

Flash Curing of Wafer Level Dielectric Films

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Wafer Dielectric Film Curing

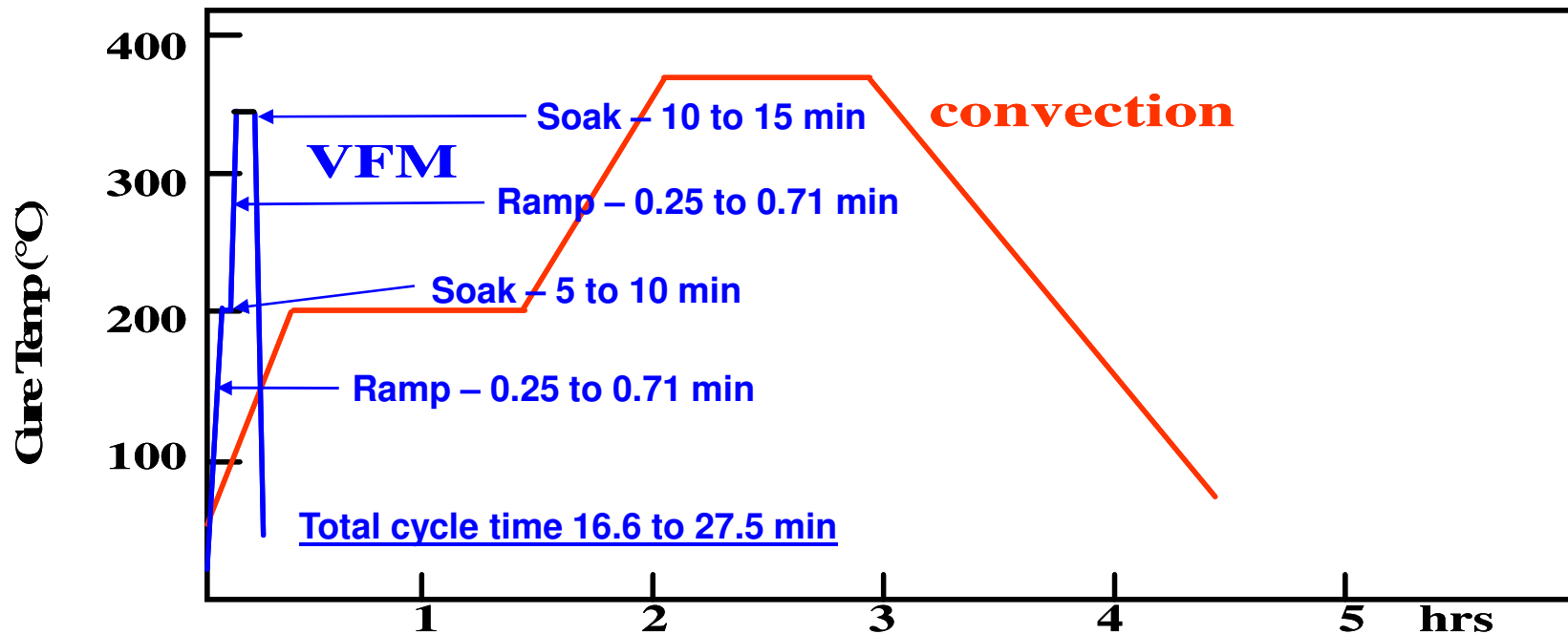
- **Stress Buffer Layer:** one layer on most die (3-5 μ)
- **Re-Distribution Layers:** two – three layers (5-7 μ)
- **Wafer Layer CSP:** two – five layers (5-10 μ)
- **Choices:** Materials – Temperatures – Throughput

Material	Tg	Elong.	Cure (°C)	WPH*
Polyimide	350	50%	375	10
PBO	350	80%	380	10
BCB	280	5%	250	8
Epoxy-Resist	200	4%	190	6

** wafers-per-hour-per-layer based on 50 wafer batch*

Variable Frequency Microwave Cure

- *Polyimide HDM-4004 (photo-sensitive) and PI5878 (nps)*
- *Eighteen wafer DOE with four variables*

