PERSPECTIVES ON INVENTING

OUTLINE

- WHAT IS INTELLECTUAL PROPERTY (IP) ?
- WHO IS AN INVENTOR ?
- THE INVENTING PROCESS
- INVENTING STYLES
- SOME PERSONAL EXPERIENCES – IT'S NEVER TOO LATE
- INGREDIENTS FOR SUCCESSFUL INVENTING
- SUPPLEMENTAL MATERIAL
  - SIGNIFICANT PARTS OF A PATENT
  - OFFICE ACTIONS
  - THE ROLE OF SIMULATION IN INVENTING
  - A PATENT EXAMPLE
  - BIOGRAPHICAL SUMMARY

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WHAT IS INTELLECTUAL PROPERTY?

1. Patents
   - **Utility**
     - **New and useful method, structure, algorithm, composition of matter, or any new and useful improvement thereof**
   - Design – ornamental design of a functional item
   - Plant
2. Trademark
   - Distinguishes products of one entity from others
     - Words, symbols
3. Copyright/mask work
   - Confers rights of authorship
     - Semiconductor mask data
     - Art, literature, music, video
4. Trade secrets
   - Prevents access by competitors

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*WHO IS AN INVENTOR?

- Inventorship is not like authorship of a paper
- Persons contributing to the concept of at least one claim are inventors
  - Excludes contributors to reduction to practice

- Filing an application in the name of someone who is not an inventor, or omitting someone who should be listed an inventor, can result in a ruling that the patent is invalid
  - application must be accompanied by an oath in which the applicant swears that he or she believes himself or herself to be the original and first inventor of the invention

***contains content from:**

http://www.yale.edu/ocr/invent_guidelines/inventorship.html

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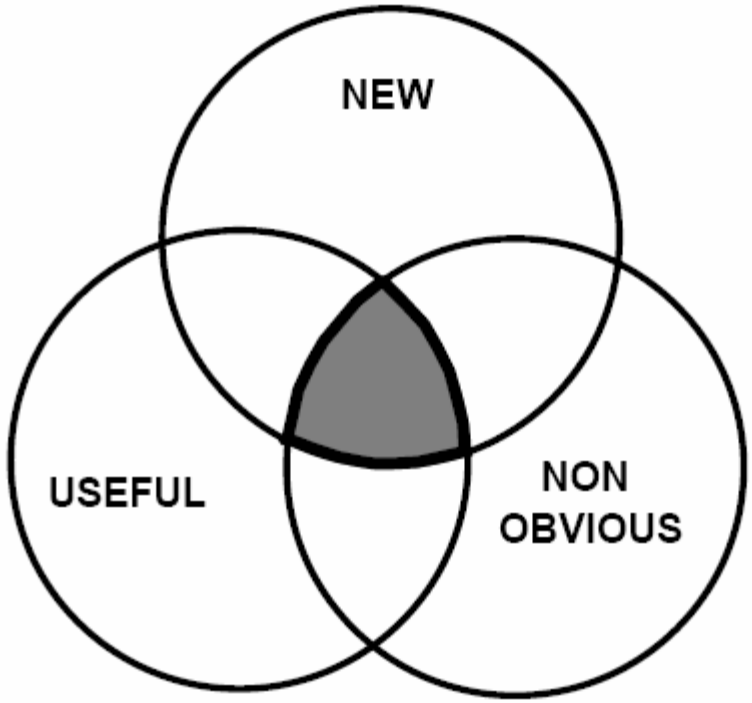
SOLUTIONS TO PROBLEMS ARE POTENTIAL PATENTS

- TECHNOLOGY IS IMPEDED BY UNANTICIPATED PROBLEMS
- SOLUTIONS ARE REQUIRED TO ACHIEVE THE GOALS OF A PROJECT

➔FERTILE GROUND FOR INVENTING

PROBLEMS ARE GOLDEN OPPORTUNITIES FOR INVENTION!

REQUIREMENTS FOR OBTAINING A PATENT



TO OBTAIN A PATENT, AN INVENTION MUST BE:

- NEW
- USEFUL
- NON OBVIOUS

PRELIMINARY WORK: IDEAS

- DOCUMENT YOUR IDEAS
  - Notes
  - Figures
  - → Documents should be signed by witnesses
- PRIORITIZE IDEAS
  - Weigh complexity vs value to the business and state of the art
  - Near-term vs long-term payback
- BROADEN IDEAS
  - Identify and exploit weaknesses in prior art
- Ideas/concepts not of immediate relevance should be put in your "INVENTOR'S TOOLBOX"

CONCEPT OF "INVENTOR'S TOOLBOX"

- THE SYNERGISTIC INVENTING PROCESS OFTEN DIVERGES FROM THE MAIN PROBLEM STATEMENT
  - **MAY LEAD TO**:
    - NEW PROBLEM STATEMENTS
    - NEW DISCOVERIES ABOUT STRUCTURES, METHODS, MECHANISMS, OR PHENOMENA SEEMINGLY UNRELATED TO THE CURRENT TOPIC
  - **SAVE** THIS NEW MATERIAL FOR FUTURE USE IN YOUR "**INVENTOR'S TOOLBOX**"
    - IN THE BACK OF YOUR MIND
    - RECALLED WHEN NEEDED

PRELIMINARY WORK: PRIOR ART

1. Find prior art from
   - USPTO database
     - Patents
     - Patent applications
   - Technical databases and libraries
     - e.g. IEEE, APS, NIST, universities

2. Ask yourself
   - How prior art relates to your invention
   - Distinctions of invention from prior art
   - Is invention taught by prior art? (Novelty test)
   - Is invention suggested by any combination of prior art? (Obviousness test)

3. Actions
   - Expect to modify your invention (many times!)
     - Work around prior art
     - Improve on prior art

PUTTING IT ALL TOGETHER: THE INVENTION DISCLOSURE

- Collect materials
  - your Notes
  - your Figures
  - Your analyses
- Write an invention disclosure
  - Should follow the format of the patent application
  - Used to "sell" your invention to review board/evaluator (corporation or other sponsoring institution)
  - Used to facilitate preparation of patent application

EXPECT "OFFICE ACTIONS"

- PTO objections (i.e. office actions)
  - Claims rejected mostly for:
    - Lack of Novelty
    - Obviousness
    - Non-usefulness
  - Office actions are very common – majority of applications
  - Inventor and attorney work together to address office actions
    - explain why the rejection/objection is improper

    or
    - amend claims to make them allowable
  - May be time consuming
  - Essentially it is a negotiating process with the USPTO

EXPECT “OFFICE ACTIONS”

- I was “blown away” by my first office action
  – totally unanticipated Modus Operandi of the USPTO

- Hundreds of subsequent office actions were handled with generally progressively increasing calmness

