Novel Method for Direct Measurement of Substrate Temperature during Copper CMP

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Outline

1. Motivation and objectives
2. Wafer carrier design and experimental conditions
3. Experimental results
4. Preliminary model results
5. Conclusions and future work

Motivation

- Driving force

  Temperature plays an important role during copper CMP !

  Based on the removal rate model proposed by Li, Borucki & Philipossian (*Journal of the Electrochemical Society*, 151, G482, 2004), wafer temperature can have a significant effect on copper removal rate:

Δ Temperature (°C)	Removal Rate Increase
+ 0.5	~ 4 %
+ 1.0	~ 9 %
+ 2.0	~ 19 %

Previous Temperature Measurements during CMP

- **Measurements of pad temperature**

  1. Chen & Diao (*CMP-MIC Proc.,* 1996), Chiou & Chen (*CMP-MIC Proc.,* 1997), Chen, Chiou, Lin & Shih (*Semicon Taiwan Proc.,* 1997)

     Used IR point mode thermal sensor to measure pad temperature as an endpoint detection technique

     Chen, Huang, Lin & Chiou (*CMP-MIC Proc.,* 1998), Hocheng, Huang and Chen (*Journal of the Electrochemical Society*, 1999)

     Used IR camera to obtain pad temperature

  2. Wang, Liu, Feng & Tseng (*Materials Chemistry and Physics*, 1998)

     Used non contact thermal sensor to measure pad temperature as an endpoint detection technique

  3. Kim, Kim, Jeong, Lee & Shin (*Journal of Materials Processing Technology*, 2002)

     Used IR camera to obtain pad temperature and investigated its effect on oxide/glass removal rate

  4. White, Melvin & Boning (*Journal of the Electrochemical Society*, 2003)

     Used IR camera to obtain pad temperature and developed a dynamic thermal model for copper polishing

Previous Temperature Measurements during CMP

- Measurements of pad temperature (continued)

  5. Sorooshian, DeNardis, Charns, Li, Shadman, Boning, Hetherington & Philipossian (*Journal of the Electrochemical Society*, 2004)

     Used IR camera to obtain pad temperature and investigated its effect on copper and ILD polishing rates

     Li, Borucki & Philipossian (*Journal of the Electrochemical Society*, 2004)

     Used IR camera to obtain pad temperature and developed a thermal model to predict wafer temperature during copper polishing

- Measurements of wafer/glass temperature

  1. Sugimoto, Arimoto & Ito (*Japanese Journal of Applied Physics*, 1995)

     Attached thermocouples to the backside of silicon wafers to measure the wafer temperature

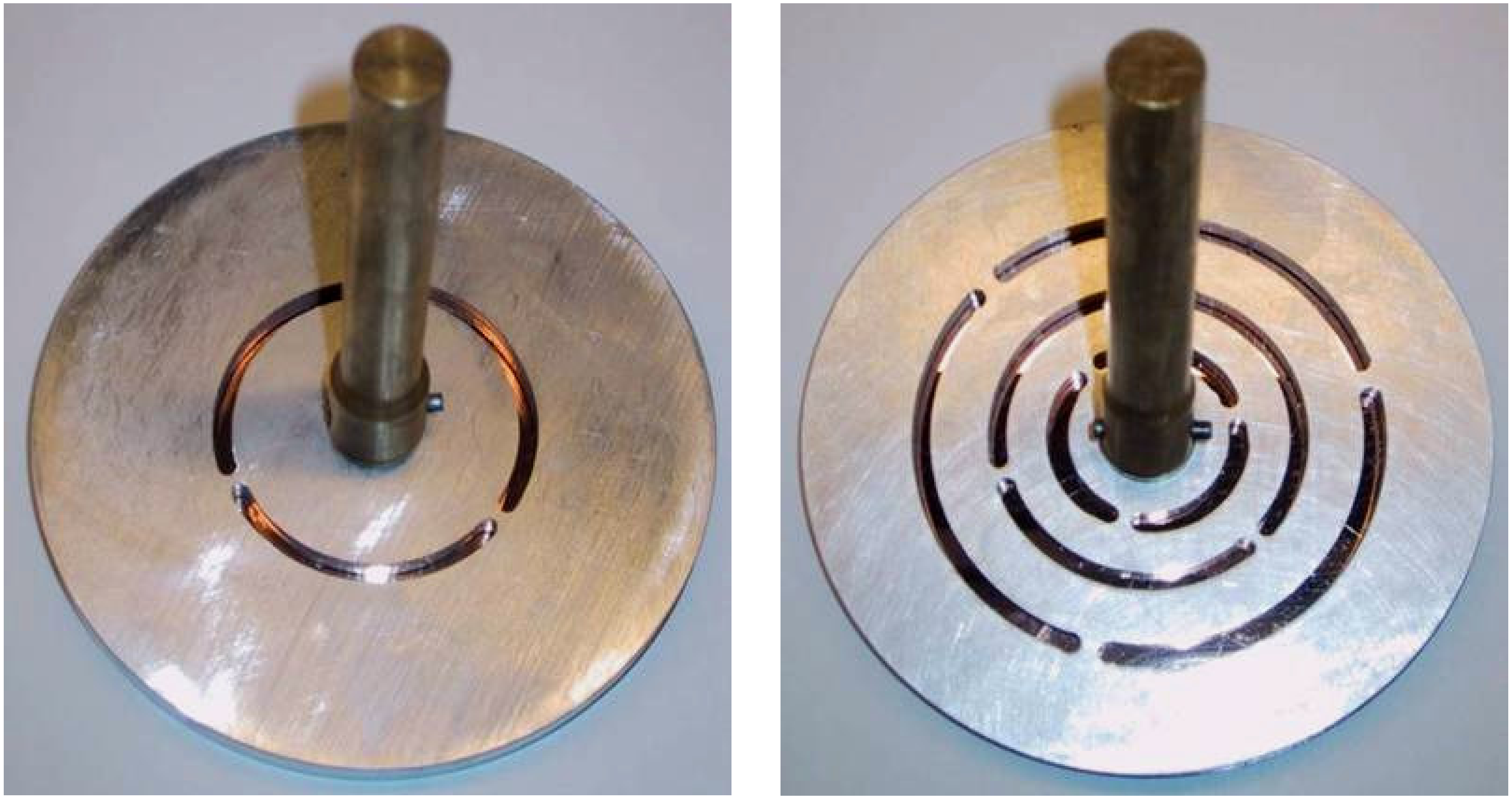
  2. Cornely, Rogers, Manno & Philipossian (*MRS Proc.*, 2003)

