Molecular Nanosystems

Ultra-high thermal conductivity solution for electronics industry

Molecular Nanosystems

OVERVIEW

- Co-founded in 2001 by Dr. H. Dai (inc. in Delaware)
- Located in Palo Alto, CA
- 3,000 ft^2 facility with fully functional lab
- Product: CNT-based thermal pad
- Funding:
  - Angel investment
  - Government grants

- Core competencies – controlled CVD CNT synthesis, characterization & package integration
- Corporate vision: provide compelling thermal solution to the electronics industry

TEAM

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Core Team	Position	Relevant Experience	Education
Srinivas Rao, PhD	CEO/CTO	13+ years at Solectron, VP of Technology; 12 years at Raychem, Eastman Kodak and RCA Labs	BS in Metallurgy, IIT Madras, MS & PhD in Material Science, Stevens Institute of Technology
Jim Protsenko	COO	10+ years of operating and finance experience; previously Associate at New Millennium Partners	BA in Economics, MS in Management Science & Engineering, Stanford University
Lawrence Pan, PhD	Director of R&D	10+ years experience in technology development and management, at Candescent Technology and Sandia Labs.	BS in Physics, MS & PhD in Applied Physics, Stanford University

Advisory Board

Hongjie Dai, PhD	World's leading expert in CNT synthesis; Professor of Chemistry, Stanford University
Michael Murray	Operations & Strategy; Managing Director, New Millennium Partners
Ken Goodson, PhD	Expert in thermal management; Professor of Mechanical Engineering, Stanford University

PROBLEM

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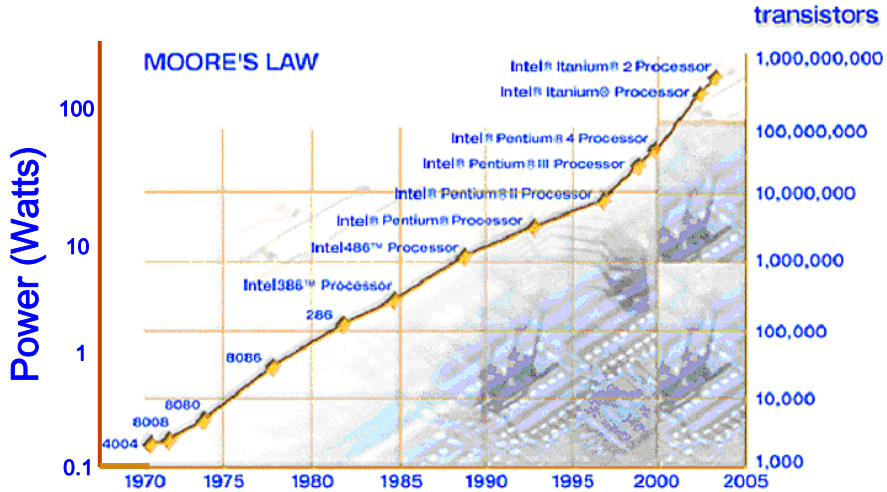
Unmanaged heat:

- Limits chip performance
- Reduces system reliability
- Increases cost and size of the solution