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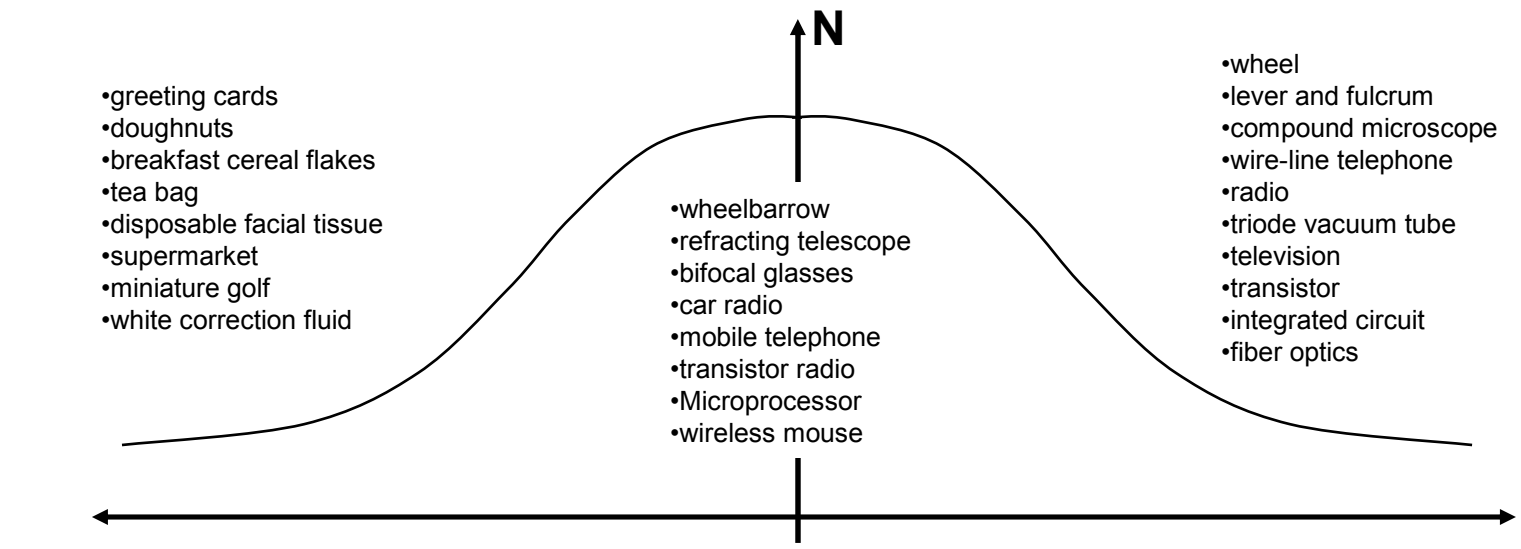
DISTRIBUTION OF INVENTOR STYLES



- **MOST INVENTORS FALL IN THE MIDDLE OF THE DISTRIBUTION**
- **YOU DON'T NEED TO WIN A NOBEL PRIZE – ALTHOUGH IT WOULDN'T HURT**

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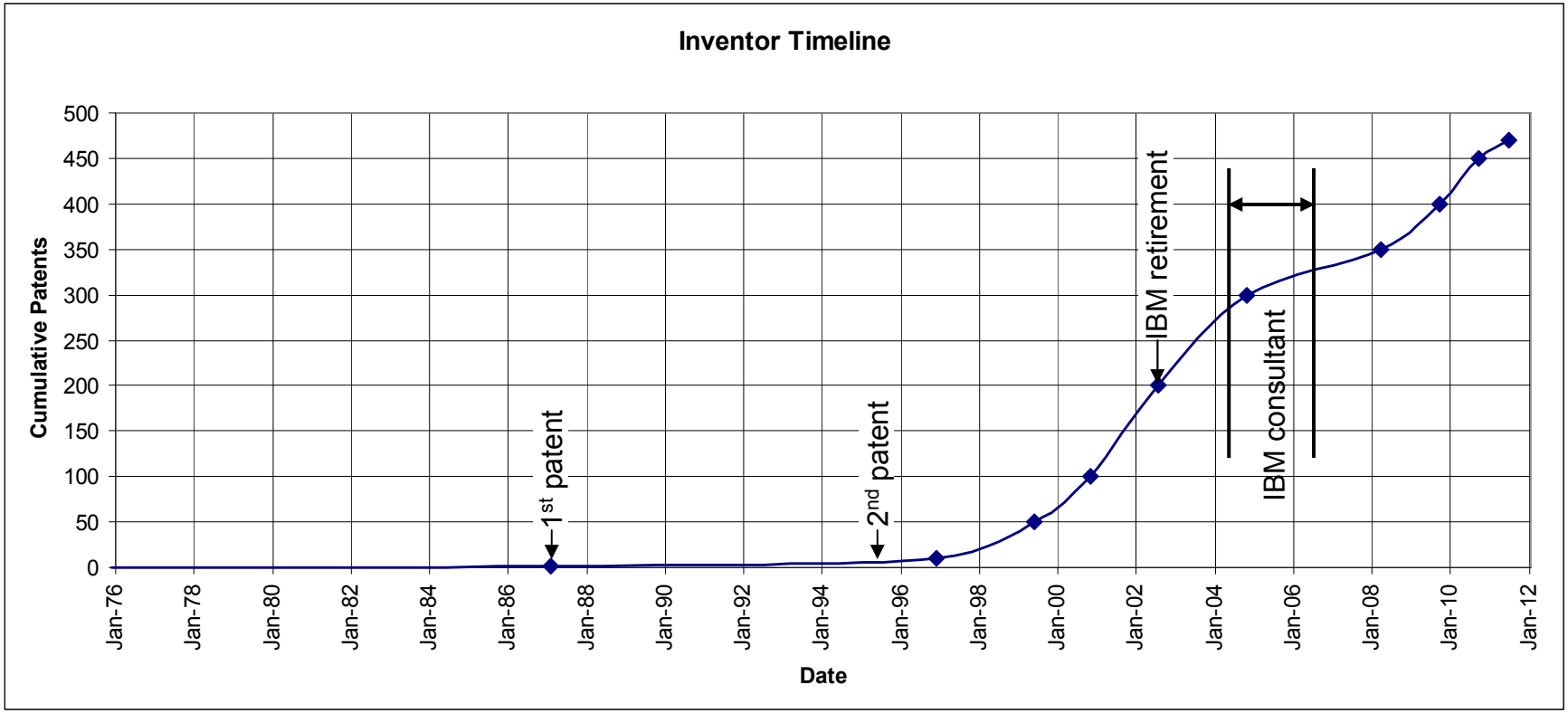
“I wasn’t born an inventor.”

Sharing some personal experiences

MY INVENTOR HISTORY

- 1975: began career at IBM
  - Several invention disclosures submitted between 1975 and 1980
  - zero filed for patent protection
  - 3 inventions protected by “publication” (IBM “publish” category)
- 1987 (Feb): first US patent issued (filed 6/’83)
- 1992: began as IBM’s lead device eng’r in 256Mb DRAM alliance with Toshiba and Siemens (Infineon)
- 1992-1995: dozens of patent applications filed
- 1995 (May): second US patent issued
- 1999 (June): 50th US patent issued
- 2000 (Nov): 100th US patent issued
- 2002 (June): completion of DRAM alliance; retired from IBM
- 2002 (Aug) – 200th US patent issued
- 2004-2006: consulted for IBM; many new patent applications filed
- 2004 (Nov): 300th US patent issued
- 2009 (Oct): 400th US patent issued
- Presently: > 470 US patents issued

MY INVENTOR TIMELINE



WHY DID IT TAKE ME SO LONG TO START INVENTING?