     Used laser induced fluorescence technique to detect the temperature under a thick glass substrate during polishing

Objectives

- Create a special wafer carrier design and directly measure the substrate temperature for copper CMP
- Investigate the temperature distribution on the wafer
- Develop a 3-D model to simulate the pad and wafer temperature during polishing

Wafer Carrier Design



Experimental Conditions

– Pad Break-In

- Conditioned at 0.5 PSI by 100-grit diamond disk rotating at 30 rpm and oscillating at 0.33 Hz for 30 min with UPW

– Pad In-situ Conditioning

- Conditioned at 0.5 PSI by 100-grit diamond disk rotating at 30 rpm and oscillating at 0.33 Hz

– Slurry

- 1 part of Fujimi 7102 + 9 part of H_2O + 0.3 part 30% H_2O_2
- Flow rate 80 cc/min

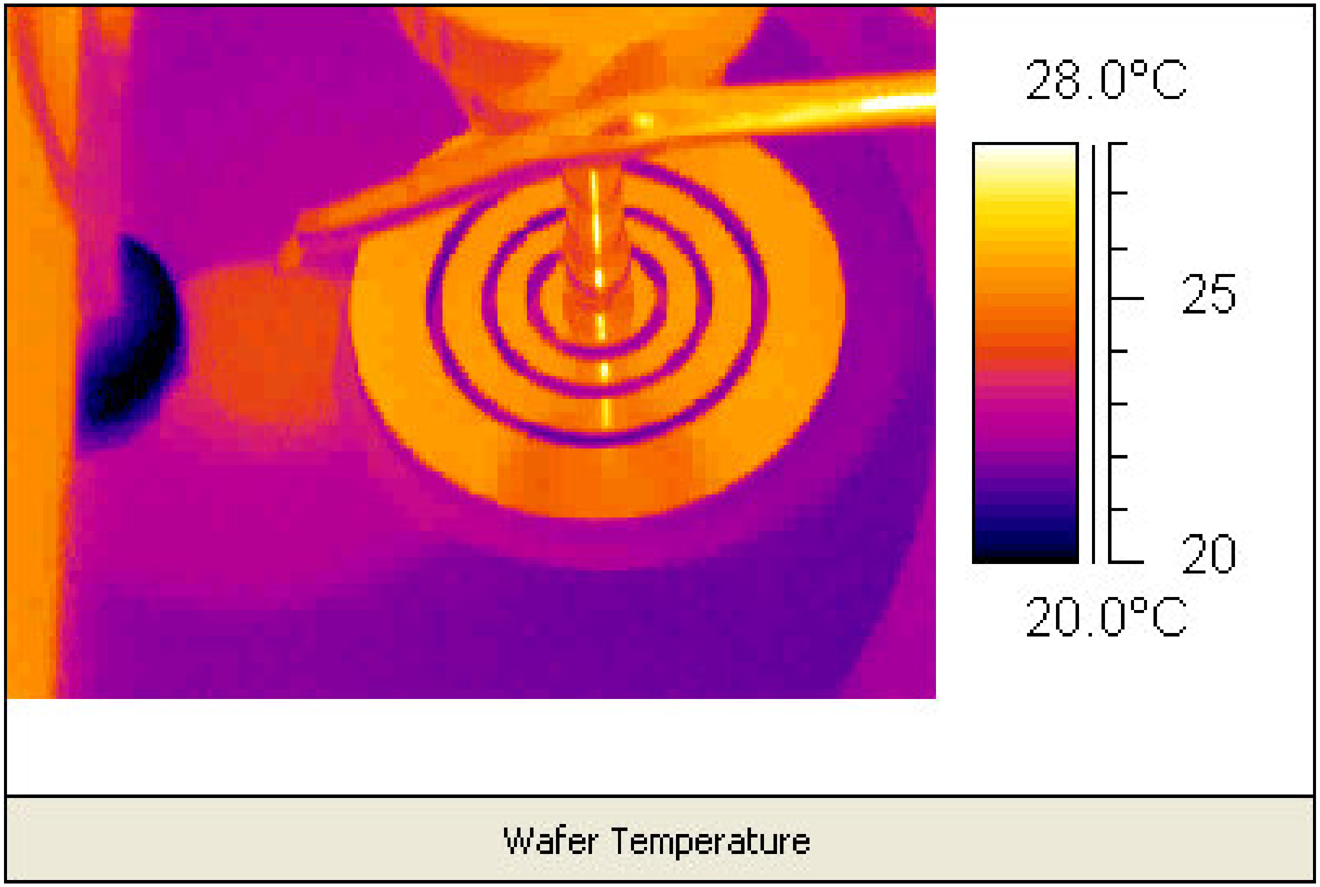
– Copper disc polishing

- 4-inch disc (99.99 % purity)
- Freudenberg FX-9 flat pad
- Polishing pressure: 2.5 PSI
- Disc-pad sliding velocity: 1.12 m/s (140 rpm)
- One-slit wafer carrier

