Temperature Measurement and Uniformity of Rapid Thermal Annealing Furnaces

Why RTP users can never accurately know the actual wafer temperature or its uniformity?

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Semiconductor Rapid Thermal Processor Technical Exchange

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Since the 1980s, temperature measurement and uniformity in Rapid Thermal Processing (RTP) systems have remained a focal point of interest in the semiconductor industry. An engineer from a well-known manufacturer once spent a significant amount of time and thousands of dollars optimizing the temperature uniformity of the RTP system in their FAB. After using a multi-point TC wafer to measure poor temperature uniformity at high temperatures, he made adjustments to improve it. However, during actual processing, the results worsened (as indicated by deteriorated sheet resistance, Rs). Surprisingly, the original, unoptimized setup yielded better process results, leaving him perplexed.

To address this complex phenomenon, we offer the following suggestions and insights to help the industry better understand and respond:

1. RTP process temperatures are in a dynamically unbalanced state: During RTP, sample temperatures exist in a constant "wave-like" dynamic condition, forming a non-equilibrium system. Therefore, the measurements inherently contain uncertainties.

2. Different measurement methods and conditions introduce significant errors: Based on our 40 years of experience in RTP temperature measurement: (1) At lower temperatures (around or below 500°C), errors are relatively minor. (2) At higher temperatures (above 500°C), measurement errors become significant, and the higher the temperature, the greater the error — sometimes exceeding 20°C. Thus, we recommend: (1) For **low temperatures**, multi-point TC wafers (e.g., 5-point) can be used to test temperature uniformity. (2) For **high temperatures**, multi-point TC wafer testing is **not recommended** as it is time-consuming, labor-intensive, and unlikely to yield accurate or useful results.

3. Physical differences between customer samples and measurement carriers make temperature uniformity measurements unreliable: Different materials (e.g., TC wafers versus actual product wafers) exhibit different thermal conduction behaviors under the same process menu, RTP furnace, and power conditions. As a result, even if temperature distribution appears uniform on a TC wafer, it doesn't necessarily reflect the true temperature behavior of the actual product wafer, and vice versa.

4. RTP process consistency relies on system design and control—not manual field tuning: RTP process uniformity and repeatability are determined by: (1) Chamber structure design; (2) Precision of heating/cooling systems; (3) Advanced temperature sensing technology; (3) Intelligent control systems. They are **not** achieved through manual multi-point measurement and adjustment on-site.

5. True wafer temperature and uniformity at high temperatures cannot be precisely known: Especially above 500°C, users can never accurately know the actual wafer temperature or its uniformity.

6. Importance of choosing a reputable RTP system brand: RTP equipment from well-established, market-proven brands with strong reputations is capable of delivering uniform photothermal energy to each wafer through high-speed temperature feedback and control systems, thereby ensuring consistent processing. We recommend customers prioritize mature brand equipment over experimental "concept RTP" systems that have not been thoroughly validated.

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