Session 302-C:
Creating the Foundation of the Flash Storage Memory Industry:
A Conversation with Eli Harari

Brian A. Berg, FMS Technical Chair
In Conversation with Eli Harari
Eli Harari Interview

Eli Harari Interview

- Princeton University (1969-73)
- Ph.D.: 1973
Eli Harari Interview

- Hughes Microelectronics, Newport Beach, CA (1973-79)
Eli Harari Interview

• IEEE Milestone dedicated in 2012 for this 1976-1978 EEPROM work, and how it led to “System-Flash”

• Harari also received the 2012 FMS Lifetime Achievement Award

IEEE MILESTONE IN ELECTRICAL ENGINEERING AND COMPUTING

The Floating Gate EEPROM, 1976-1978

From 1976-1978, at Hughes Microelectronics in Newport Beach, California, the practicality, reliability, manufacturability and endurance of the Floating Gate EEPROM—an electrically erasable device using a thin gate oxide and Fowler-Nordheim tunneling for writing and erasing—was proven. As a significant foundation of data storage in flash memory, this fostered new classes of portable computing and communication devices which allow ubiquitous personal access to data.

August 2012
Dov Frohman invented EPROM at Intel (1971)

Dov interviewed Eli in 1979 for a job at Intel
Eli Harari Interview

• Worked at Intel (1979-81)
• Eli proposed an SSD to Intel President Andy Grove

“10x” Story from Ted Hoff
Eli Harari Interview

• Co-founded Wafer Scale Integration (1983-88)
• Business plan:
  – WaferDisc
  – then high-speed EPROM
  – then Programmable System Devices
Eli Harari Interview

• Founded SunDisk (March 1, 1988)
“System-Flash” was a joint effort of Eli, Bob Norman and Sanjay Meherotra.
• “System-Flash” included:
  – Error correction and dynamic defect mapping
  – Wear-leveling
  – Logical-to-physical mapping
  – Low stress write and erase voltages
  – Intelligent caching: speed, and write reduction
  – Garbage collection
  – Repair of disturbed cells
  – Magnetic disk drive interface
Eli Harari Interview

- “System-Flash” created an SSD
  - host-independent plug-compatible disk drive replacement
- Goal for SSD: 1 million read/write cycles
  - Also required a high-endurance flash transistor
  - Cost reductions through Moore’s Law and MLC
  - Industry standard formats for removable storage
IEEE talk in 1990

IEEE Electron Devices Society
Santa Clara Valley Chapter
Meeting Notice

FUTURE DIRECTIONS FOR SEMICONDUCTOR NON-VOLATILE MEMORY

Speaker: Eli Harari
SunDisk Corporation
Santa Clara, CA 95054.

Place: Santa Clara University,
Daly Science Center
Room No. 206

Time: Tuesday, January 16th 1990, 7:30 pm.

Semiconductor non-volatile memories have in the past been an imperfect solution looking for a problem. In the coming decade, the problem, or a major market opportunity, will present itself in the form of an emerging new class of compact, portable products, such as hand-held computers, electronic notebooks, solid-state cameras, portable copiers and Fax machines, and cellular telephones. At the same time, certain types of non-volatile memory technologies, such as Flash EEPROM are at the threshold of overcoming major technological hurdles and transforming themselves from frog to prince (or king) in the new market environment.
Eli Harari Interview

- Operational device in 1990/’91
- First SSD: 20 MB ATA 2.5” device
First products sold to GRiD Systems for their GRiDPad pen computer (Eli is 2nd from left; Bob Norman is 3rd from left; Jeff Hawkins at far right)
Later in 1991:

- PCMCIA SSD was available
- SunDisk landed a contract to deliver 10,000 SSDs to IBM for their ThinkPad laptop
Eli Harari Interview

• Relationship with Western Digital, Seagate and Al Shugart
Eli Harari Interview

• Relationship with Kodak
• SanDisk story
  – Disruption
  – Moore’s Law
  – 100,000X cost reductions over 25 years (1990-2015)
Eli Harari Interview

- 2009 IEEE Robert Noyce Award
- 2014 National Medal of Technology and Innovation