– Copper wafer polishing

- 4-inch wafer, 20,000 A PVD copper film on top of a 1000 A PVD tantalum barrier layer
- IC-1000 K-groove pad
- Polishing pressure: 2.0 PSI
- Wafer-pad sliding velocity: 0.96 m/s (120 rpm)
- Three-slit wafer carrier

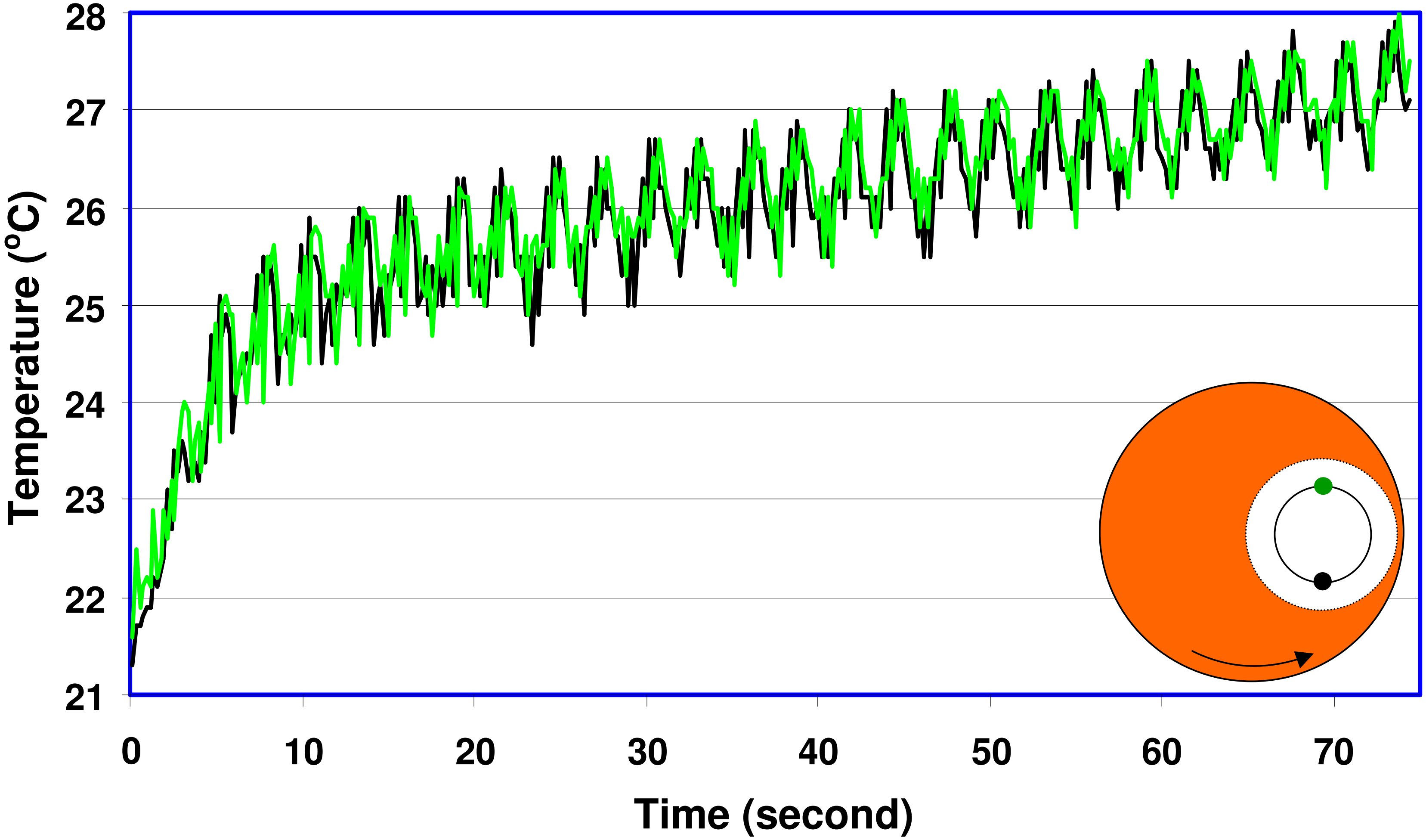
Real-time Pad and Wafer Temperature Measurement



