Commentary
Volume 13:9, 2022

Journal of Physical Mathematics

ISSN: 2090-0902

Open Access

Application to Semiconductor Wafer Processing of Observer Design for a Nonlinear Heat Equation

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Description

Worldwide, the need for more and more computing power and storage space for data is driving up the demand for semiconductor components. The semiconductor industry faces new challenges as a result of the rapid advancement of technology and the imposed demands on device performance. Photolithography, ion implantation, and etching are just a few of the hundreds of processes involved in the production of contemporary microchips. These actions are repeated on a regular basis. For the development of perplexing coordinated circuits, single-wafer handling is liked over clump processes, as these cycles empower a lot better elements. The temperature of the process fluids or materials involved often has a significant impact on the quality of the final product, and heat and mass transfer mechanisms frequently occur in a number of silicon wafer production steps. In single wafer spin clean or wet chemical etching, the wafer must frequently be heated to a predetermined temperature, such as to chemically treat the surface of silicon wafers with highly reactive gases or to remove condensation from the surface prior to processing. The latter form part of what is known as rapid thermal processing (RTP), which typically necessitates temperatures in the 300-400°C range or even higher. Baking is the process of removing condensation, and it takes place at lower temperatures, typically around 150°C. Halogen lamps or a large number of high-power LEDs embedded beneath the wafer provide the heating. Large temperature gradients within the wafer must be avoided in order to prevent thermal stress in the wafer during heat up. Temperature control is necessary to solve this problem. In any case, the foundation of a criticism temperature regulator is trying as in many applications the contactless in-situ estimation of the whole surface temperature isn't accessible. Because of their low emissivity, thermal imaging cameras, for instance, are unable to precisely measure the temperature of low-doped wafers. The temperature cannot be measured at all or only point wise on the wafer surface for the majority of RTP or low temperature thermal processes [1].

However, full state information, such as the temperature measured at multiple points along the wafer's radius or the entire radial surface temperature, is frequently required for the design and implementation of a feedback controller. As a result, a state observer, also known as an estimator that derives the spatial and temporal evolution of the wafer surface temperature from available measurements, is frequently required for the implementation of such controllers in a production tool. A distributed parameter system (DPS) is the phenomenon by which the temperature of the wafer surface changes over time and space. Partial differential equations (PDEs) are the governing equations that control a system's dynamic behavior. An observer for a DPS can theoretically be designed based on an approximation via a lumped parameter system or directly using the PDE when following a model-based design paradigm. The first strategy, also known as early lumping, typically comes with the loss of pertinent system dynamics information. The fact that stability results obtained for finite-dimensional approximations may not necessarily apply to the PDE model makes this issue delicate. Additionally, the system order of the finite-dimensional approximations is typically high. In many design approaches, the observer's order is also determined by the order of the model. This can result in computationally intensive high-order algorithms for PDE approximations with finite dimensions [2,3].

Lately, late lumping has been widely evolved as a charming option in contrast to early lumping plan as the previously mentioned disadvantages don't exist. At the implementation stage, the approximation, which is ultimately required for real-time setup implementation, is performed. The original PDE model's robust stability holds for the lumped model as long as the approximation produces stable and robustness-preserving results. Therefore, the particular PDE structure can be utilized for the observer and controller design without regard to the final approximation method. The associated theory for 1D spatial domains for linear DPSs has been well-developed. Back stepping modal (or spectral) decompositions modal (or spectral) decompositions and high-gain observers are among the specific methods discussed here. A number of spatial dimensions have also been included in the back stepping strategy. Literature is less abundant for nonlinear and semi linear PDE models. An extended Luenberger observer design has been proposed. Methods for estimating variable structures have been developed. Researchers looked into absolute stability and observers based on nonlinear evolution equations. In asymptotic observers have been addressed for transport–reaction systems whose reaction rates are unknown. In high-gain observers were utilized, and matrix inequality-based designs were examined [4].

For some classes of semi linear and quasilinear systems, the backstepping method has been extended. Approaches to observer design based on dispersion have been discussed. Even though these results show that late-lumping design methods have a lot of potential, they all involve a lot of preliminary analysis and design steps that necessitate a thorough understanding of PDE theory. The pointwise measurement injection observer design, first proposed in for 1D semi linear heat equations, has been extended in to classes of semi linear parabolic systems, and in to a class of 1D parabolic transport–reaction systems with unknown inputs. It is a relatively straightforward design strategy that only requires fundamental knowledge of PDEs. A reduced-order observation scheme from finite-dimensional systems that imposes measurement information in the form of an algebraic constraint is similar to the design. A single in-domain measurement and a flawless, unperturbed model have already been taken into consideration when applying this strategy to nonlinear heat equations. A Kirchhoff state transformation was used to create the observer design and a retransformation was used to get the temperature estimate. In this paper, an eyewitness for frameworks represented by a nonlinear bothered 1D intensity condition in tube shaped facilitates with in-space estimations is planned. The observer's design is necessary for estimating the temperature of silicon wafers in semiconductor production; however, its use is obviously not restricted to this particular instance [5].

The pointwise measurement injection observer described is extended by the proposed observer, which takes into account a variety of nonlinearities. Forcing essentially sensible suspicions on the framework elements, the eyewitness assessment blunder combines to zero dramatically which is officially demonstrated by Lyapunov procedures. Pointwise disturbances acting directly at the sensor location have no effect on the observer's robustness. The

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Date of Submission: 01 September 2022, Manuscript No. jpm-22-81203; **Editor assigned:** 03 September 2022, Pre QC No. P-81203; **Reviewed:** 17 September 2022, QC No. Q-81203; **Revised:** 22 September 2022, Manuscript No. R-81203; **Published:** 27 September 2022, DOI: 10.37421/2090-0902.2022.13.388

estimation error dynamics are shown to be input-to-state stable in the presence of non-vanishing bounded distributed disturbances. Finally, an experimental validation of the proposed observer scheme on a semiconductor processing tool is carried out. In order to accomplish this, a mathematical model of the procedure is created. It is based on the model that was suggested. In this model, the focus is on modeling the input shape functions that relate the electrical power that is supplied to the heating device, or actuator, and the heat flux density that is introduced into the wafer.

Conclusion

A thermographic camera that can measure the entire surface temperature of wafers with a high dopant level is included in the validation tool. The spatio-temporal evolution of the estimation error can be computed with a distributed radial temperature measurement. Furthermore, this setup can theoretically simulate any number of pointwise sensors. The experimental results confirm the theoretical findings, demonstrate that the stability analysis's assumptions are reasonable, and demonstrate that convergence speed and implementation effort are effectively balanced. In contrast to the theoretical results are experimentally validated on a semiconductor wafer processing unit, the design is carried out in the original coordinates, and the Kirchhoff transformation is used only for the convergence assessment. In addition, multiple in-domain temperature measurements are taken, an imperfect model with distributed perturbations is considered, and robust convergence is established in terms of input-to-state stability. As a result, the preliminary findings in are expanded upon, extended, and experimentally validated by the current paper's findings.

Acknowledgement

None.

Conflict of Interest

None.

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How to cite this article: Menin, Rodolfo. “Application to Semiconductor Wafer Processing of Observer Design for a Nonlinear Heat Equation.” J Phys Math 13 (2022): 388.