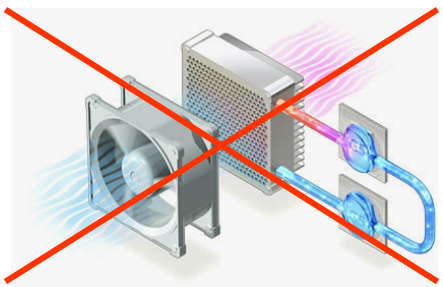


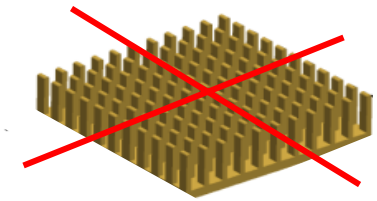
Historical power trend for Intel CPUs

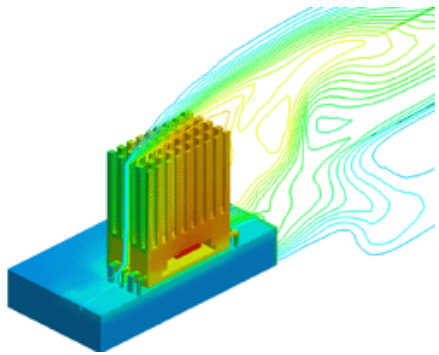
Source: Intel Technology Journal, 2004

Delphi's cooling solution for Apple computer

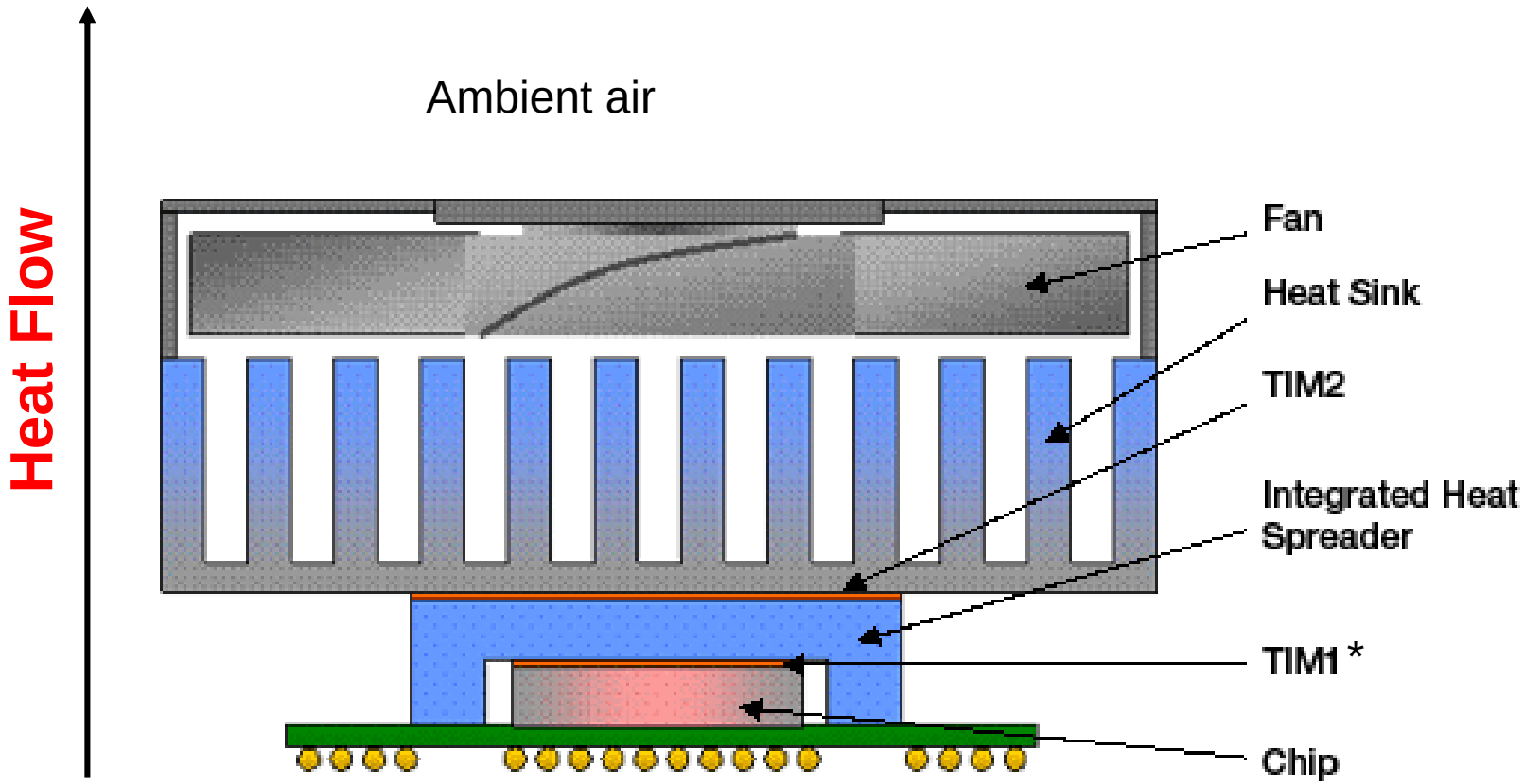
- Shrinking BLT
- Jet -Turbine





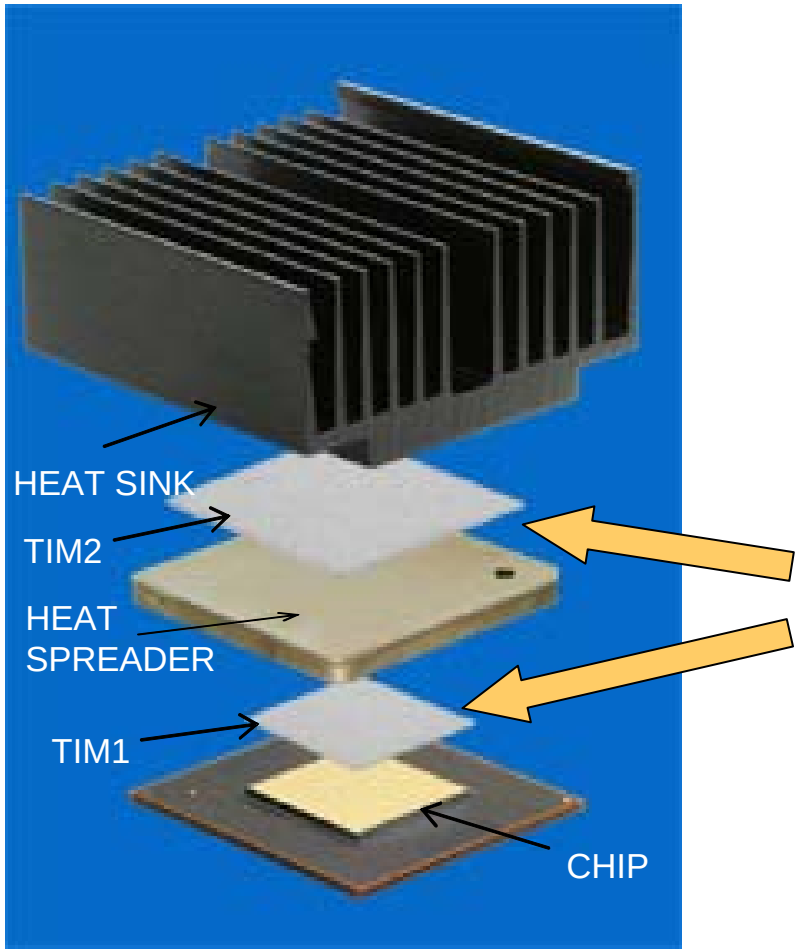


TYPICAL PACKAGE

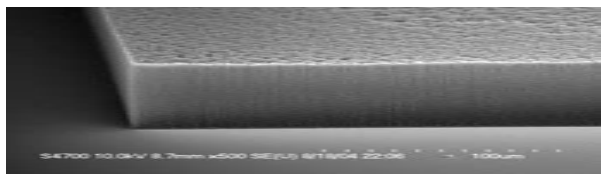


*TIM - thermal interface material

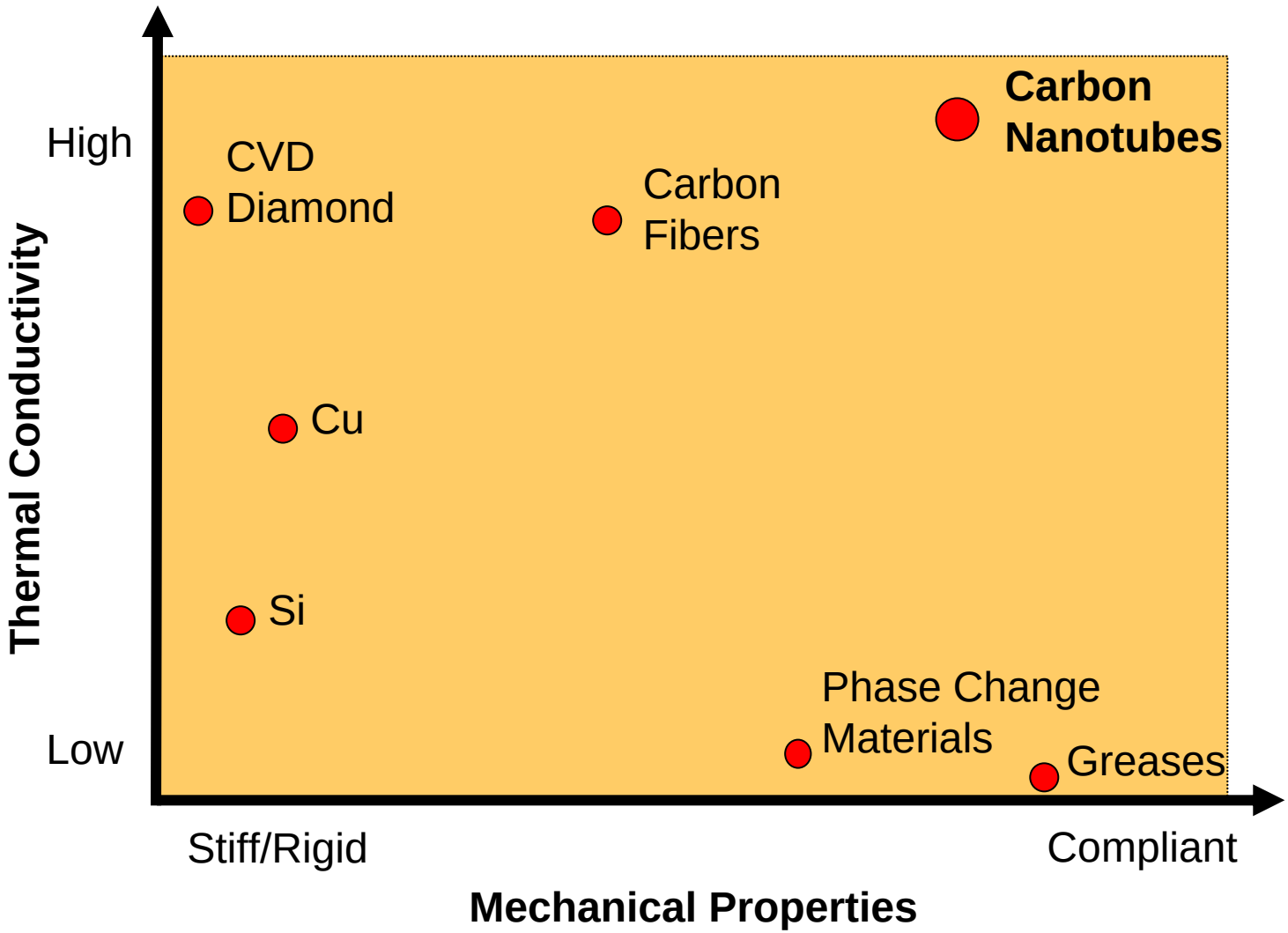
SOLUTION



CNT-based thermal pad



NANOTUBES – NATURAL CHOICE



VALUE PROPOSITION

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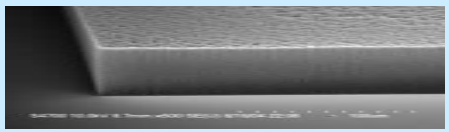
CNT thermal pad characteristics



- Low thermal impedance
- Compliant
- Inexpensive

Value for customers

- **PERFORMANCE:**
  - higher chip power – Enhanced Reliability
  - higher chip frequency
- **DESIGN (more flexibility):**
  - smaller heat sinks
  - Quieter fans (possible elimination)
  - Longer runtime battery
- **COST** (least expensive and most reliable of alternative cooling strategies)

