OLED Assisted Write/Erase for Flash Memory Scaling Beyond the 45nm Node

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Summary

- Proposing organic light emitting diode (OLED) assisted Flash architecture
- First attempt to integrate organic light emitting technologies with existing Si technology
- OLED fabricated on top of a flash cell
- Optically assisted write and erase performed at lower voltages – improves scaling prospects
- Lower power, increased cycle endurance and increased write/erase speed are other prospects

Issues with Flash Scaling

- Flash scaling is following Moore's law
- Consensus is that conventional flash cell can only scale up to 45nm node
- Variety of reasons :-
  - Gate oxide can not be scaling because of increased direct tunneling and stress induced leakage currents – SILC. Data retention requirements dictate oxide thickness to be 60-80Å
    - Hence, to achieve minimum write/erase speed, voltages can not be reduced
    - Channel length and array pitch can not be reduced due to punch through and parasitic FET problems
  - Flash can only be cycled for about a million times
  - Write/erase speeds are orders of magnitude smaller than read speed due to involvement of transport across large (3.1eV) barriers

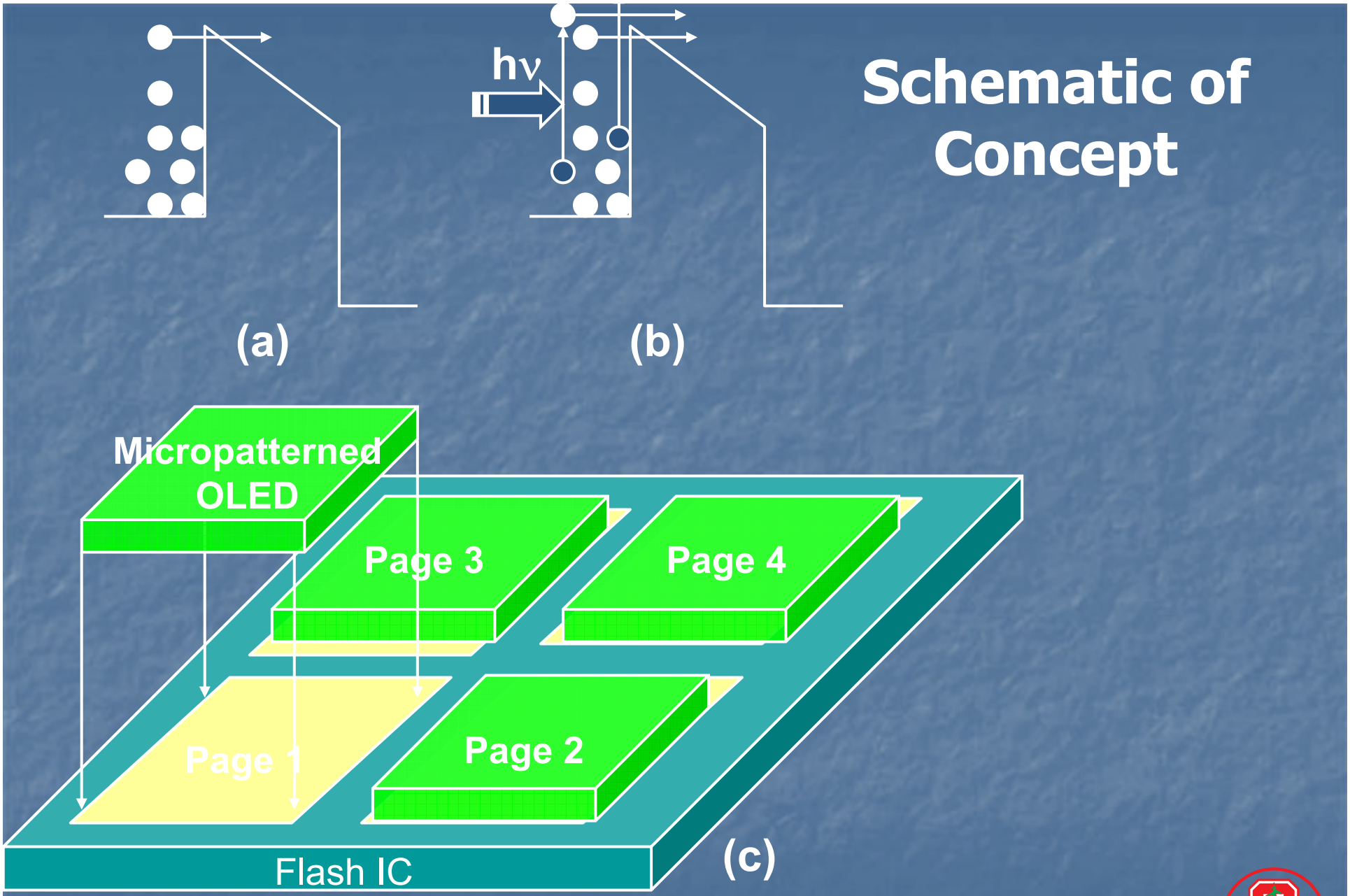
Issues with UV erasable EPROM

- UV-EPROM scheme uses UV radiation for enabling the stored carriers to tunnel through the barrier to erase the memory
- Whole array is exposed in one go – no page erase functionality
- Very poor coupling of radiation requires lengthy exposure times
- Light source is not integrated on the flash IC
- Does not work for write processes
- Not suitable for portable purposes – power and size issues