Wafer Temperature

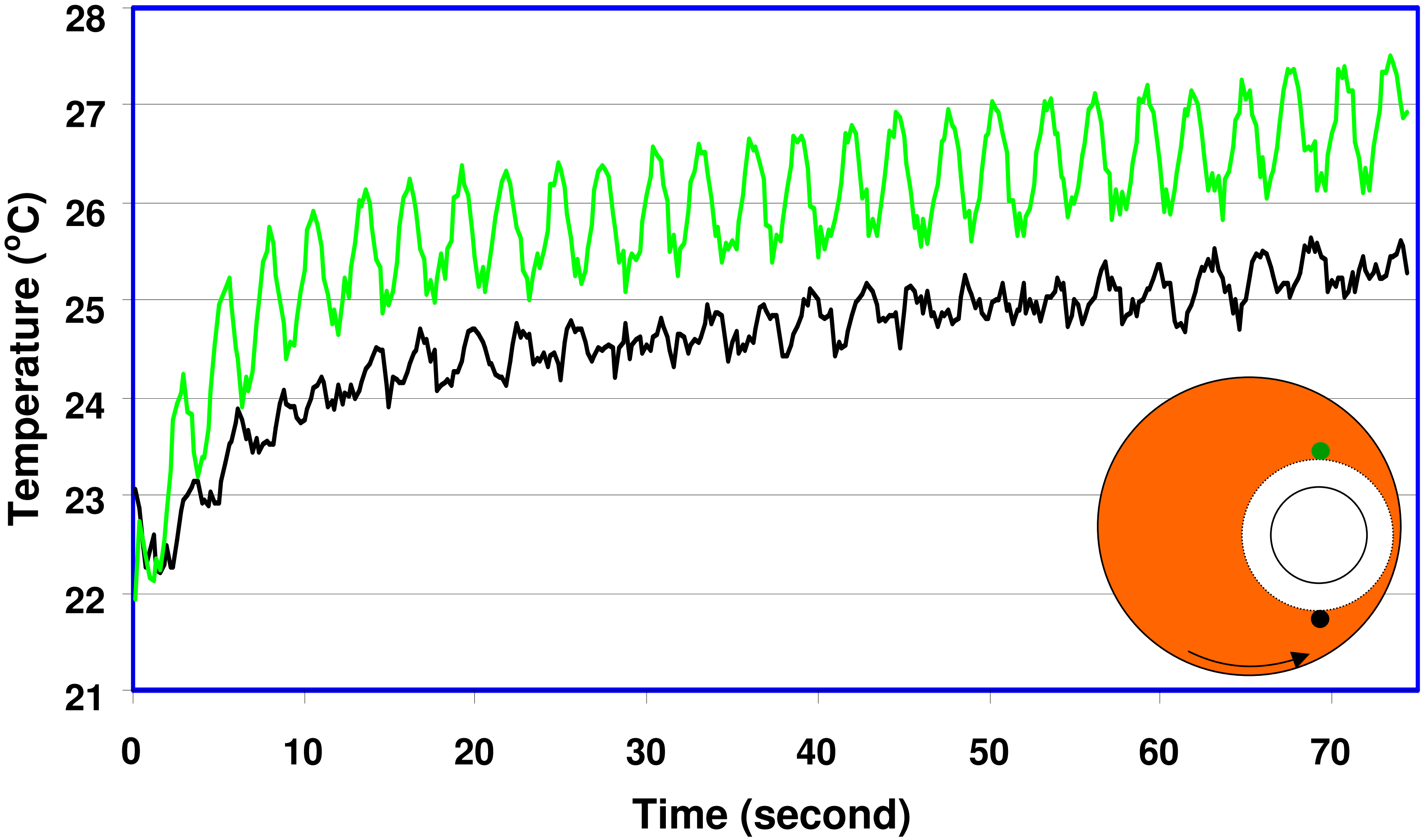
Copper Disc Transient Temperature

Copper Disc Polishing on FX-9 Flat Pad



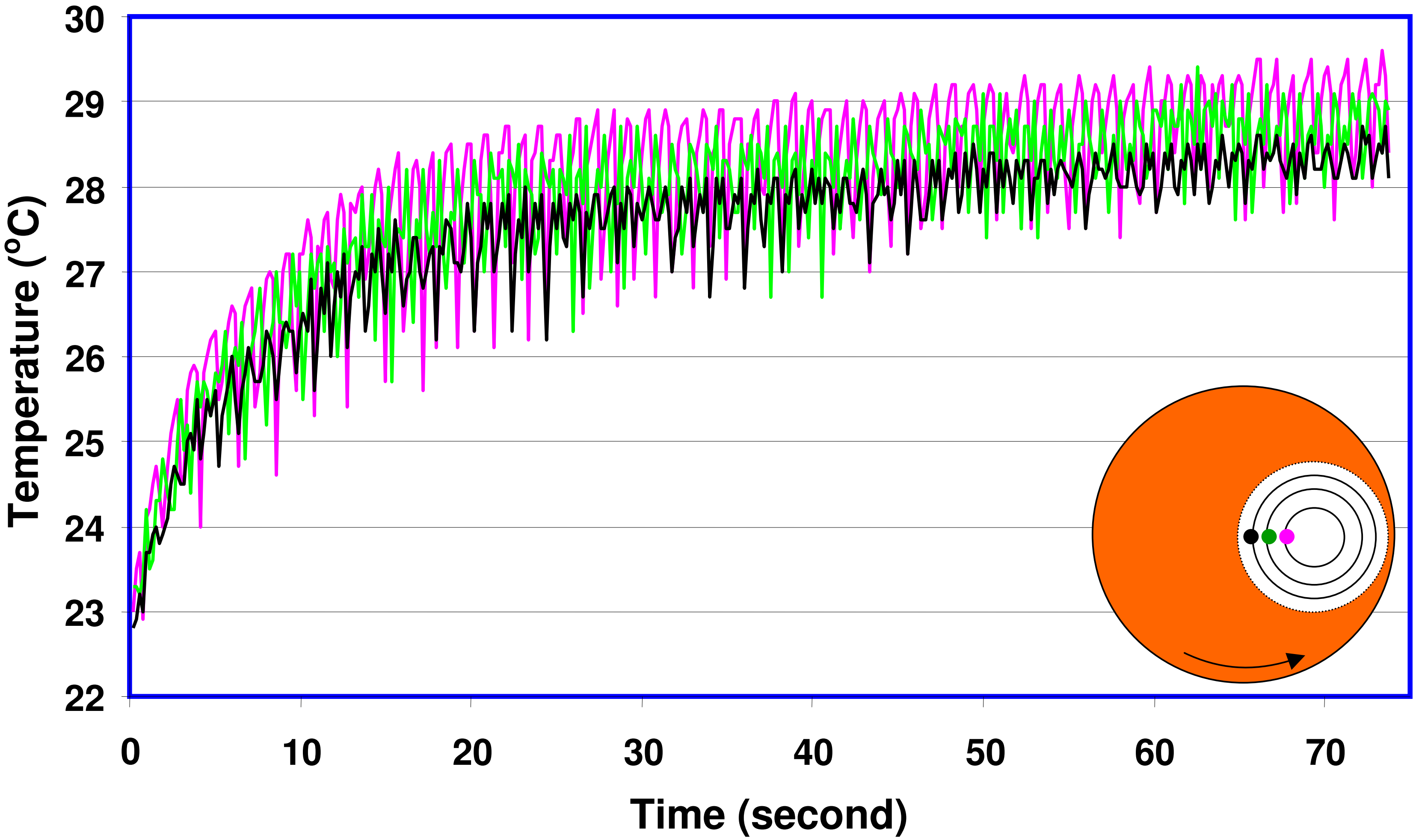
Pad Transient Temperature

Copper Disc Polishing on FX-9 Flat Pad



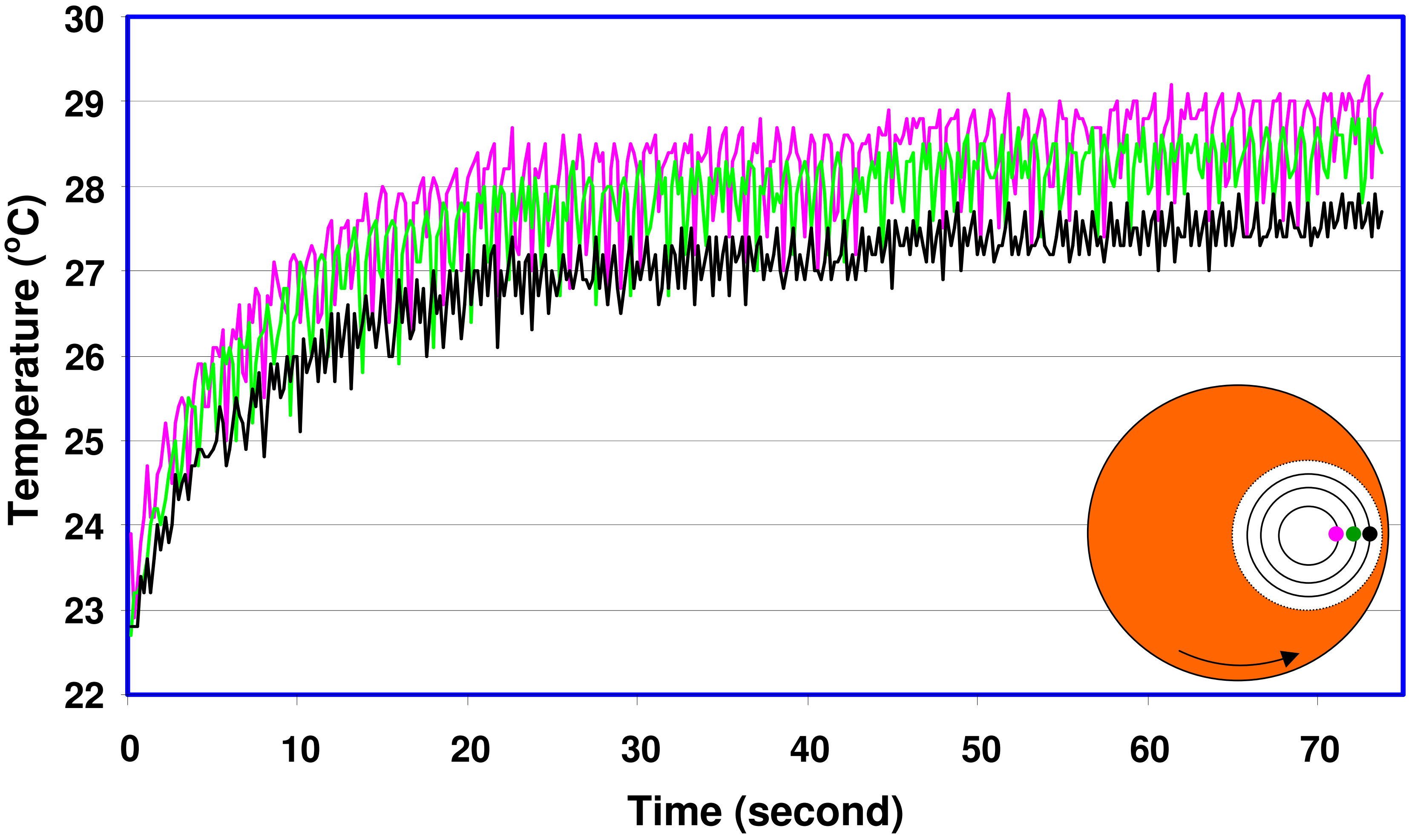
Copper Wafer Transient Temperature

Copper Wafer Polishing on IC-1000 K-groove Pad



