Introduction to Memristors

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The Problem with NAND Flash

Flash memory

Source: D. Ruggeri, MICRON

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## Going 3D

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<tr>
<td><strong>Samsung</strong></td>
<td>21nm</td>
<td>19nm</td>
<td>16-19nm V-NAND (24 layers)</td>
<td>12nm V-NAND (32L)</td>
<td>12nm V-NAND (48L)</td>
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<td><strong>Micron</strong></td>
<td>20nm</td>
<td>20nm</td>
<td>16nm</td>
<td>3D NAND</td>
<td>3D NAND Gen. 2</td>
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<td><strong>Intel</strong></td>
<td>20nm</td>
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<td>15nm</td>
<td>3D NAND BiCS</td>
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<td><strong>Toshiba</strong></td>
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<td><strong>SanDisk</strong></td>
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Motivation for New Technologies

• Scalability of 3D
• Volatile technologies:
  – Energy (leakage, refresh in DRAM)
  – Limited density and scalability

Source: E. Esteve, IPNEST

Chip energy

Source: E. Esteve, IPNEST
Emerging Nonvolatile Memory Technologies

- RRAM
- PCM
- STT MRAM
- CBRAM
Memristor
The Missing Fourth Element?

Memristor – Memory Resistor

Resistor with Varying Resistance

- Decrease resistance

Current

Voltage

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Resistive RAM (RRAM, ReRAM)
RRAM Status

• Product: Panasonic

• Prototypes: 24nm 2-layer 32Gb (ISSCC 2013) 40us read, 230us write

SanDisk® TOSHIBA

• Research/development:
Conductive Bridging RAM (CBRAM, PMC)

- Low voltage/power
CBRAM Status

• Products:

  adesto™  ALTIS

• Prototypes:

  27nm 16Gb (ISSCC 2014)
  2us read, 10us write, 1T1R, 6F²

  SONY  Micron

• Research/development:

  TOSHIBA
Phase Change Memory (PCM, PCRAM, PRAM)
PCM Status

• Products:
  - Samsung: 20nm, 8 Gb, 2012
  - Micron: 45nm, 1 Gb, 2012-14

• Prototypes:
  - IBM, SK hynix, ST, WD: 32 Gb

• Research/development:
  - Intel, Micron: 128 Gb? 2016?
Spin-Torque Transfer Magnetoresistance RAM (STT MRAM)
STT MRAM Status

• Products:

  64Mb, DDR3, 400 MHz

• Prototypes:

  Qualcomm
  1Mb, 45nm
  Hitachi
  32Mb
  Qualcomm
  4Gb

• Research/development:
Shared Properties

- BEOL CMOS compatibility
- Resistive
- Nonvolatility
- High endurance
- Speed
- Density
- Low voltage
- Retention
Challenges

• Selectors
• Device variations
• Yield
• Power
• Endurance

Source: Crossbar, IEDM 2014

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Immediate Applications

- NAND Flash replacement
- Storage Class Memory
- Embedded NVM
On-Die Intensive Memory Circuits and Architectures

Multistate Register

RRAM Crosspoint

CMOS FF

Continuous Flow Multithreading

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FPGA

Source: P.-E. Gaillardon, University of Utah

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Logic with Memristors

Integrating memristors with standard logic

Beyond Moore

Logic within memory

Beyond Von-Neumann

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Neuromorphic Computing

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Circuits

Source: T. Prodromakis, University of Southampton

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Summary

• Need for new nonvolatile memory technology
• Challenges
• Opportunities for novel applications:
  – Logic
  – Programmable circuits
  – Neuromorphic
  – On-die memory
Thanks!

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