A CONFLUENCE OF EVENTS OCCURRED AT MID-CAREER

1. Technical maturity
   - integration of a breadth of experience
   - technical recognition
2. The right projects projects
   - leading technical roles in advanced DRAM and CMOS
3. The blessings of my management – conducive environment
4. Networking with experts in related fields
5. Sense of urgency to do something with my career

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INGREDIENTS FOR SUCCESSFUL INVENTING

- A PASSION FOR SEEKING SOLUTIONS & ADVANCING THE STATE OF THE ART
  - PERSISTENCE AND DOGGED DETERMINATION
  - SELF-CONFIDENCE
    - MAY BE STRENGTHENED OR WEAKENED DEPENDING ON EXPERIENCES
  - ENCOURAGEMENT OF MENTORS

INGREDIENTS FOR SUCCESSFUL INVENTING

- "TECHNICAL MATURITY"
  - RECOGNIZED EXPERT IN ONE OR MORE FIELDS RELATED TO PROBLEM
  - A BROAD PERSPECTIVE OF THE ART
    - UNDERSTANDING INTERRELATIONSHIPS AMONG RELATED TECHNICAL AREAS
    - CRITICAL THINKING
      - CHALLENGE CONVENTIONAL WISDOM

INGREDIENTS FOR SUCCESSFUL INVENTING

- THE RIGHT OPPORTUNITIES AT THE RIGHT TIME
  - -RECOGNIZING OPPORTUNITIES
    - -PROBLEMS NEEDING SOLUTIONS
    - -GET THERE FIRST!
  - - CHALLENGING PROJECTS
  - - BLESSINGS OF MANAGEMENT
  - - PATIENCE
  - - IT'S NOT ONLY LUCK

INGREDIENTS FOR SUCCESSFUL INVENTING

- WILLINGNESS TO WORK WITH OTHERS
  - NOT FOR LONERS
  - TEAM WITH COMPLEMENTARY SKILLS
  - SYNERGISM➔SPARKS NEW IDEAS

INGREDIENTS FOR SUCCESSFUL INVENTING

- WILLINGNESS TO PURSUE OUTRAGEOUS IDEAS
  - PARADIGM SHIFTS
  - TURN PROBLEMS INTO FEATURES
  - EXPERIMENT WITH “WHAT IF”
  - ACCEPT RISK
  - ALWAYS QUESTION “CONVENTIONAL WISDOM”

INGREDIENTS FOR SUCCESSFUL INVENTING

- AN OPEN MIND WHEN INVENTION IS CHALLENGED
  - BY OTHERS
  - BY YOURSELF

INGREDIENTS FOR SUCCESSFUL INVENTING

- MUST BE INCREDIBLY ORGANIZED
  - JUGGLING ACT AMONG NUMEROUS INVENTIONS
    - DRIVING EACH INVENTION TO COMPLETION
    - PREPARING INVENTION DISCLOSURES & PATENT APPLICATIONS
    - ADDRESSING MULTIPLE OFFICE ACTIONS
    - COMING UP WITH NEW STUFF ALL THE TIME

INGREDIENTS FOR SUCCESSFUL INVENTING

- SUPPORTIVE RESOURCES
  - DEMONSTRATION OF OPERABILITY
    - SIMULATION SOFTWARE
    - EXPERIMENTAL FACILITIES
  - INTELLECTUAL PROPERTY DEPARTMENT
    - PATENT ATTORNEYS AND AGENTS
    - LEGAL AND BUSINESS CONSULTANTS

SUPPLEMENTAL MATERIAL

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SIGNIFICANT PARTS OF A PATENT

1. THE SPECIFICATION

   a) BACKGROUND

      Description of the problem solved, value and benefits of the invention

   b) SUMMARY OF THE INVENTION

   c) BRIEF DESCRIPTION OF THE DRAWINGS

   d) DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

      i) Must enable one of ordinary skill to practice the invention without undue experimentation

      ii) Must disclose “best mode” of practicing the claimed invention

      iii) Examples (optional)

2. DRAWINGS

SIGNIFICANT PARTS OF A PATENT

3. CLAIMS

- “Independent claims” define the broadest legal rights being sought with the patent
- "Dependent" claims contain all the limitations of the “Independent claims”
- Must be supported by the “detailed description of invention” in the “specification” section

My experience: Claims may be tricky to write. Every word may have legal significance. Often it is wise to employ the assistance of an experienced patent attorney/agent to obtain the broadest claims.

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OFFICE ACTIONS

Lack of Novelty

- 35 USC (Title 35 of the United States Code) **102** defines **novelty**
  - Something not known or used by others, has not been patented or described in a publication, or offered for sale in the US more than one year prior to the date of the patent application

OFFICE ACTIONS

Obviousness

- 35 USC (Title 35 of the United States Code) **103** defines **non-obvious**
  - The differences between the subject matter of the invention and the prior art must be such that the invention would not have been obvious to a person having ordinary skill in the art
  - Other tests for non-obviousness:
    - Invention is not suggested or taught by combination of prior art
    - Invention could not be conceived by combining prior art
    - But, invention may be conceived from a combination of the prior art, if it is motivated by an unexpected or unanticipated result
      - » e.g. problem solved by prior art is a feature of the new invention

OFFICE ACTIONS

Lack of usefulness

- MPEP (Manual of Patent Examining Procedure) 608.01 & 706.03 defines **useful (utility)**
  - Patent application must contain such description of details as to enable any person skilled in the art to make and use the invention
    - Application may be rejected for lack of utility
      - » being inoperative, based on perpetual motion, frivolous, fraudulent, or against public policy

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THE ROLE OF SIMULATION IN INVENTING

- Provides insights into physical mechanisms
  - -Allows rapid answers to “what ifs”
  - -Enables quantification of effects
  - -Understanding recognized problems
- Enables early anticipation/prediction/discovery of problems
  - -Before others do
- Promotes brainstorming
  - -e.g. turn a problem into a feature of an invention
- Demonstrates operability of invention
- Greatly reduces costs of experiments
  - -Reduces need for actual hardware

THE ROLE OF SIMULATION IN INVENTING

- 2D/3D semiconductor process, device and electromagnetics simulation played an important role in at least 50% of my inventions

  -demonstrated operability of invention

  -predicted an unknown problem

  -helped understand a known problem

  -catalyzed new inventions

THE ROLE OF SIMULATION IN INVENTING

- **INVENTIVE AREAS FOR WHICH SIMULATION HAS WORKED VERY WELL**
  - **Novel device structures**
    - 3D DRAM cells
    - novel MOSFETs (gate wrap-around, finfet, vertical channel)
  - **Dimensionally coupled electrical effects**
    - sensitivity of parasitic currents to geometry and operating conditions
      - coupled MOSFET/bipolar structures
  - **SOI (silicon-on-insulator) body charge hysteresis effects**
    - performance enhancement – dynamic threshold voltage
    - parasitic suppression