Performance Comparison

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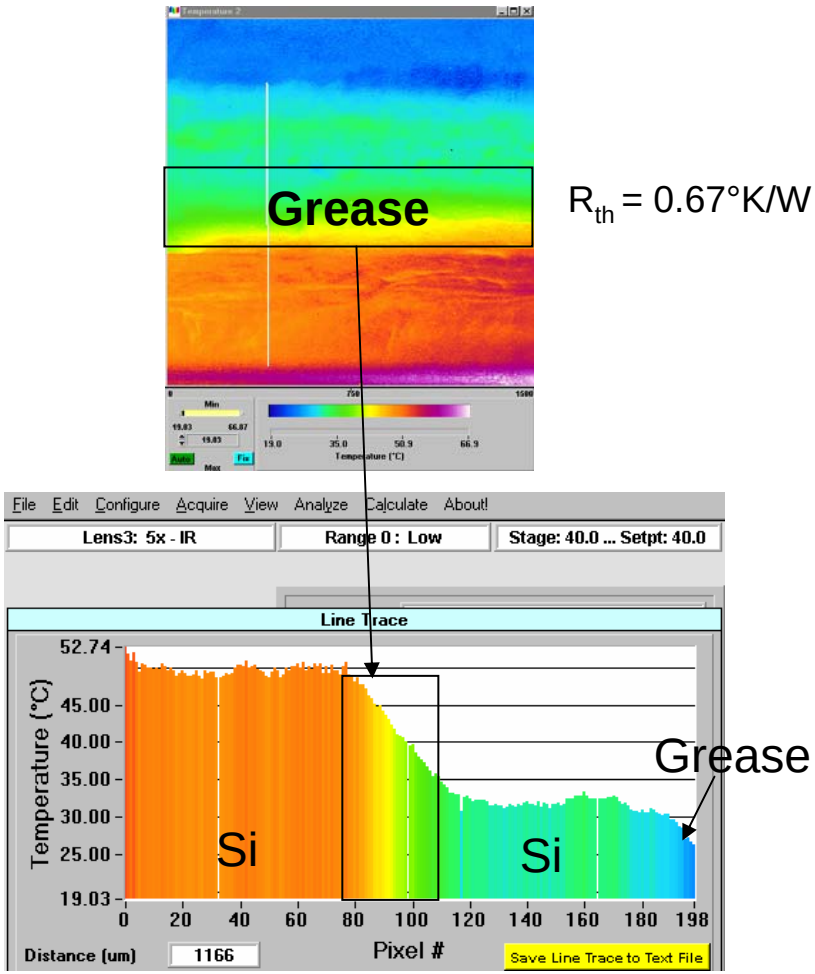
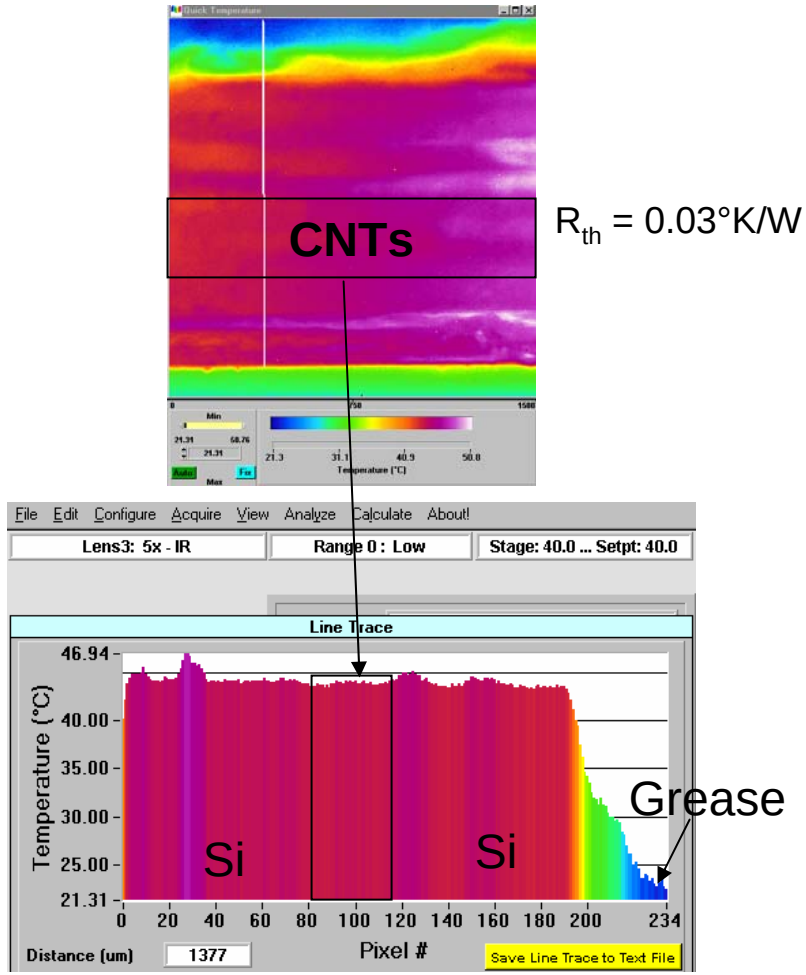
Significant temperature drop through grease in Si-Grease-Si stack



R_{th} = 0.67°K/W

No temperature drop through CNTs in Si-CNT-Si stack



R_{th} = 0.03°K/W

COMPETITIVE ANALYSIS

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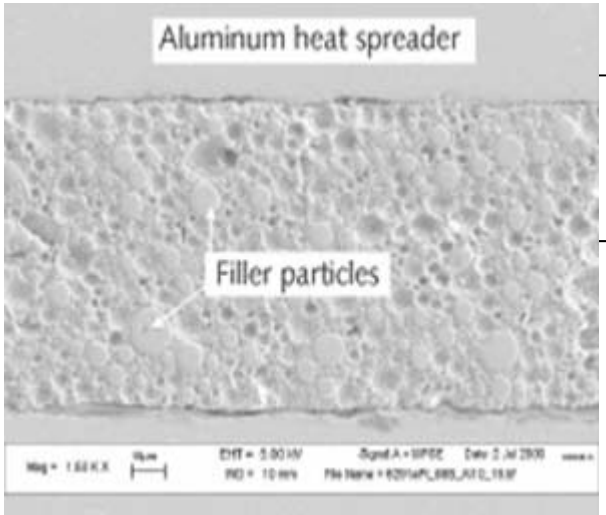
Incumbents



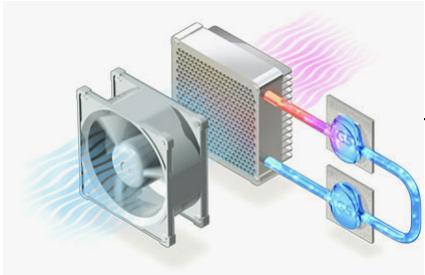
→ Heat spreader supply base

→ TIM supply base

Shortcomings:
- High thermal impedance
- Thermal mismatch for hard solders or metal fatigue for soft
- Short lifespan & difficult rework

Heat stack, heat fin suppliers

Liquid cooling



→ Heat exchanger systems

Shortcomings:
- $$$
- Reliability problems
- Still need a good TIM

Emerging Technologies

Other CNT-based, graphite fibers, Peltier coolers

Shortcomings:
- Less compelling value proposition
- Significant technical risk
- Added electronics, expensive

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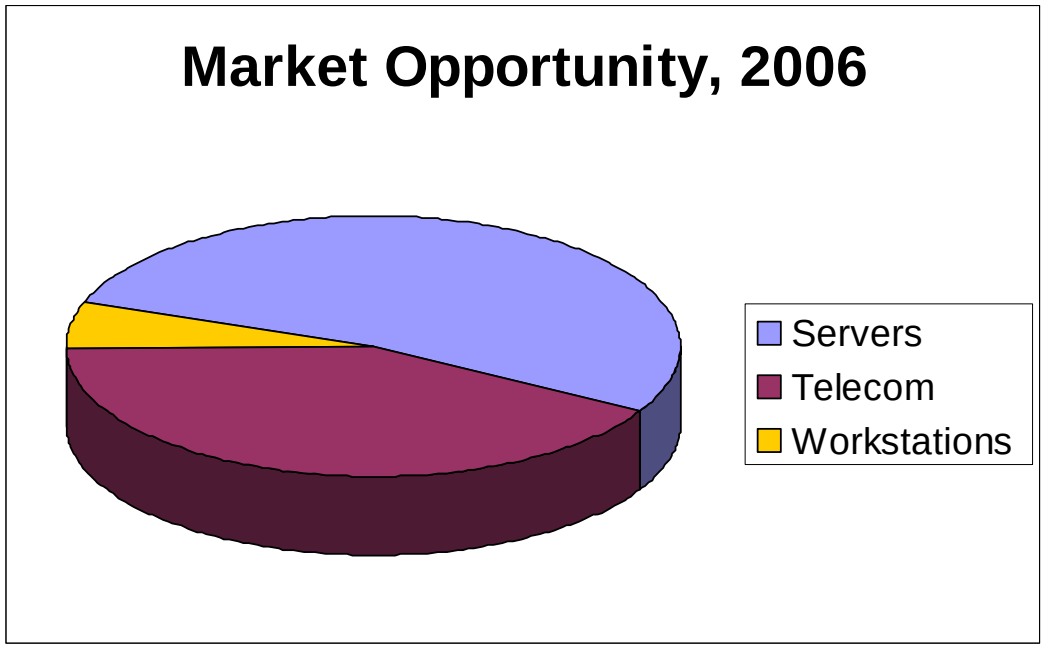
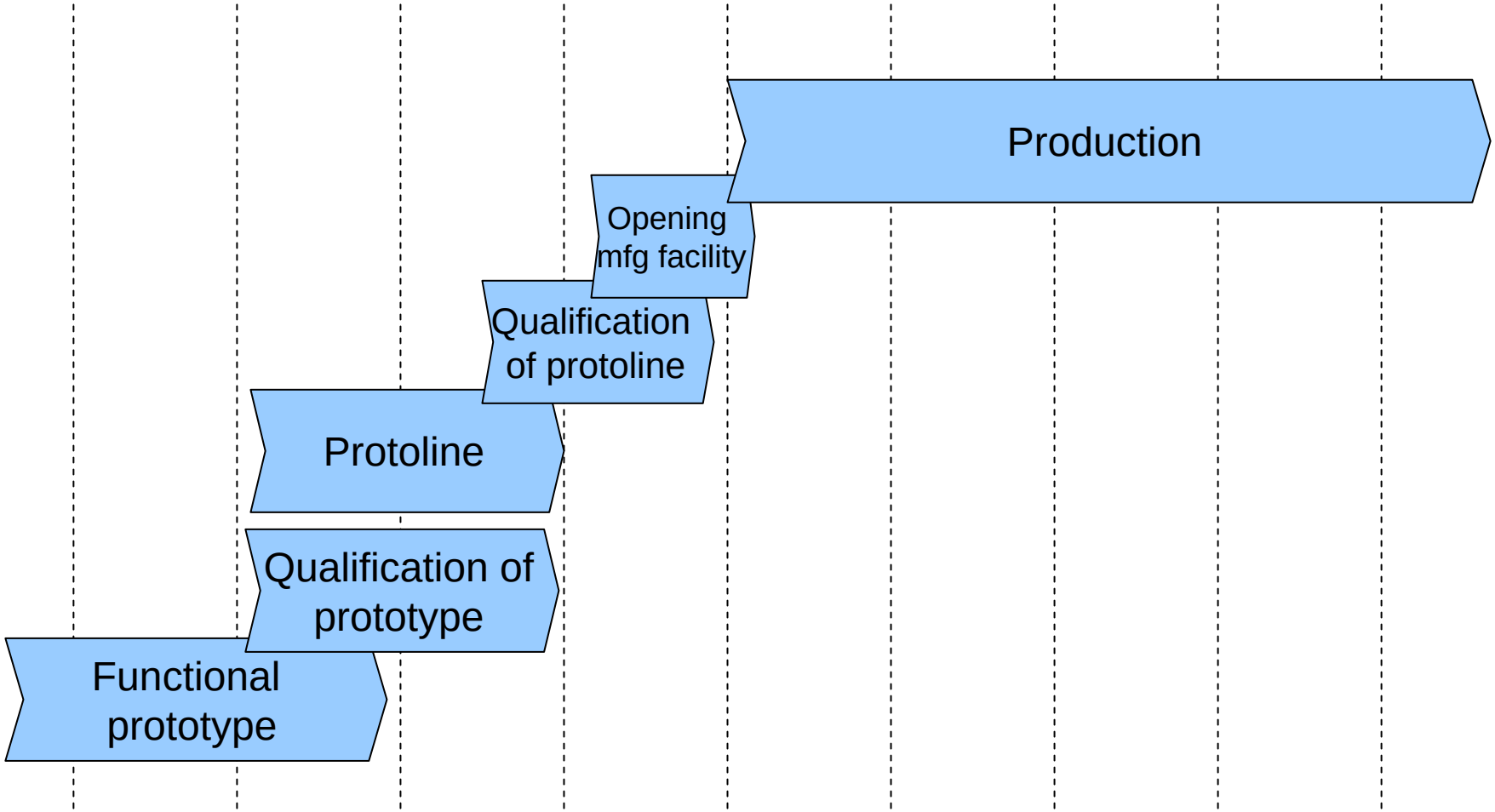
BARRIERS TO ENTRY

- Strong intellectual portfolio:
  - Twenty pending and provisional applications related to ways to control CNT growth, methods of fabrication, heat sink designs and overall integration with reduced contact resistance
- Head start in the CNT synthesis area (~five years of accumulated know-how)
- Established relationships with potential customers and partners
- Short R&D cycle
- Established infrastructure:
  - Deposition, characterization, measurement equipment

OPPORTUNITY

- Electronics Thermal management market - $5 B in 2006
- Addressable TIMs market - $300 M today → $700 M in 2009
- Enter as high performance TIM provider



NEAR-TERM MILESTONES

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