Modeling Variable Frequency Microwave Curing for Semiconductor Packaging

Daniel Cepeda, Jose Vidal, Cleon Davis, and Gary May

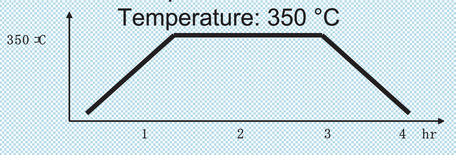
MiRC Microelectronics Research Center Georgia Institute of Technology

Motivation

Semiconductors are found in computers, phones, and all other electronics. Due to high demand, there is a great need to reduce semiconductor manufacturing cost. One way to do so is to reduce processing time. Variable Frequency Microwaves (VFM) curing can drastically reduce processing times when compared with conventional thermal methods. However, the interactions that occur during VFM curing are not well understood. Thus, there is a need for process modeling.

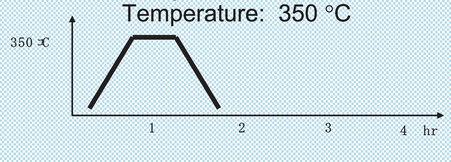
Conventional (Thermal) Curing

Hold Time: 3 - 4 hours
Ramp Rate: 3°C/min
Temperature: 350 °C



VFM Curing

Hold Time: 30 minutes
Ramp rate: 15-45°C/min
Temperature: 350 °C



Background

Fixed Frequency Microwave (FFM) was the first type of microwave processing used by researchers. This technique has many limitations in terms of industrial applications, including:

- Arcing of metallic surfaces
- Uneven heating of materials
- Creation of hot spots

Figure 1 – Energy distribution inside a FFM chamber (left) and energy distribution inside a VFM chamber (right)

VFM processing eliminates some of the inefficiencies of FFM processing by stepping through 4096 frequencies over a 1.15 GHz bandwidth every 0.1 s, which produces:

- Even heat distribution
- Capability to process metals

Methods

Statistical Experimental Design is a method that allows for the systematic identification of factors, as well as the analysis of experimental results.

- **Fractional Factorial (Screening)**: Isolates unnecessary factors then creates a specific subset of a Full-Factorial, with each factor used at two levels.
- **D-optimal**: Chooses a number of runs from a set of candidates in which there exist constraints on particular factor settings.

Inputs	Range
Cure Time	0 to 30 minutes
Ramp Rate	15 to 45 °C/min
Hold Temperature	150 to 350 °C/min
Center Frequency:	6.1375 to 6.7125 GHz
Bandwidth	0.010 to 0.575 GHz
Sweep Rate	0.1 to 10 seconds
Responses	
In-plane Index of Refraction	Through-plane Index of Refraction
Percent Imidization	Birefringence

Expected Results

By conducting the experiments and analyzing the data, the following results are expected:

- Significance of input factors
- Characterization of VFM curing
- Data for use in neural network modeling

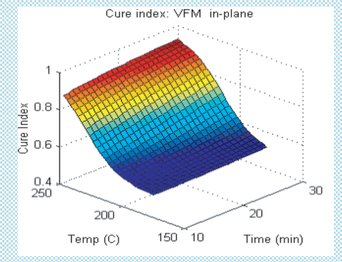


Figure 2 - Diagram of the Cure Index of VFM processing with respect to time and temperature

Conclusions

There are many benefits of using VFM curing for semiconductor packaging:

- Polymers cured in a reduced time.
- Uniform heating
- Elimination of arcing when metals used inside VFM chamber

Future Work

- Complete experiments
- Use subsequent data for neural network modeling
- Optimize process recipes using genetic algorithms

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