THE ROLE OF SIMULATION IN INVENTING

- **A CHALLENGE FOR SIMULATION**
  - **MOSFET crystal lattice strain effects**
    - model for mobility dependence on strain needs work
    - must rely more on experimental data
      - lateral vs transverse, tensile vs compressive strain
      - very different behavior for NFETs and PFETs
    - however, structures/methods for inducing desired strain patterns were successfully simulated

THE ROLE OF SIMULATION IN INVENTING

- **AND THEN THERE ARE INVENTIONS WHERE SIMULATION WAS NOT USED**
  - Novel interconnect structures
    - SRAM cell wiring for improved density
  - Hybrid substrates
    - integrated SOI and bulk CMOS
  - Wiring formed on sidewalls of insulating mandrels

CAVEAT ABOUT SIMULATION

- Don’t lose sight that simulation relies on models which represent the physics of past experience
- Use caution when attempting to extend the verified domain of a model into the area of the inventive ideas
- Ideally, simulation and experimental verification should go hand in hand
  - modify underlying physics of existing models when necessary
  - however, experimental verification of modeled results is not a requirement to receive a patent
    - but, extremely desirable to help assure that the invention is useful

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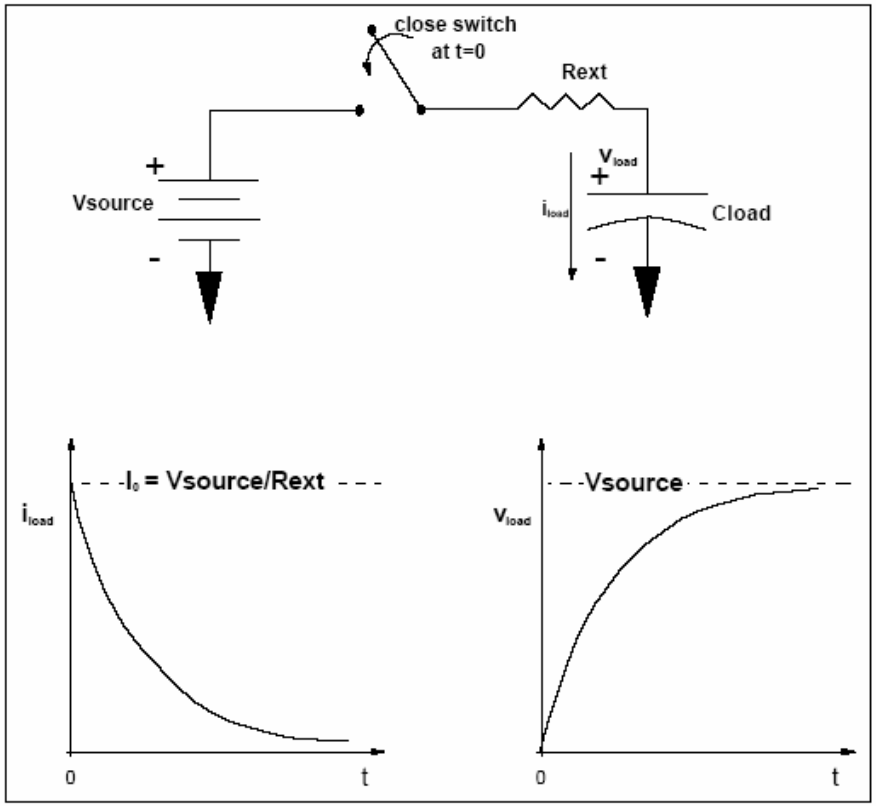
PATENT EXAMPLE SHOWING USEFULNESS OF 3D DEVICE MODELING

PATENT EXAMPLE: BACKGROUND

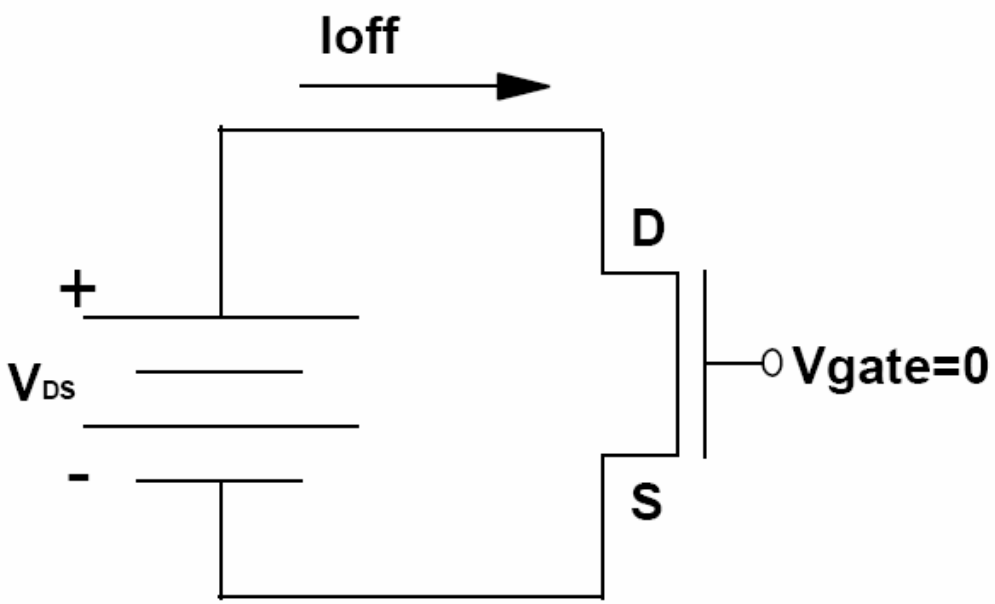
BROAD PROBLEM STATEMENT: The quest for the perfect switch



- "PERFECT" SWITCH
  - ZERO RESISTANCE WHEN CLOSED (Ron)
  - INFINITE RESISTANCE WHEN OPEN (Roff)
  - Ron/Roff $\rightarrow$ 0

