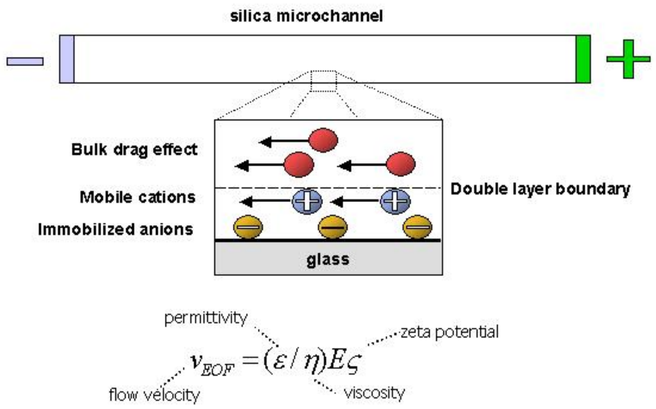
Silicon Microfluidics Using Field Effect Flow Control

Nate Sniadecki, Cheng Lee, Don DeVoe

Maryland MEMS LAB

Field-Effect Flow Control: FlowFETs

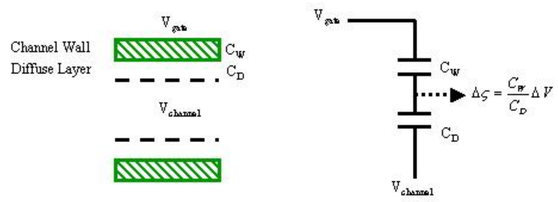
- FlowFET = electrical gating of electroosmotic flow
- Applications in valving, mixing, combinatorial synthesis, bioseparations, and other microsystems where fluid flow in complex microchannel networks is desired
- FlowFETs enables pumping within interconnected microchannel networks through local modulation of an electrical gate voltage, similar to electron flow control in CMOS FETs. Based on electroosmotic flow (EOF):



$$v_{EOF} = (\varepsilon/\eta)E\zeta$$

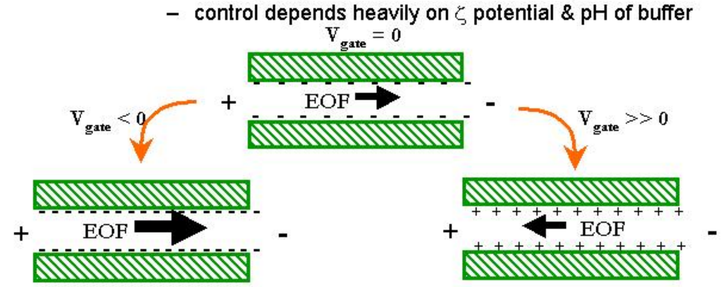
permittivity, zeta potential, flow velocity, viscosity

- EOF uses a longitudinal field for electrokinetic pumping, but.
- ζ potential can be controlled using a transverse electric field
  - capacitive divider network formed by dielectric wall (C_W) & electrical double layer within channel (C_D)

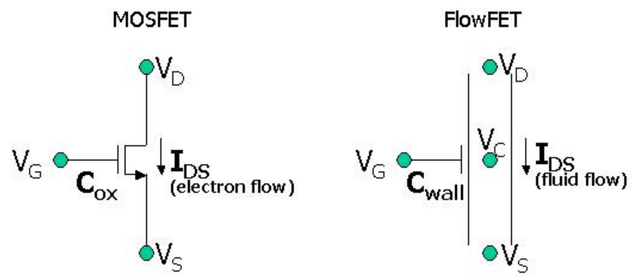


Applications:
- Electrokinetic valving
- Micro/Nanochannel pumping
- Combinatorial synthesis

- V_G modulates the ionization charge density at the wall
  - velocity may be modified without altering EOF field
  - control depends heavily on ζ potential & pH of buffer

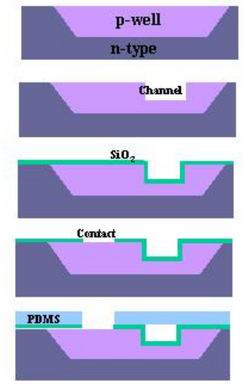


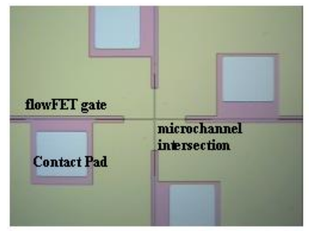
MOSFET analogy



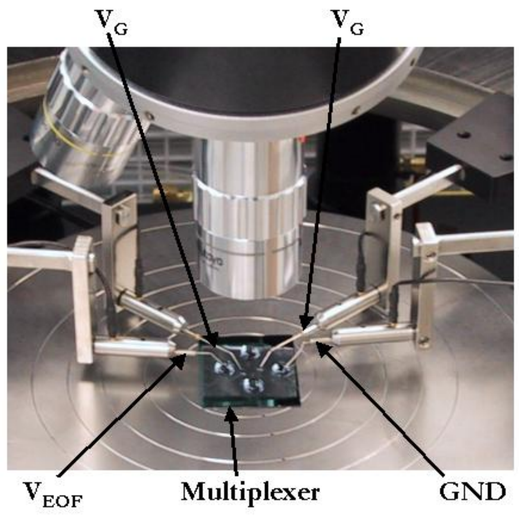
$I_{DS} = (1/2)\mu_n C_{ox}(W/L)(V_{GS}-V_T)^2$ $I_{DS} = (\varepsilon/\eta)\zeta_o(V_{DS}/L)(1+V_{GC}C_{Cwall}/C_{dl})$

Fabrication





Testing Methodology



Testing on Probe Station

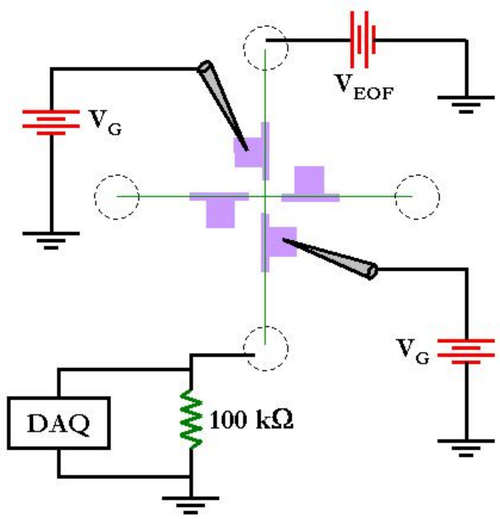


Diagram of Testing Circuit

Flow Control Characterization

- Least-square fitting
  - ε-ACA pH 3: -15.5×10^{-3} cm²/(V² s)
  - ε-ACA pH 4: -7.2×10^{-3} cm²/(V² s)
  - PBS pH 5: -4.4×10^{-3} cm²/(V² s)

Compare with theory: