

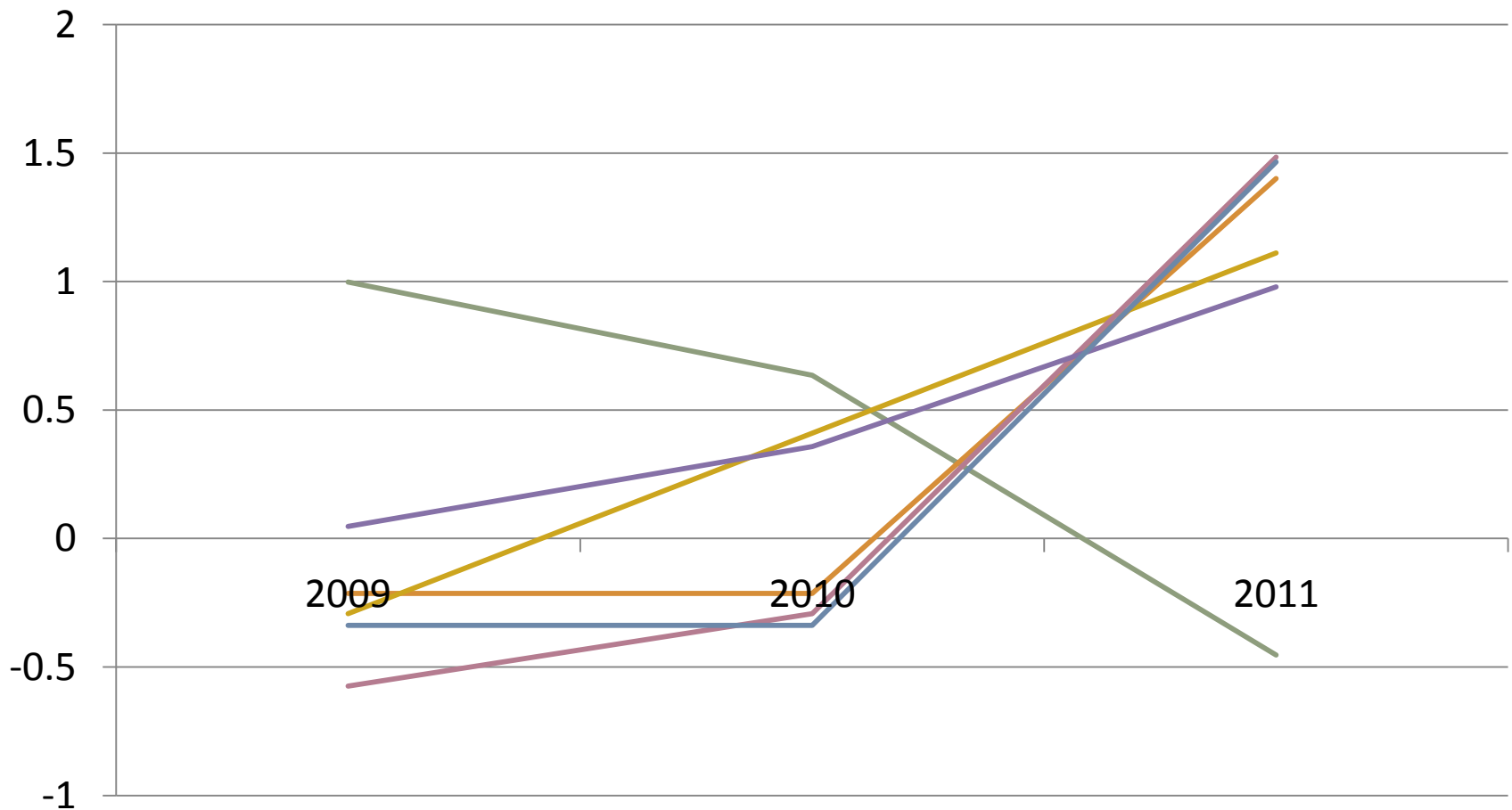
# Trends and Competitive Activity in Thermal Management R&D

SEMI-THERM Executive Briefing:  
Thermal Management Market Visions & Strategies  
March 18, 2013

Kevin M. Closson  
Senior Analyst  
Nerac, Inc.



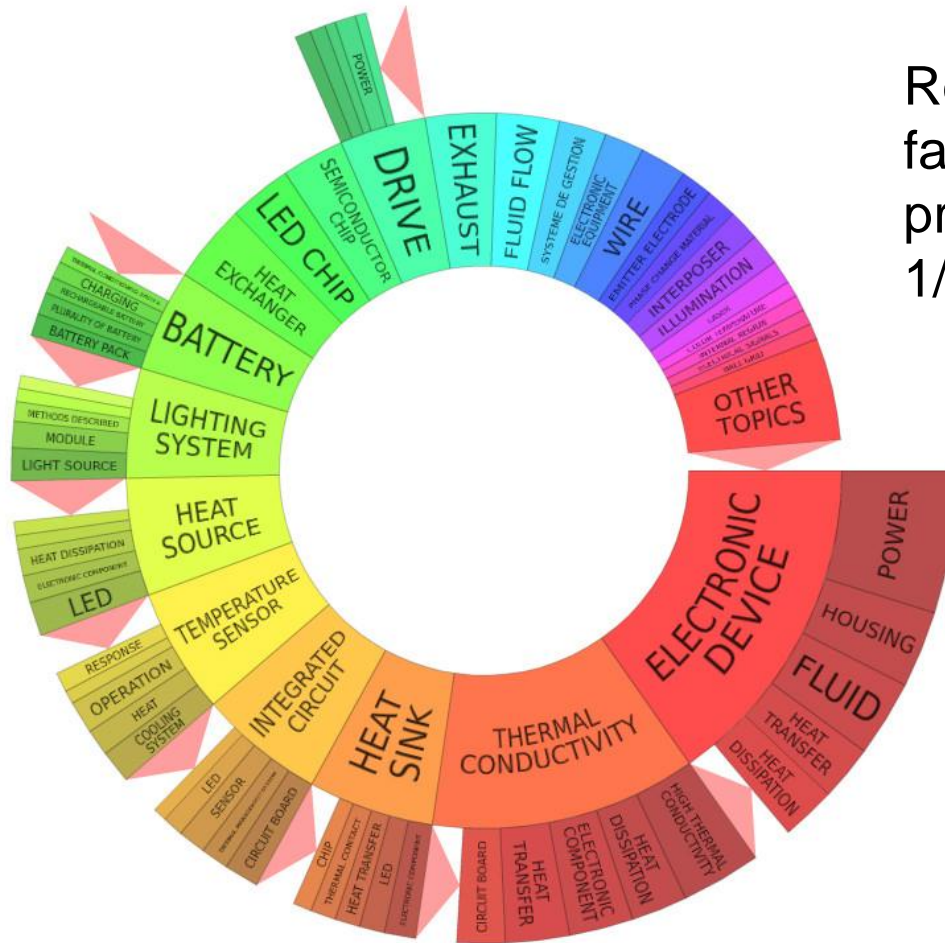
# Recent history of R&D spending for companies in TM space



# Patent analysis



# Patent analysis

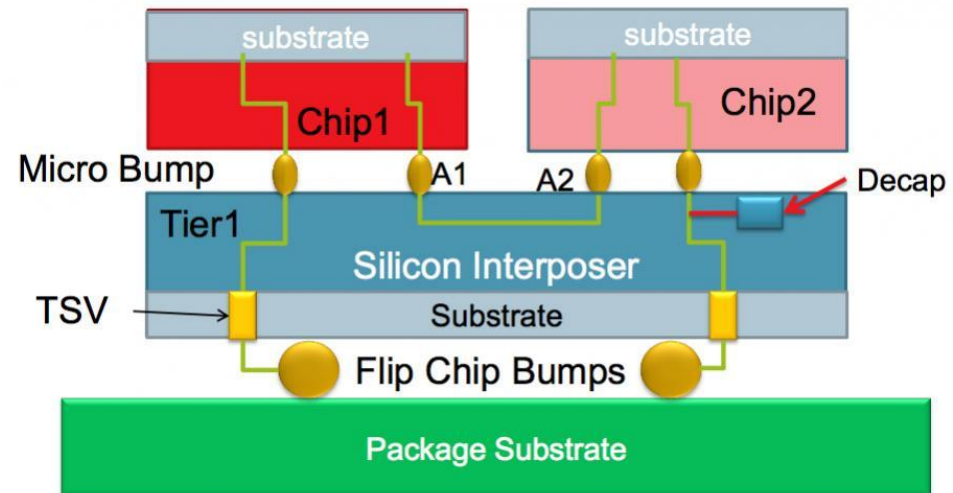
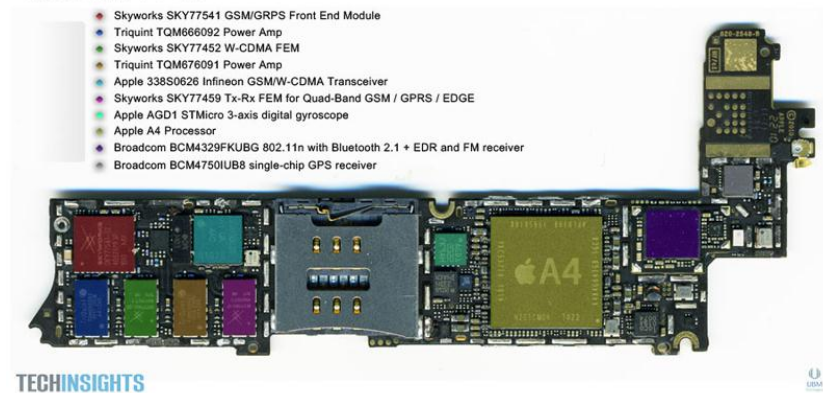


Relevant patent families with priority date after 1/1/2010

# Key trends affecting thermal management

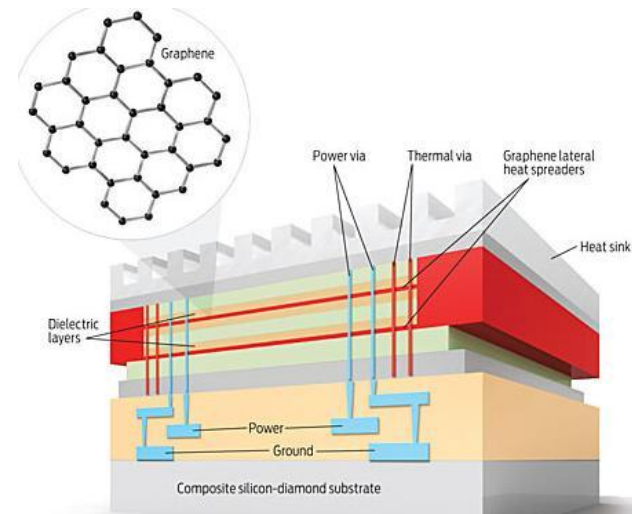
- Increasing component density
- Widening use of 3-D IC, SiP, PoP and SoC

Apple iPhone 4 - Front



# Key trends affecting thermal management

- Lower/dynamic power requirements
- Emergence of nanomaterials as viable “ingredient” in materials
- More stringent EMI requirements



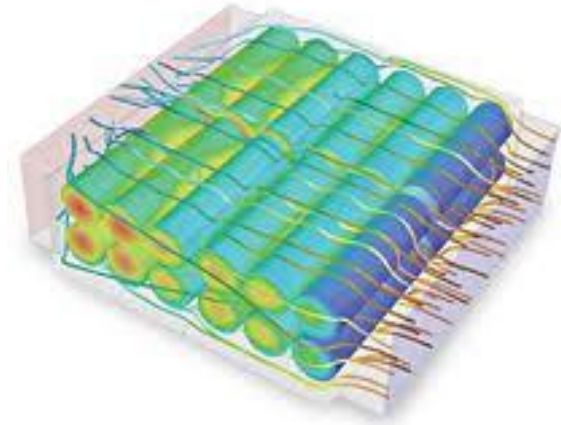
# Key trends affecting thermal management

- Increasing electronics use in automotive applications
- Proliferation of handheld computing devices



# Key trends affecting thermal management

- Battery thermal management
- LED lighting
- Inclusion of more sensors related to TM





# Emerging technologies and trends - TIMs

- Inclusion of nanomaterials and composites
  - Graphene
  - Carbon nanotubes
  - Various composites
- Chemistries to improve both bulk conductivity and wetting
- Non-silicone materials

# Emerging technologies and trends - hardware

- Thin film two-phase cooling
- 3-D packaging solutions
  - Heat spreading or isolation between stacked die with incompatible thermal profiles
  - Thermal TSVs
  - Microchannels
  - Hot spot cooling (TECs and PCMs)
  - Integration with EMI solutions

# Specific competitive activities



Granted a number of patents for its TM techniques related to wireless devices



Thermally conductive material filling blind vias for multi-chip packaging



Introduced pourable silicone TIM



# Specific competitive activities



Partnership with GE on LED lighting



Acquisition of TE maker Nextreme;  
expansion of thin film TE product line



Awarded numerous heat pipe patents



# Specific competitive activities



Heat spreader with highly conductive material inserts; launch of Liqui-Form line



Introduced CarbAl carbon-based nanocomposite bulk material



Introduced new line of liquid cooling systems



# Specific competitive activities



Patents on use of thin film TEC



Marketing encapsulated phase change materials



High performance micro-tube heat exchangers



# Notable university research

- Sandia National Labs – “Sandia Cooler” fan-less heatsink on air bearing licensed to unnamed LED maker and CPU heatsink maker
- Stanford (Ken Goodson) – two main research thrusts: PCMs and CNTs
- Georgia Tech (Yogendra Joshi) – microfab techniques applied to TM problems
- UC Riverside (Alexander Balandin) – graphene for TM

# Near-term opportunities & challenges

## Opportunity

## Challenges

Solutions for smaller and 3D packages and mobile computing

- TM often an afterthought
- Dealing with hot spots, thermal crosstalk, heat isolation
- Accurate simulation

“Zonal” solutions; integration with load shifting

- Coordination with OEMs
- Thermal lag



# Near-term opportunities & challenges

## Opportunity

## Challenges

Integration of nanomaterials

- Ability to model accurately
- Effects on viscosity, electrical conductivity, etc.

Phase change materials

- Packaging and integration
- Characterization and matching to application

# Near-term opportunities & challenges

## Opportunity

## Challenges

Combination with EMI shielding

- Relative performance trade-offs
- Only applicable in some applications

LED lighting

- Dependent on market success of LEDs
- Packaging/aesthetic constraints
- Convoluted supply chain

Integration with battery management systems

- Dealing with OEMs (automotive supplier)
- IP to navigate

# R&D directions

## TIMs

- Solutions for PoP, SiP
- Inclusion of nanomaterials for better performance

## Heat sinks

- Nanomaterials
- Metamaterials

## Fans

- Improved blade designs
- Ultra-low profile

# R&D directions

## Software

- Analysis of dynamic systems
- Improved models for 3-D packages

## Facilities

- Push cooling closer to emitters
- Facility siting and use of ambient air
- DC systems