PATENT EXAMPLE: BACKGROUND

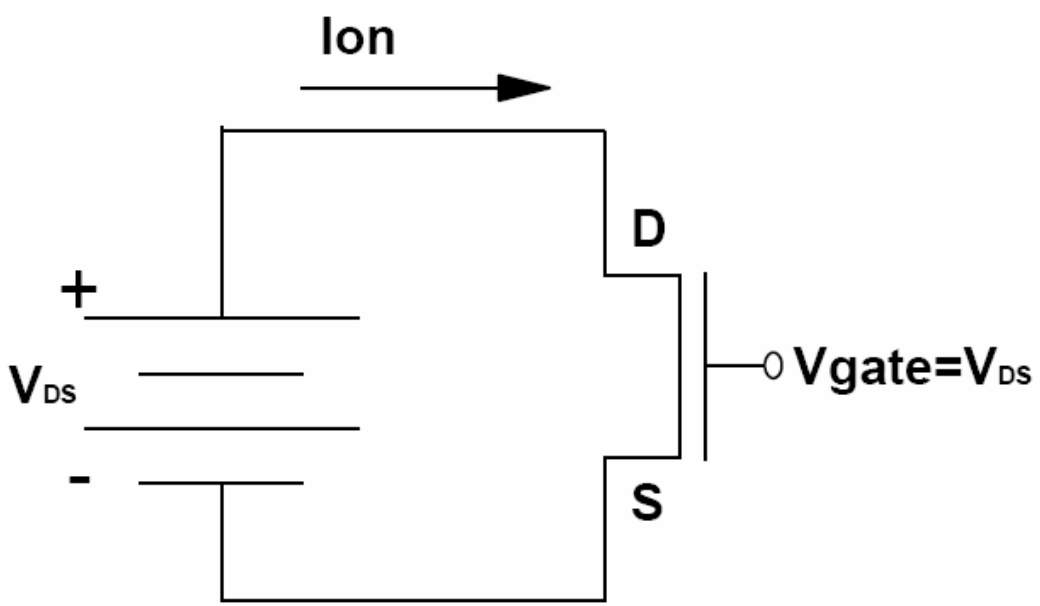
THE MOSFET IS A NON-IDEAL SWITCH



- A MOSFET HAS A LEAKAGE CURRENT WHEN IN OFF-CONDITION (SWITCH OPEN)
  - $R_{off}=V_{DS}/I_{off} < \infty$

PATENT EXAMPLE: BACKGROUND

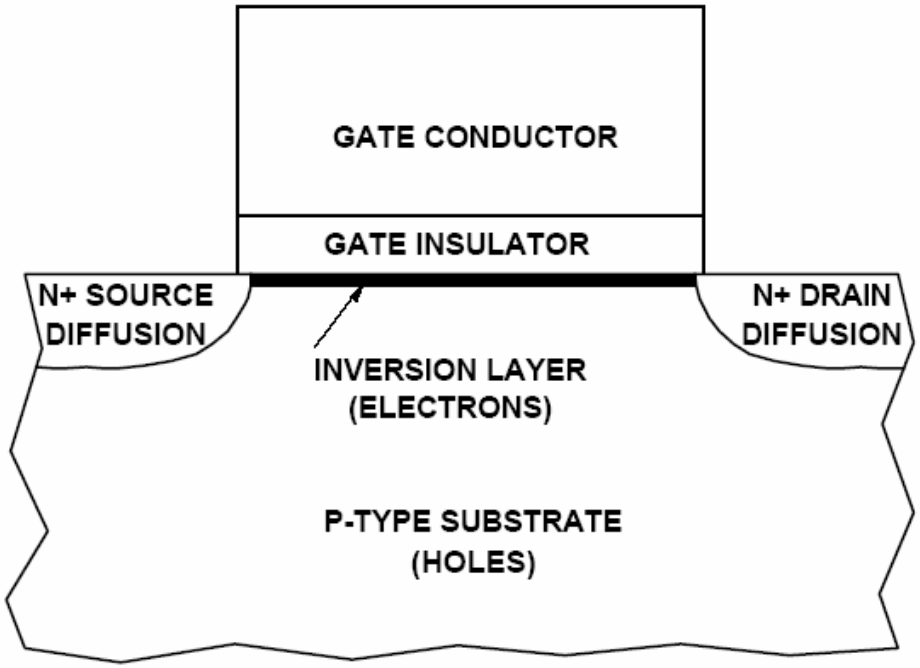
THE MOSFET IS A NON-IDEAL SWITCH



- A MOSFET HAS INTERNAL RESISTANCE WHEN IN ON-CONDITION (SWITCH CLOSED)
  - $Ron=V_{DS}/Ion > 0$
  - IN REAL MOSFETs Ron/Roff > 0
    - **HOW CAN Ron/Roff BE MINIMIZED ?**
    - **HOW CAN Ion/Ioff BE MAXIMIZED ?**

PATENT EXAMPLE: BACKGROUND

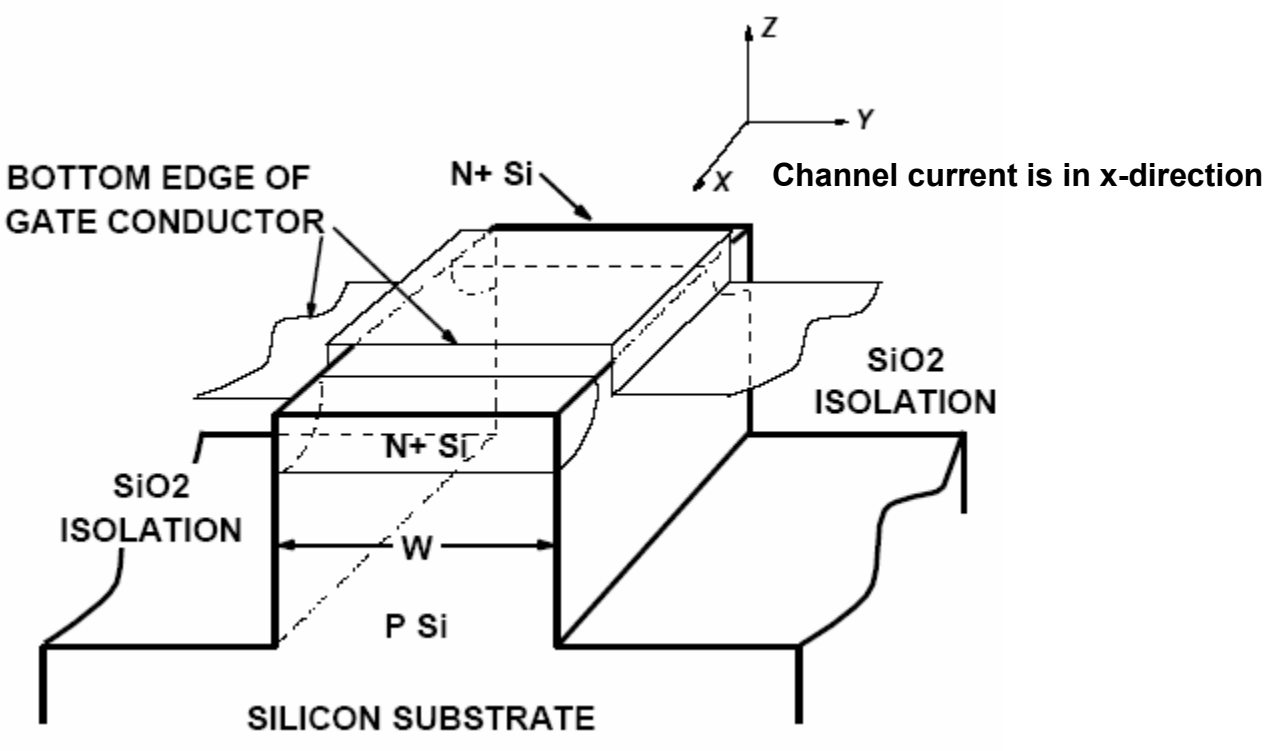
A "TEXTBOOK" MOSFET



- APPLICATION OF GATE VOLTAGE HIGHER THAN THRESHOLD VOLTAGE FORMS A CONDUCTIVE CHANNEL (INVERSION LAYER) WHICH CONNECTS SOURCE AND DRAIN (SWITCH CLOSED)