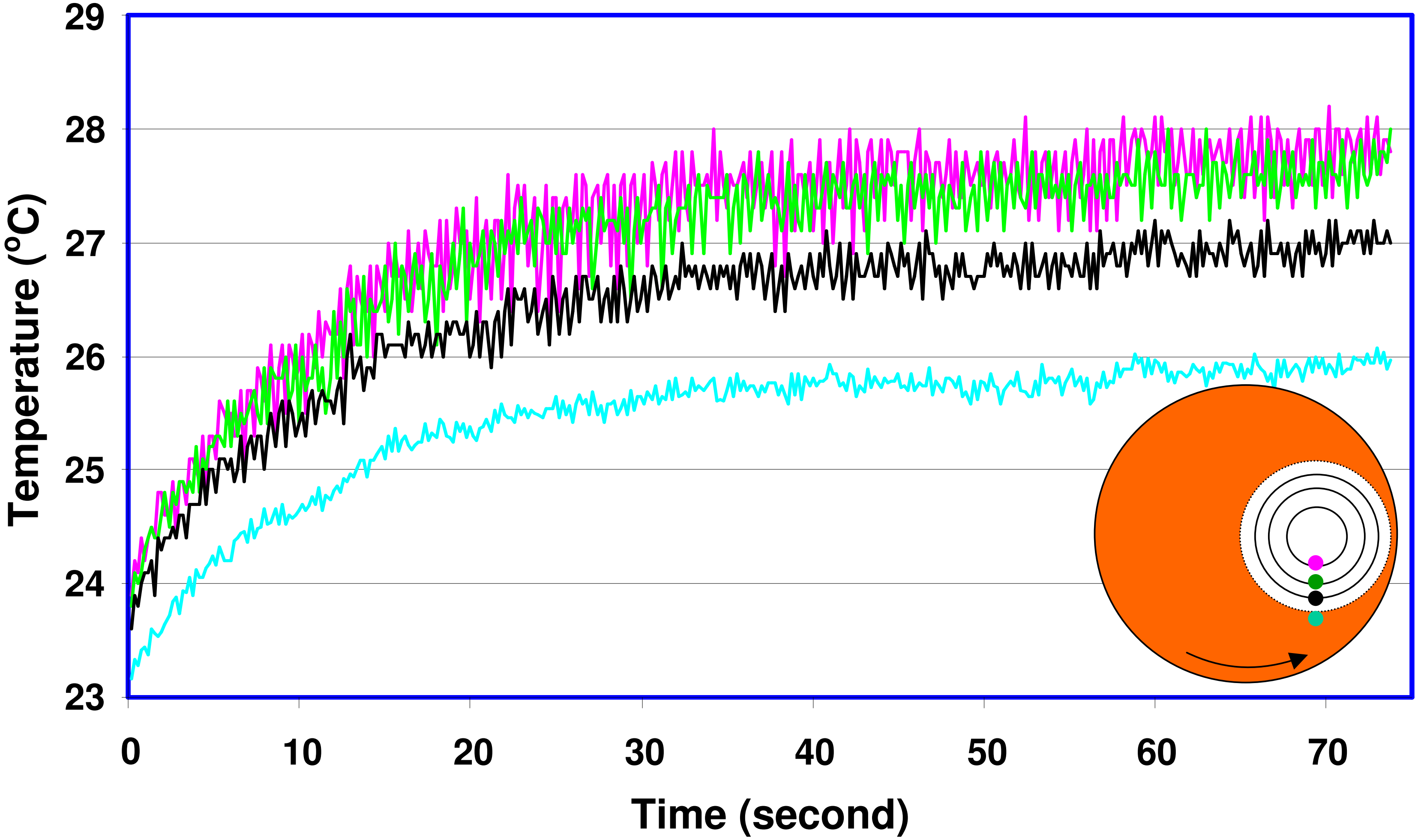
Copper Wafer Transient Temperature

Copper Wafer Polishing on IC-1000 K-groove Pad



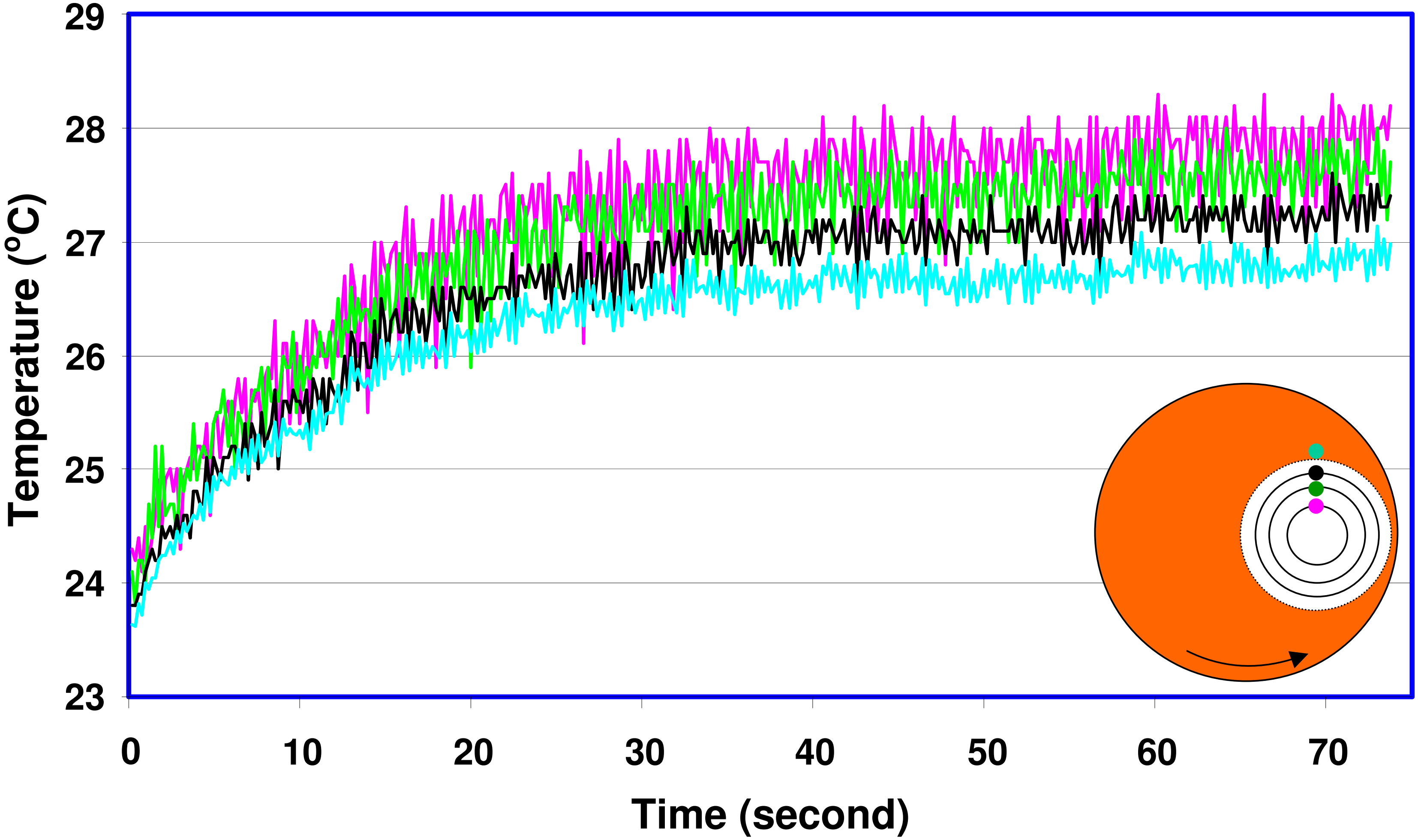
Copper Wafer and Pad Transient Temperature