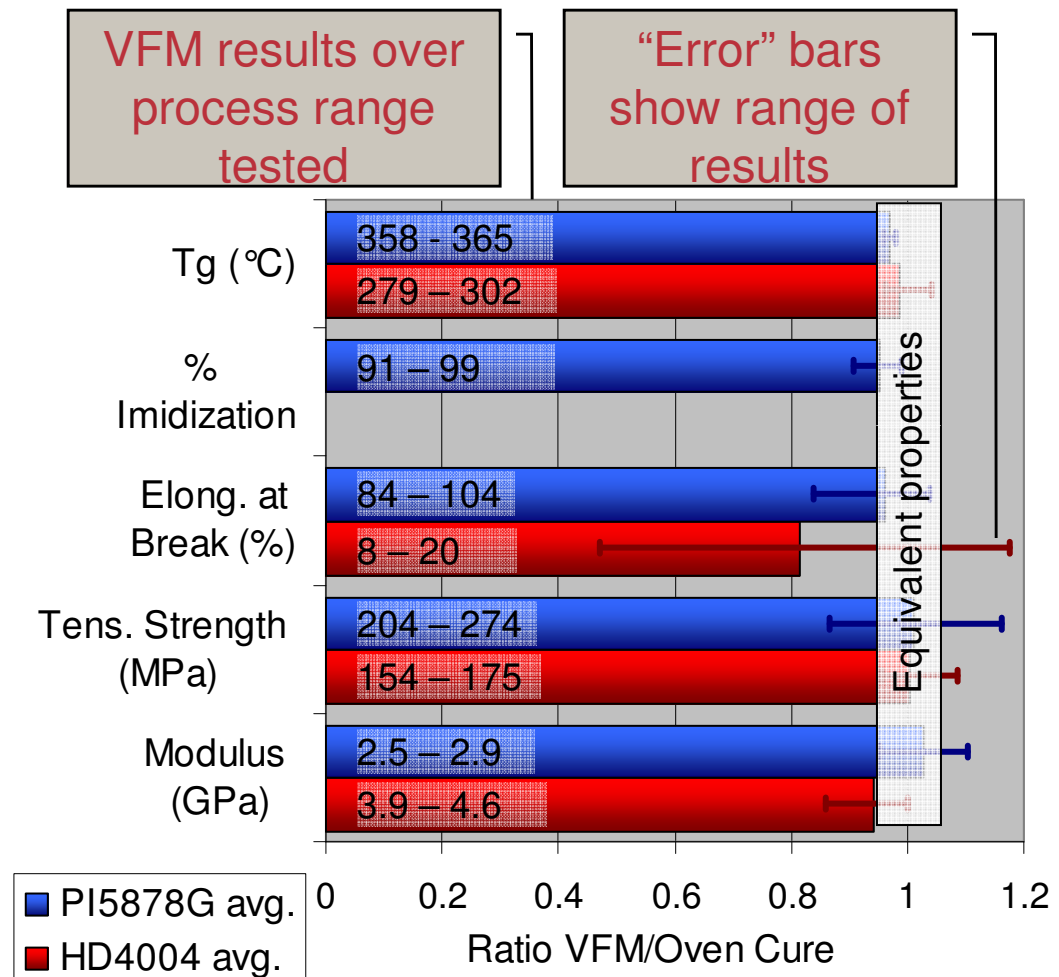


- *Can “flash curing” produce the same film properties?*

Both Polyimides well cured by flash VFM

Properties show small dependence on the VFM process variables tested

- Spread in elongation results due to experimental method
- Ramp rate to 200°C has least effect



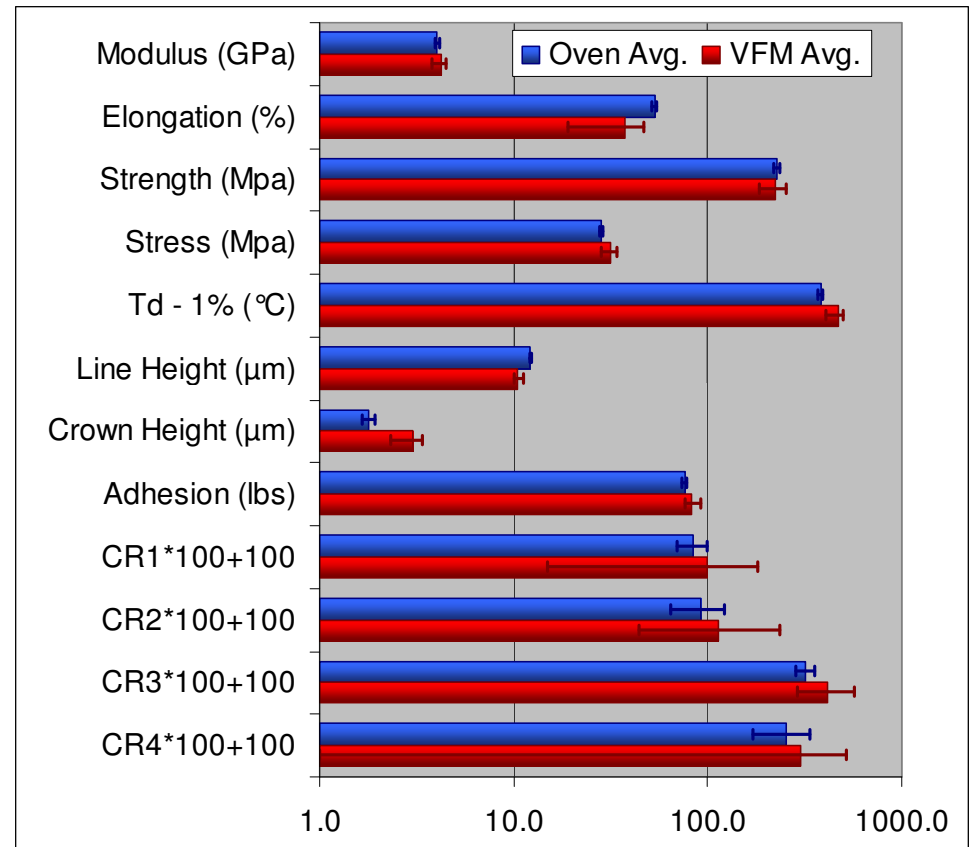
VFM cure at 350°C meets or exceeds oven cure

Range of results for VFM cure overlaps oven cure for most properties

Differences are consistent with higher cure by VFM

Chemical resistance tests:

- CR1 - NMP, RT 30 min
- CR2 - 10% H₂SO₄, 3 hr, RT
- CR3 - NH₄OH/H₂O₂/H₂O 1:1:5 80°C, 30 min
- CR4 - TMAH/H₂O/DMSO 1/3/96 80°C, 30 min

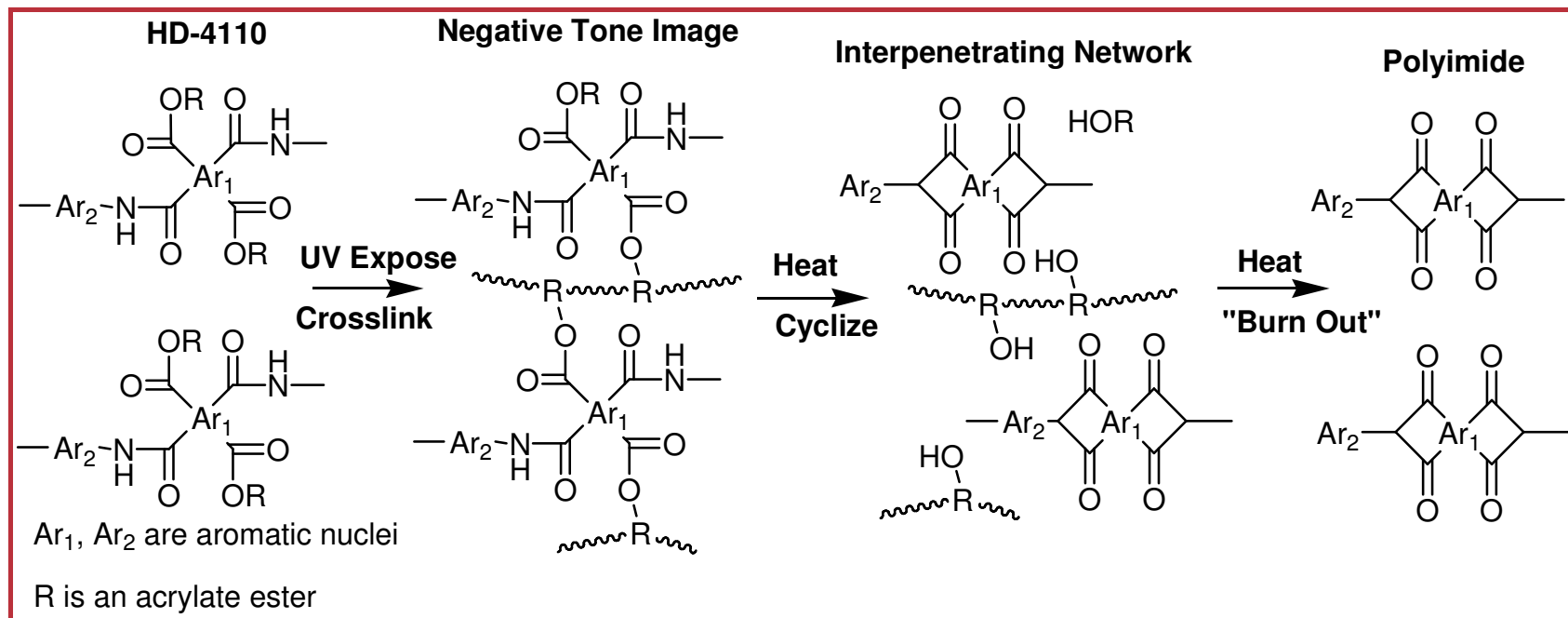


Note: "Error" bars for Oven cure results show standard deviation in data. "Error" bars for VFM cure show range of responses

Cure of HD4110 involves cyclization and “photopackage” burnout

HD4110 process chemistry

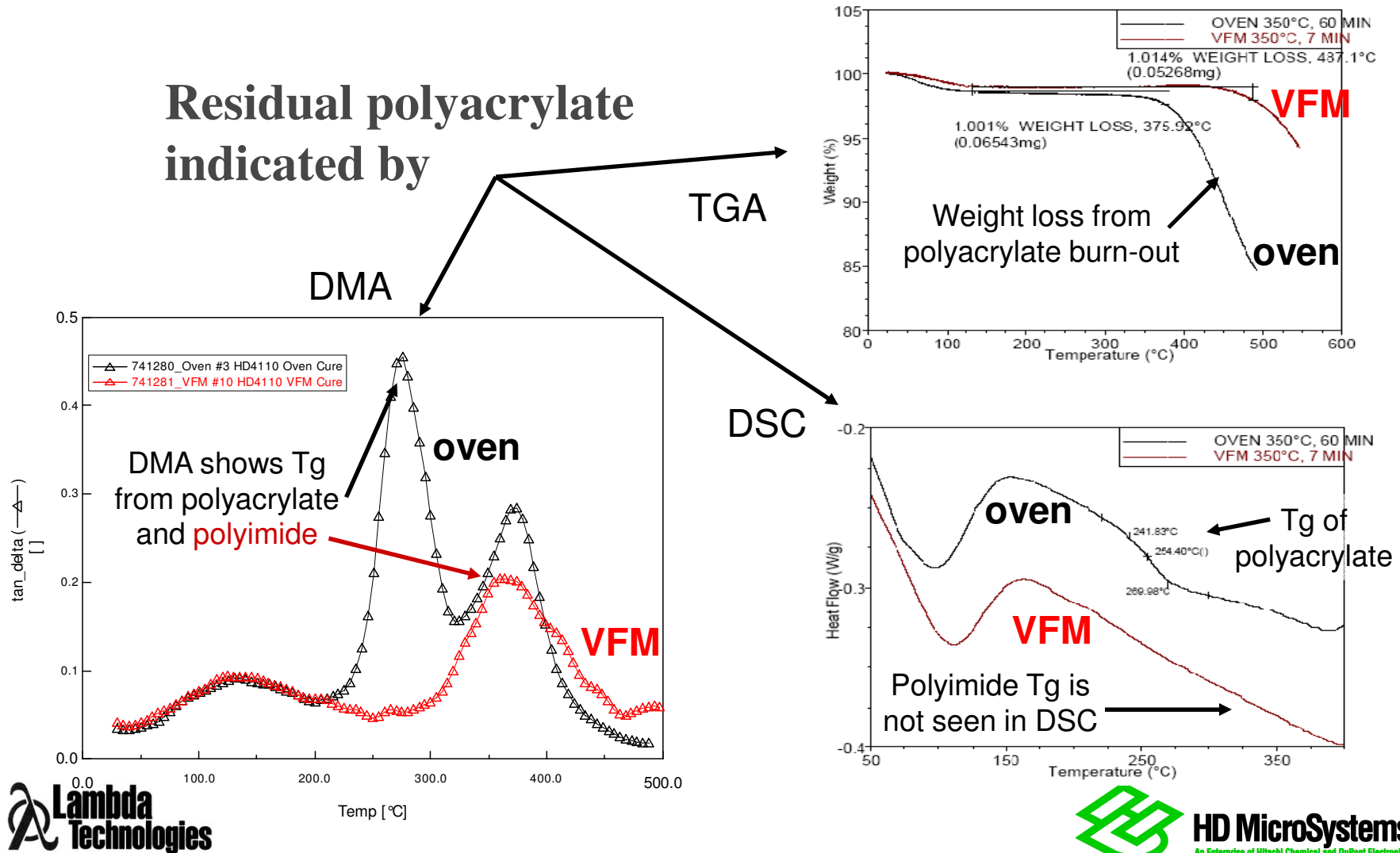
- Photo-exposure yields crosslinked network
- Imidization forms linear polyimide, burn-out removes crosslinker