PATENT EXAMPLE: THE PROBLEM

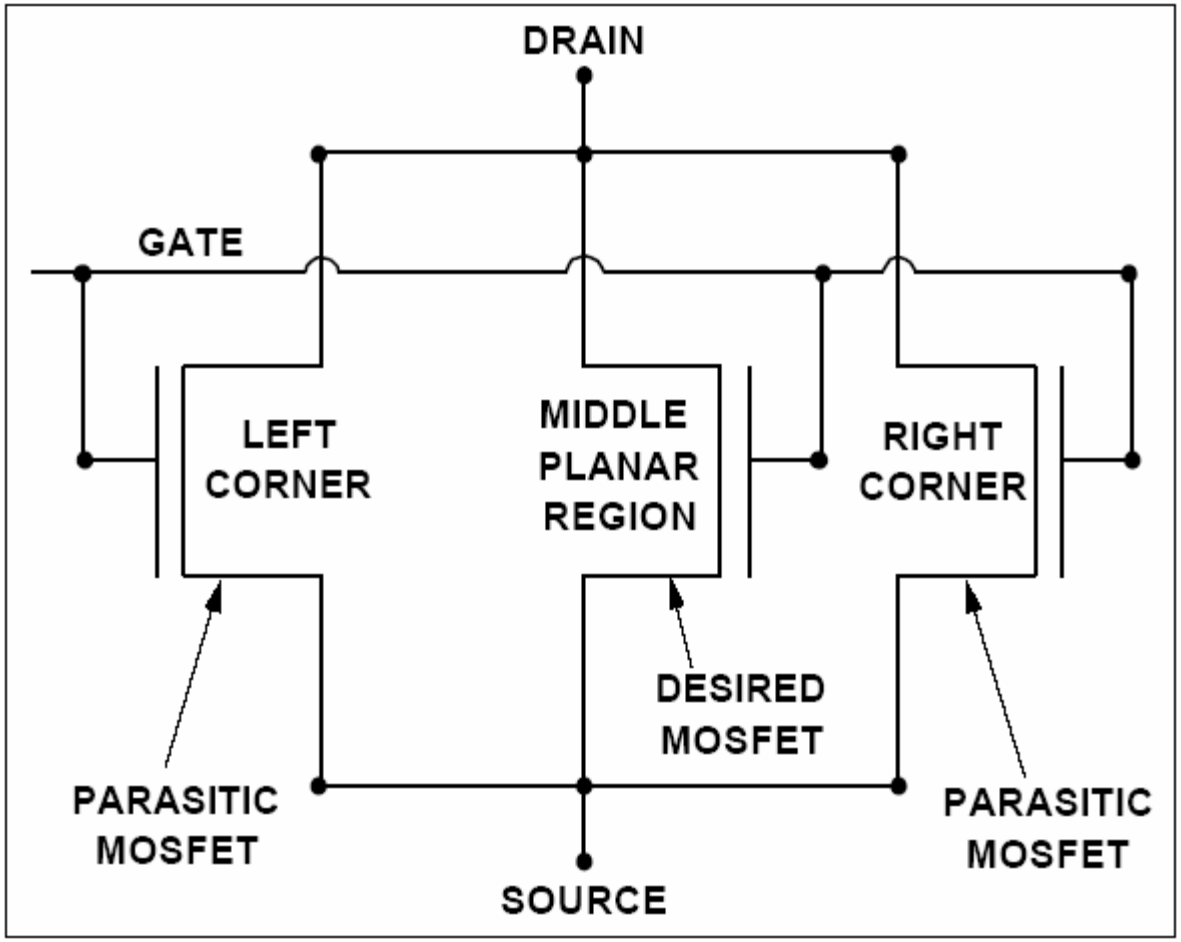
FOCUSED PROBLEM STATEMENT: How can the channel current contributed by the silicon corners of a MOSFET bounded by shallow trench isolation (STI) be minimized?