Benefits of OLEDs

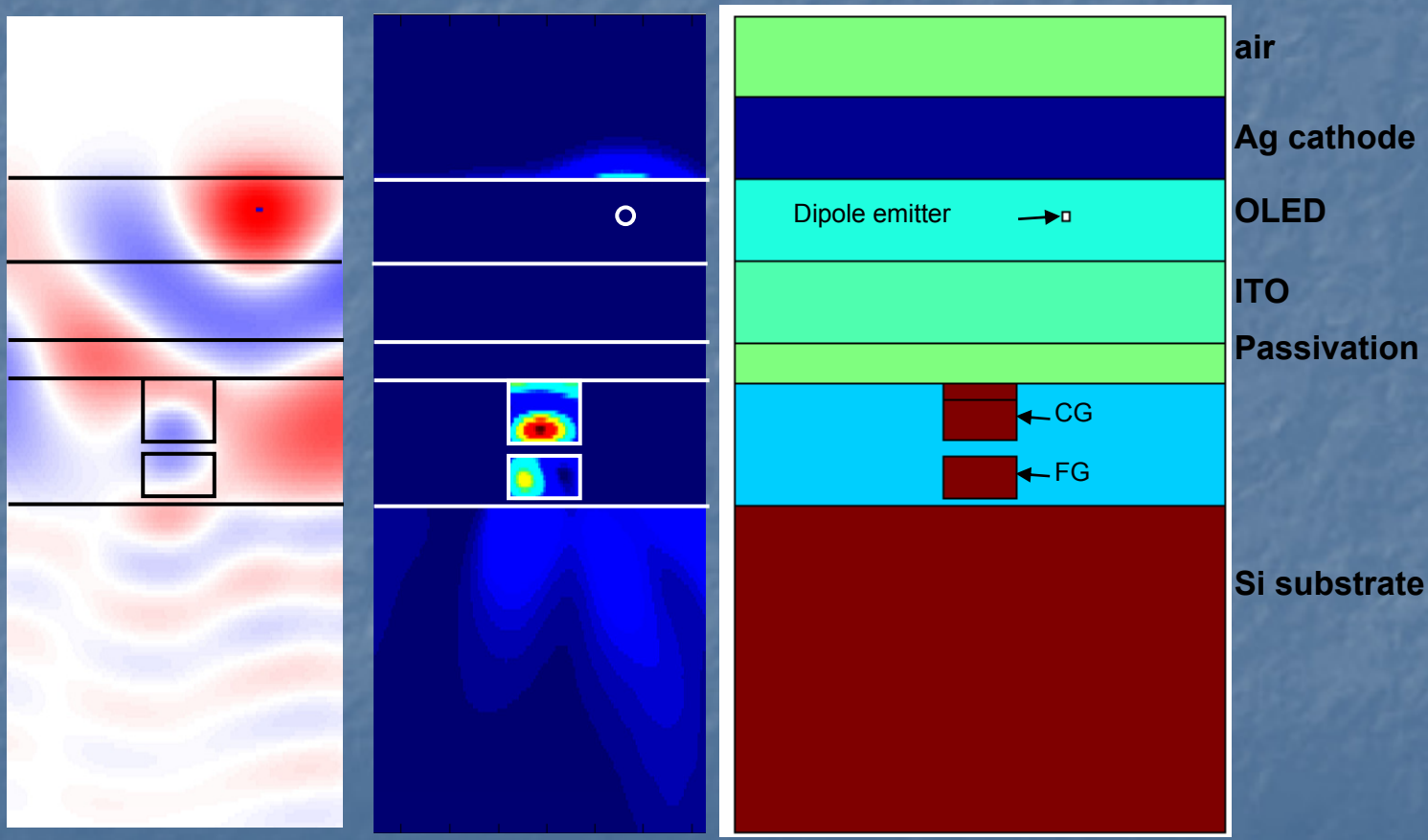
- Fairly matured technology over a past decade
- Can be grown over virtually any substrate
- Near field coupling makes it much better than the external UV source in UV-EPROM
- Estimated photon flux of ~$3*10^{19}$ photons/s/cm^2 at estimated wavelength of 413nm has already been achieved with OLEDs
- Micropatterned OLEDs provide page erase functionality as well
- Assist erase as well as write process