350°C oven cure leaves residual “photopack”

VFM cure does not

Residual polyacrylate
indicated by



340°C VFM cure of HD4110 ~ oven cure 350°C

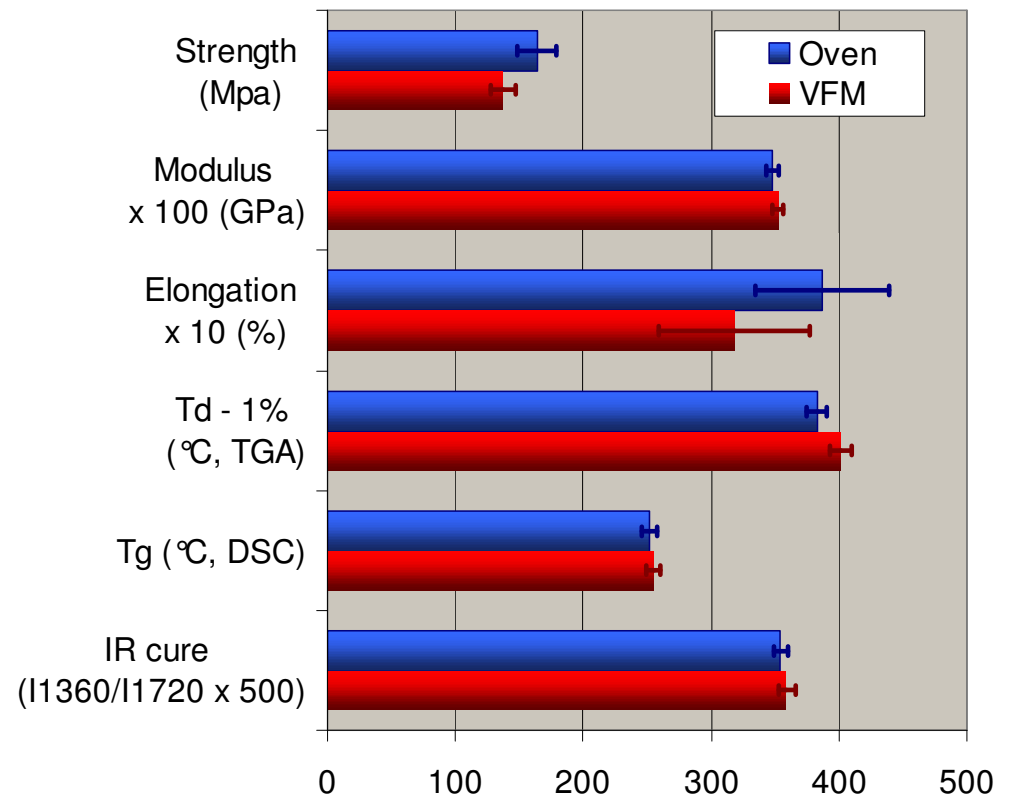
94% reduction in cycle time

WPH = 167

Mechanical and thermal properties very similar

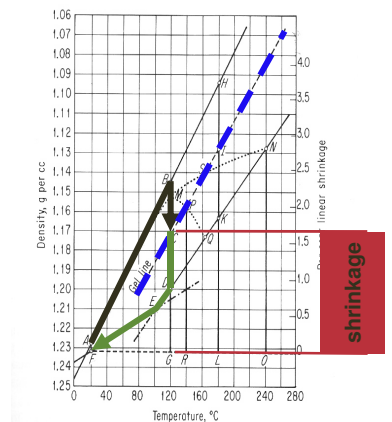
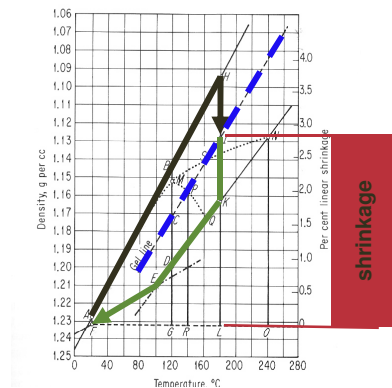
- Results averaged for 8 VFM cured films, 9 oven cured films
- Comparable standard deviations found

Oven: 60 min@350°C, 5.0 hr cycle
VFM: 8 min@340°C, 0.3 hr cycle



Fast Ramp but Low Warpage?

- 60 deg/min ramp rates – 30-50% lower wafer bow
- Most wafer warpage is due to dielectric cure processes
- Oven curing uses long ramps to reduce stress
- Microwave cure is uniform in the bulk; less stress
- Lower temperature cure reduces stress
- PI and PBO at 250°C show x- and y- axis bow <50%
- Epoxy-resist dielectrics 30 minute cure with bow <50%
- Uniform VFM cure increases adhesion



VFM shown to lower manufacturing and energy costs

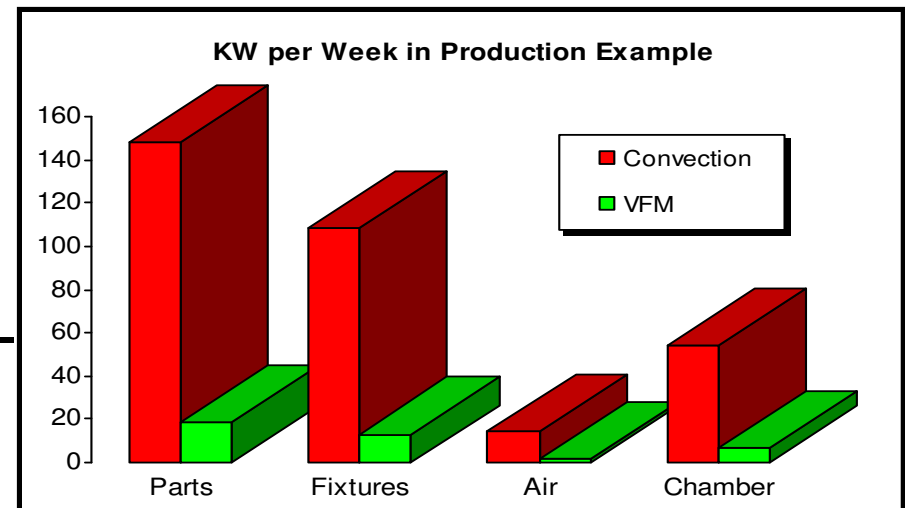
- **Time reduction**

- Cycle time reduced from >4 hrs to <20 minutes
- Major benefit for process development or mixed lot production
- Prototype batch VFM (300 mm wafers) shows excellent temperature uniformity

- **Energy reduction**

- Energy transferred efficiently to the wafers – no energy wasted heating the oven
- No energy required to cool the oven after cure

Example of energy savings in a non-IC application



Conclusions

- **“Flash” VFM cure cycle times are greater than 50 wafers per hour**
- **Cure is complete and matches all thermal and mechanical properties**
- **Cure removes all “residuals” from photopackage**
- **Soak time is most important variable; ramp speed and 200°C soak are not**
- **Very fast ramp speeds do not increase stress**
- **Wafer warpage decreased by 30-50%**
- **Lower cure temperatures produce same cure properties**
- **Improved adhesion from uniform cure at surfaces**