PATENT EXAMPLE: THE PROBLEM

SIMPLE DC EQUIVALENT CIRCUIT OF PROBLEMATIC MOSFET

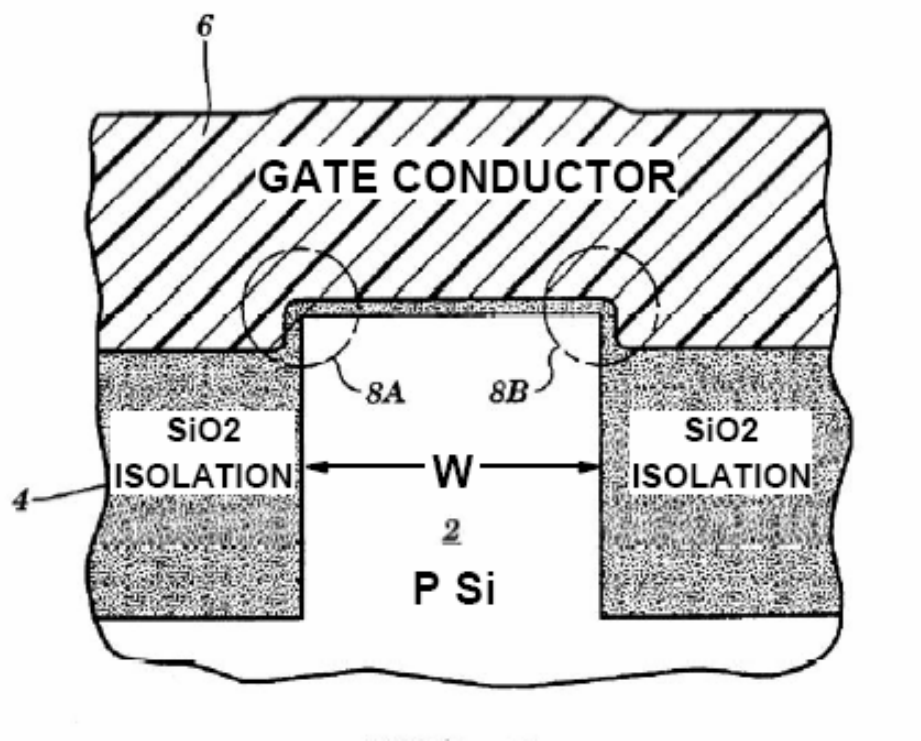
- Need to suppress parasitic MOSFETs



PATENT EXAMPLE: THE PROBLEM

PHYSICAL CROSS-SECTION SHOWING PARASITIC CORNERS

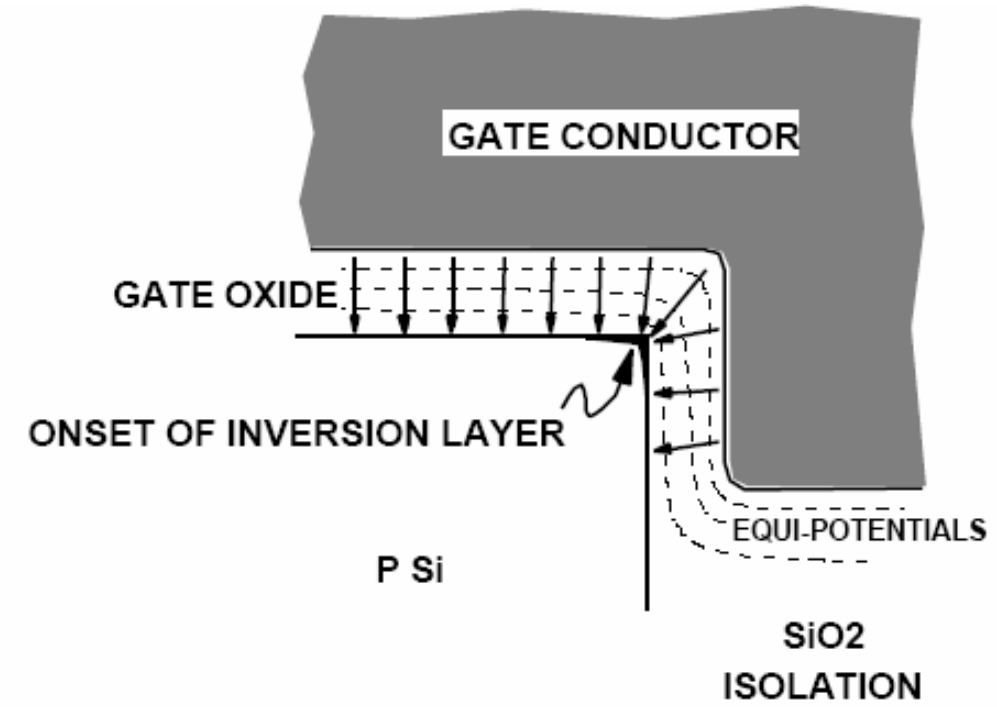
- Need to suppress conduction at parasitic corners (8A, 8B)



PATENT EXAMPLE: THE PROBLEM

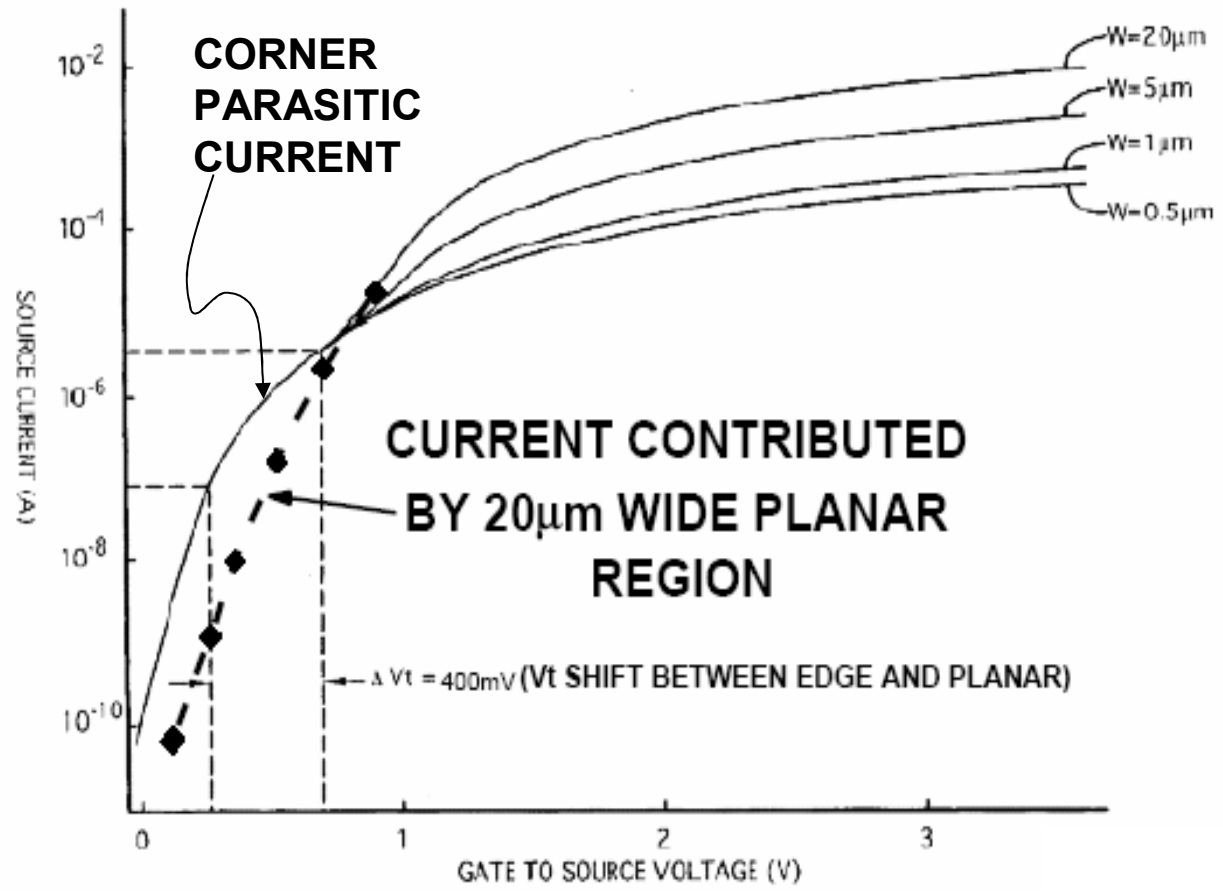
PHYSICAL MECHANISM RESPONSIBLE FOR CORNER CONDUCTION

- Small radius of curvature at corners → enhanced electric field → inversion occurs before mid-section



PATENT EXAMPLE: THE PROBLEM

SIMULATED PROBLEMATIC MOSFET CURRENT



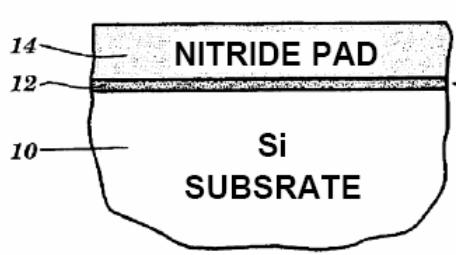
PATENT EXAMPLE

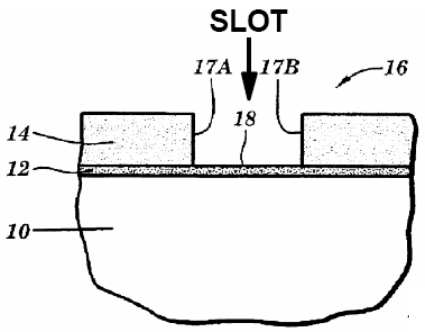
INVENTION SEEKS TO SUPRESS CORNER CURRENTS WITHOUT DEGRADING CURRENT FROM MID-SECTION OF CHANNEL