Schematic of Concept



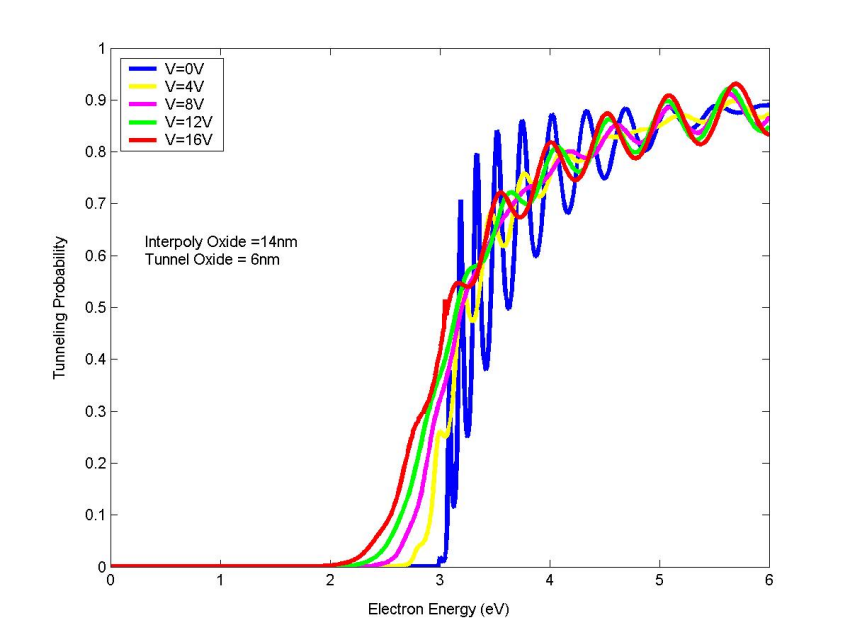
Optical Coupling Simulations

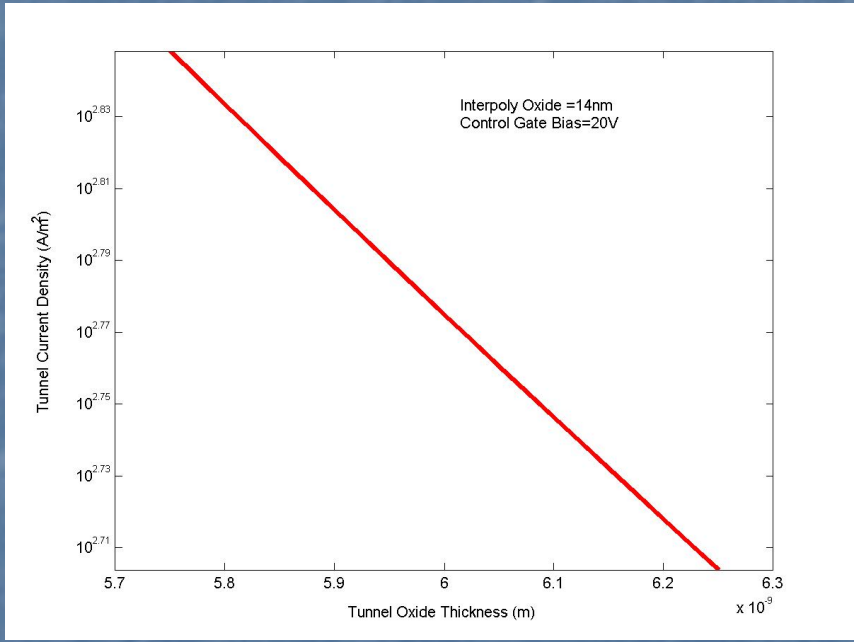
Finite-element electromagnetic model
Large fraction of emitted radiation couples to floating gate (FG) and substrate



Current and Photon Flux Estimates

- With 20V of control gate voltage (without an OLED), gate current is ~770A/m^2
- Which leads to write/erase time of a fraction of ms for threshold voltage shift of~3V
- For 15V gate operation we need an additional current of ~730A/m^2
  and for 10V operaton ~767A/m^2 supplied by the excited carriers.
- Which translates to a photon flux of ~3*1019 photons/s/cm2





Conclusions

- An initial exploration of idea indicates the feasibility of this novel idea
- Exploits the strengths of two radically different semiconductor technologies – organics for optics and Si for storage and transport
- First attempt to integrate organic technology with existing Si technology
- Of immediate relevance to the industry
- Bare minimum incremental investment

Future Work

- Calculation of optical hot carrier generation rate by combining the detailed band structure of Si (up to ~3eV) and finite element electromagnetic simulation
- Monte Carlo simulation of hot carrier transport
- Design and optimization of OLED
- Integration of micropatterned array of OLEDs on Flash IC