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Development of the system for Determining the Thermal Expansion Coefficient of Thin Film

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Extended Abstract

This study presents the development of a novel detection system for rapidly extracting the Coefficient of Thermal Expansion (CTE) of thin-film materials using an innovative electrical signal measurement method. The system employs a stable current to heat a microbridge standard test-key, facilitating thermal deformation. By measuring the pull-in voltage ($V_{pull\text{-}in}$) and applying it to an empirical formula, the CTE of thin-film materials can be accurately determined. This approach eliminates the need for complex optical setups or temperature change measurements, making the process more economical and practical for production lines.

Key system features include the use of SOI wafers as the material for fabricating microbridge standard test-keys and a streamlined measurement process leveraging a semiconductor device analyzer. The silicon material's CTE, known to be 2.60×10^{-6} K^{-1}[1], was used to validate the system. The experimental results showed that the system measured the thermal expansion coefficients of silicon at different lengths as 2.59×10^{-6} K^{-1} for 250 µm, 2.62×10^{-6} K^{-1} for 275 µm, 2.56×10^{-6} K^{-1}, for 300 µm and 2.53×10^{-6} K^{-1} for 275 µm. The system determined the average thermal expansion coefficient of silicon to be 2.575×10^{-6} K^{-1}, with an error of only 0.96%, confirming the system's accuracy and reliability.The study also optimized key system parameters, such as heating current and duration, to enhance measurement precision and avoid test-key damage. For different test-key sizes, the critical current (I_{cr}) and the maximum heating time (t_{st}) were determined. For a 250 µm test-key, the critical current is 9.5 mA, with a maximum heating time of 8 seconds, while for a 325 µm test-key, the critical current is 7.0 mA, with a maximum heating time of 16 seconds. Moreover, the system successfully calculated the thermal deformation trends (Δg-t curves) using capacitance change data (ΔC-t curves), ensuring reliable and reproducible measurements.

Compared to traditional optical methods, this system significantly reduces complexity, as it requires only a semiconductor parameter analyzer and bypasses additional temperature monitoring equipment. It addresses limitations of conventional methods by providing precise CTE measurements without the risk of damage from excessive current or prolonged heating.

This research contributes to the field by offering a high-accuracy, stable, and economical solution for determining thin-film material properties. The system's practical design and robust performance highlight its potential for rapid, in-line testing of thin-film components in industrial production environments.

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