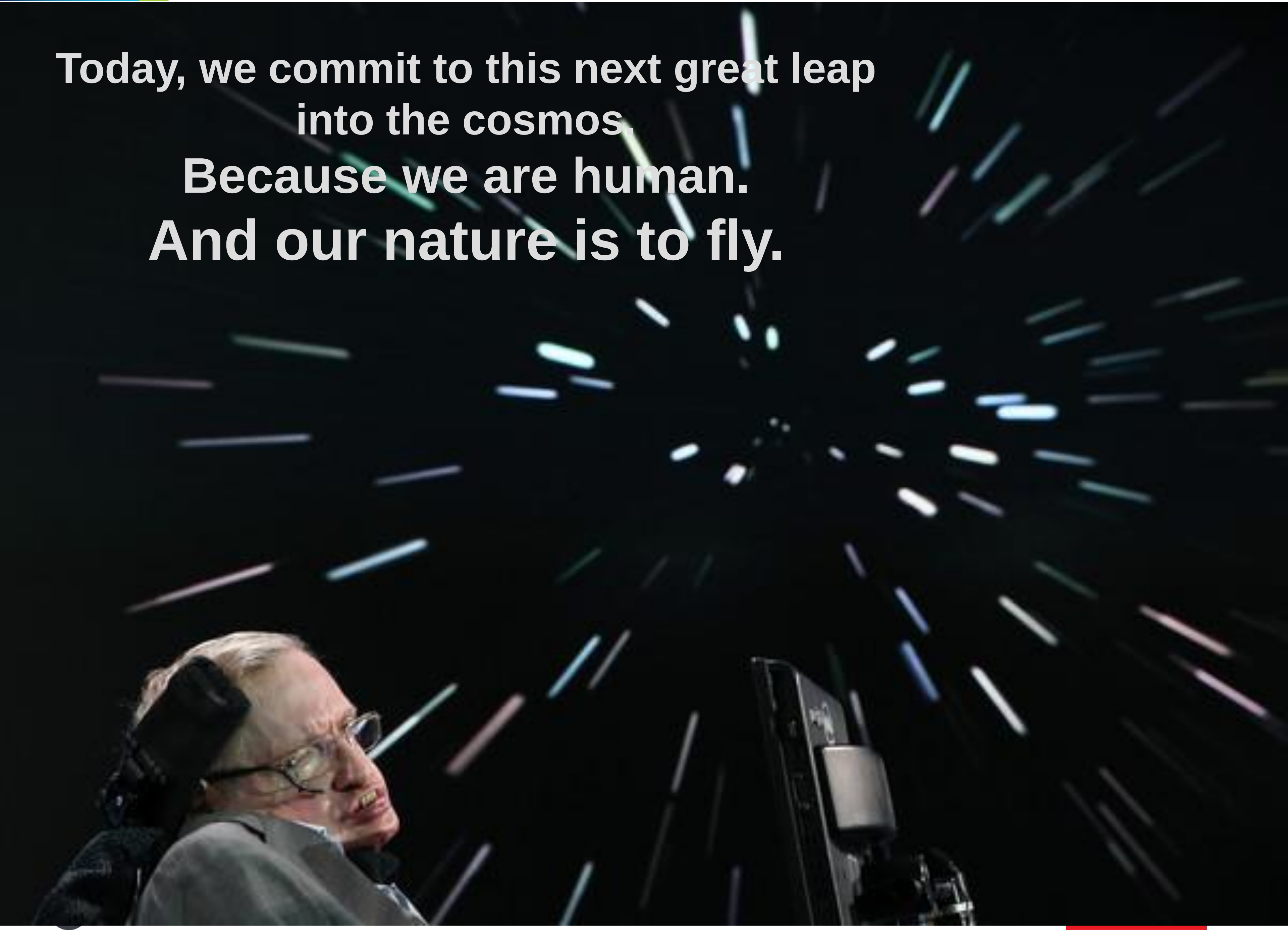
0.000000000000000001A (10^{-18}A, 1aA)

= 6.241 electrons/second

Note: Q of 1e$^-$ = 1.6X10^{-19} C
1A = 6.2 x 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.