PATENT EXAMPLE: THE SOLUTION

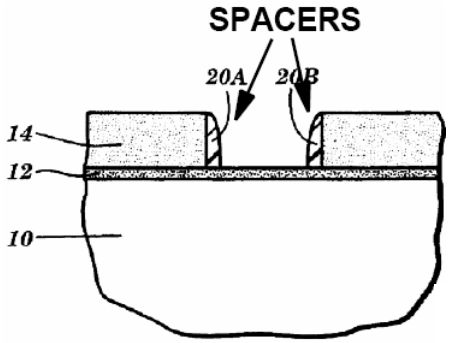
US 5,798,553
"TRENCH ISOLATED FET
DEVICES, AND METHOD FOR THEIR
MANUFACTURE"

PATENT EXAMPLE: THE SOLUTION

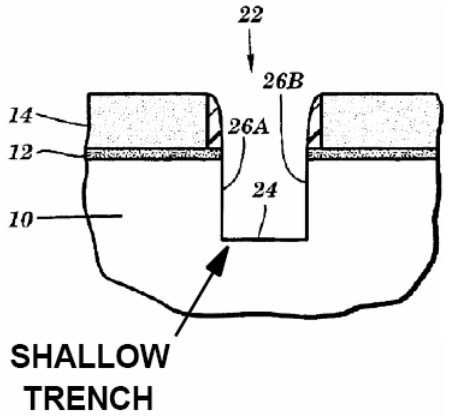




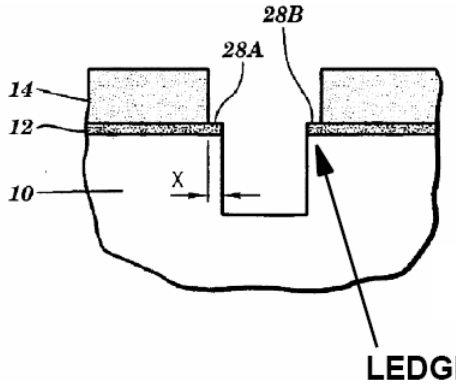
Form slot in nitride pad



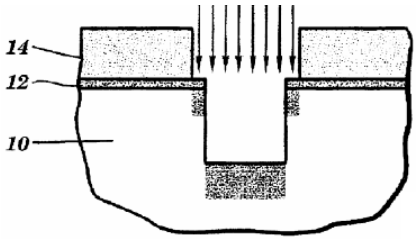
Form spacers on slot sidewalls



Etch shallow trench



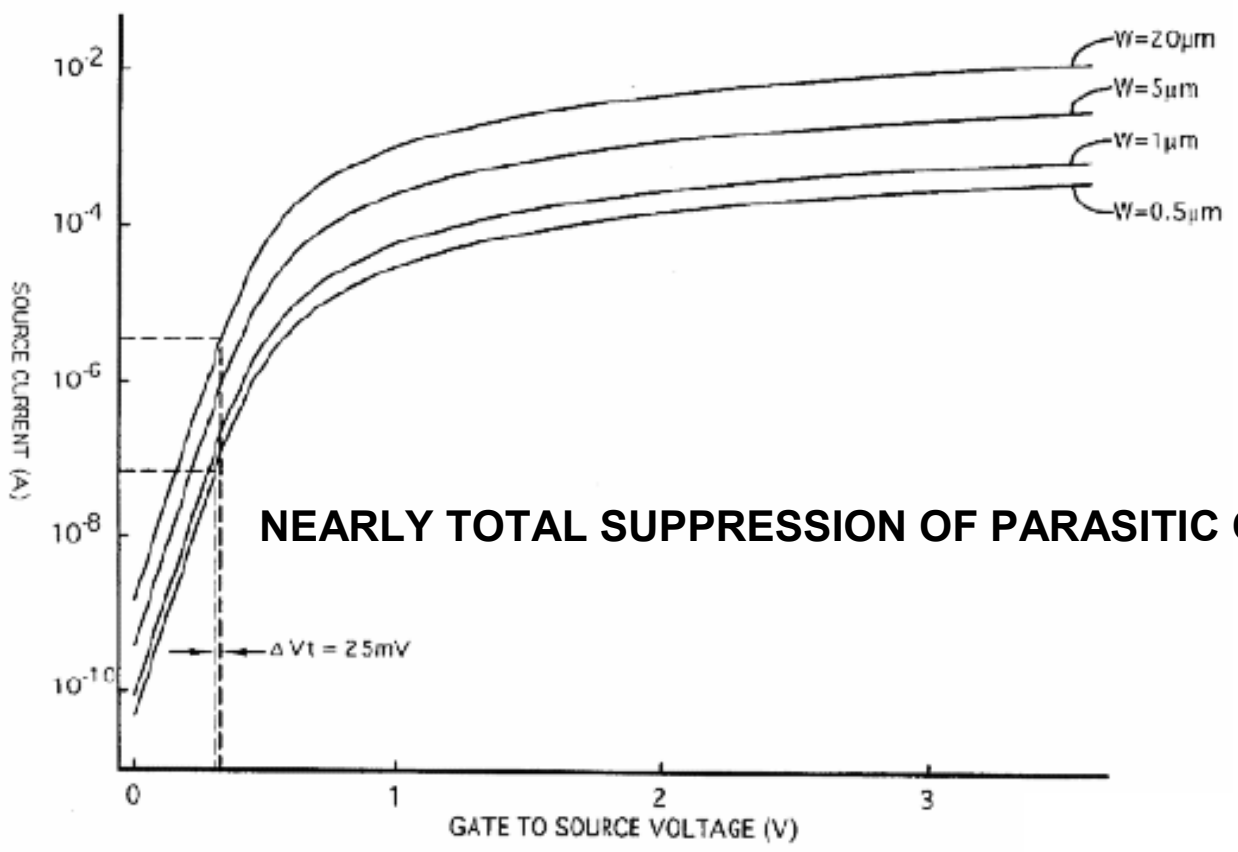
Remove spacers to expose ledge



Implant ledge to suppress corner conduction

PATENT EXAMPLE: THE SOLUTION

SIMULATED INVENTIVE MOSFET CURRENT



NEARLY TOTAL SUPPRESSION OF PARASITIC CURRENT

BIOGRAPHY

- Born in New York, NY, 1946.
- Ph.D.E.E. from City University of NY, 1975
- 30+ year career in Microelectronics R&D
  - beyond the 45nm CMOS node
  - spanning 32Kb through 1Gb DRAM generations
- Areas of expertise:
  - intellectual property development, prosecution, and litigation support
  - application of simulation to device design and process integration of advanced DRAM and logic semiconductor technologies
- One of IBM's most decorated inventors:
  - Corporate recognition for innovations to DRAM cell structure, process integration, and SOI technology