Copper Wafer Polishing on IC-1000 K-groove Pad

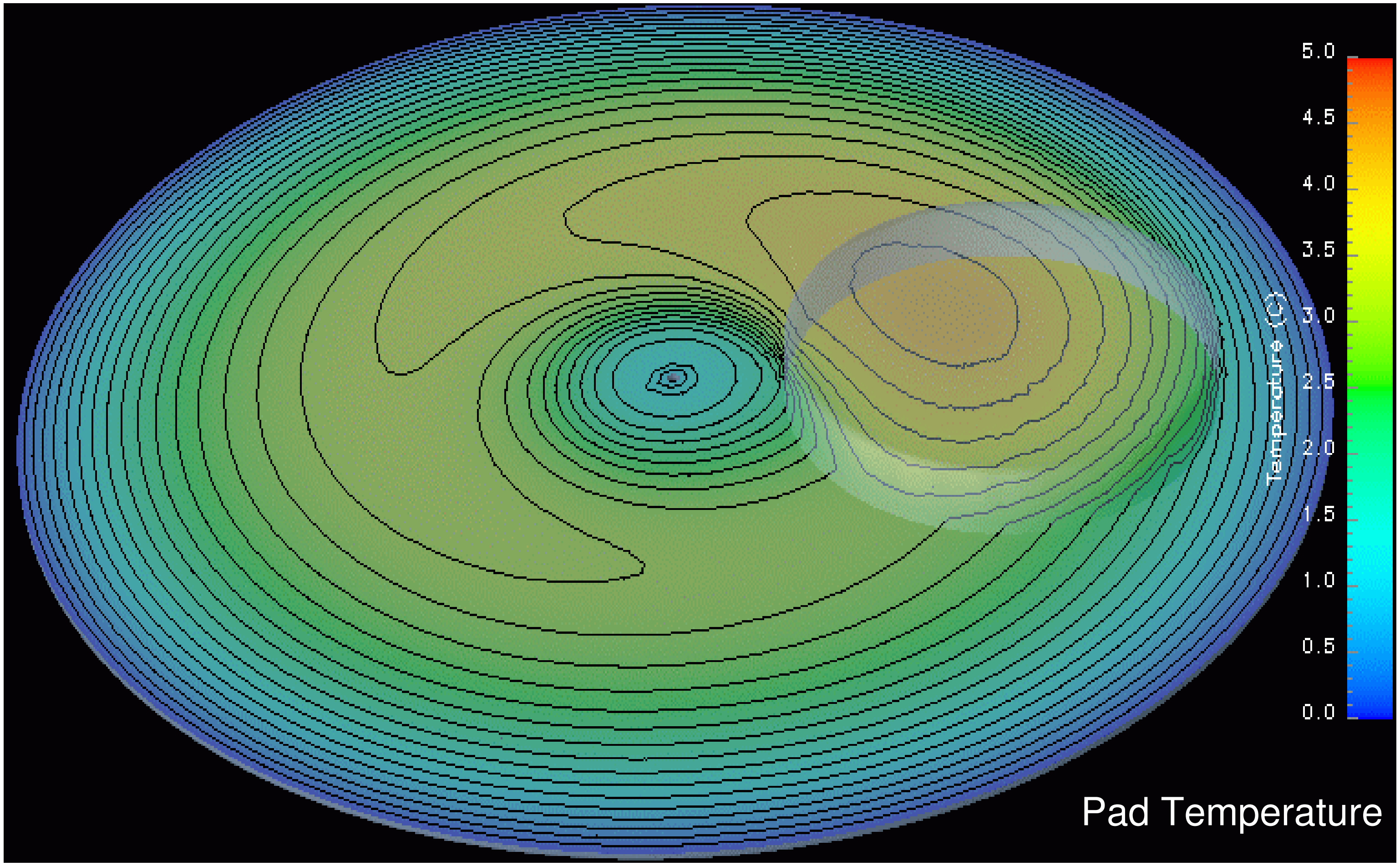


Copper Wafer and Pad Transient Temperature

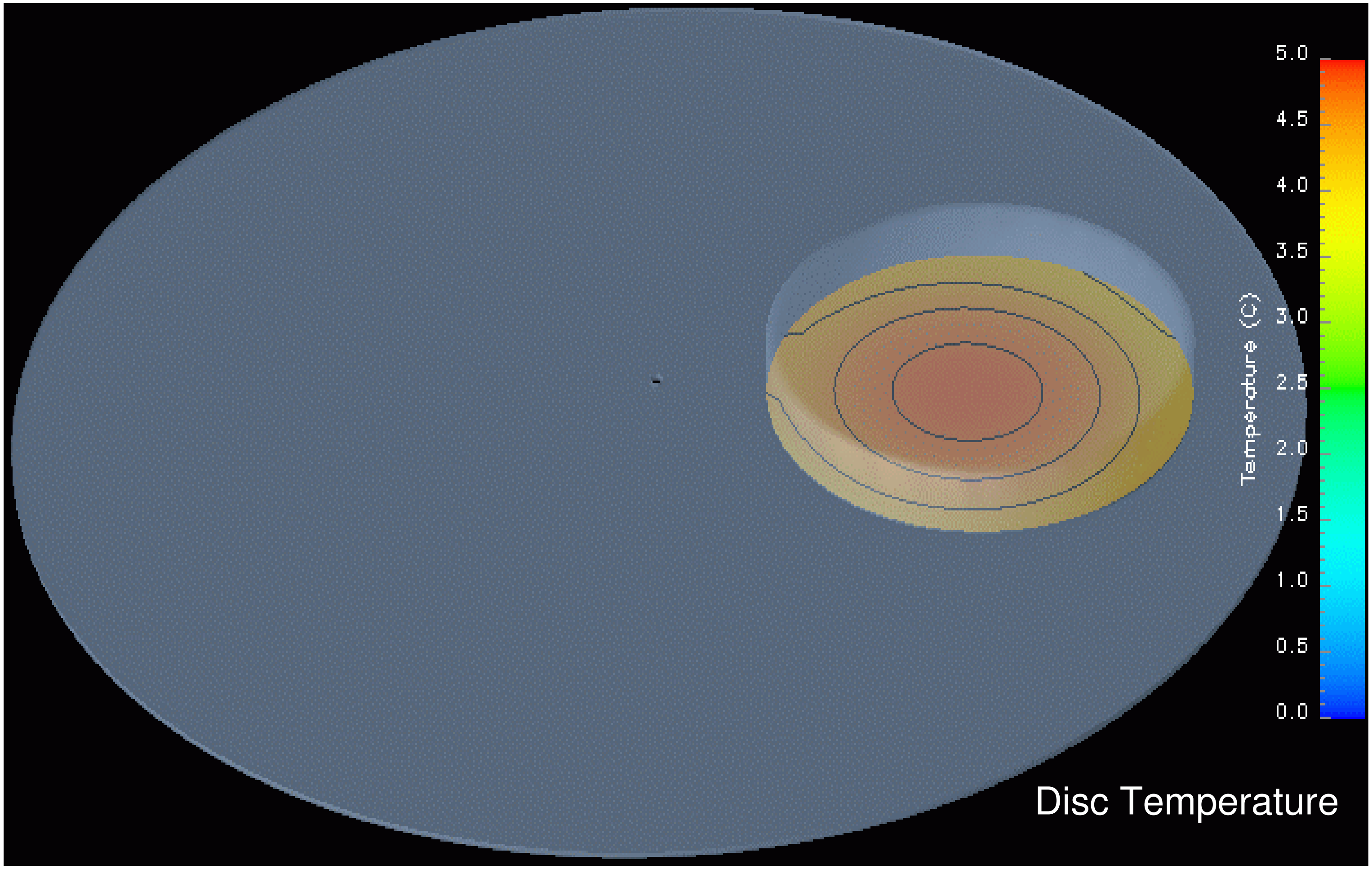
Copper Wafer Polishing on IC-1000 K-groove Pad



3-D Numerical Modeling of Pad Temperature



3-D Numerical Modeling of Disc Temperature



Conclusions

- Using specially designed wafer carriers, direct measurement of copper disc and copper wafer temperatures during polishing is achieved.
- Copper disc and wafer temperatures are higher than those at the pad leading and trailing edges.
- There is a temperature distribution on copper wafer, which is closely related to the slurry flow during polishing.
- Preliminary simulation results from a 3-D thermal model agree well with the experimental data.

Future Work

- **Perform temperature measurements at different polishing conditions with different pads to further investigate the relation between the wafer temperature and the pad temperature and their effects on removal rate for both copper and ILD CMP.**

- **Include conditioner and pad grooving effects in the 3-D thermal model to simulate pad and wafer temperatures during polishing.**

Acknowledgement

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