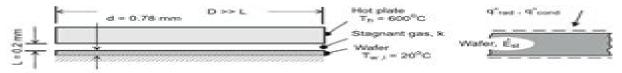
PROBLEM 1.41

KNOWN: Hot plate-type wafer thermal processing tool based upon heat transfer modes by conduction through gas within the gap and by radiation exchange across gap.

FIND: (a) Radiative and conduction heat fluxes across gap for specified hot plate and wafer temperatures and gap separation; initial time rate of change in wafer temperature for each mode, and (b) heat fluxes and initial temperature-time change for gap separations of 0.2, 0.5 and 1.0 mm for hot plate temperatures 300 < T_h < 1300 C. Comment on the relative importance of the modes and the influence of the gap distance. Under what conditions could a wafer be heated to 900 C in less than 10 seconds?

SCHEMIATER



ASSUMPTIONS: (1) Steady-state conditions for flux calculations, (2) Diameter of hot plate and wafer much larger than gap spacing, approximating plane, infinite planes, (3) One-dimensional conduction through gas, (4) Hot plate and wafer are blackbodies, (5) Negligible heat losses from wafer backside, and (6) Wafer temperature is uniform at the onset of heating.

PROPERTIES: Wafer: = 2700 kg/m³, c = 875 J/kg K; Gas in gap: k = 0.0436 W/m K.

ANALYSIS: (a) The radiative heat flux between the hot plate and wafer for $T_h = 600$ C and $T_w = 20$ C follows from the rate equation.

$$q_{rad} = T_b^4 - T_w^4 = 5.67 + 10^{-8} \text{W/m}^2 - \text{K}^4 = 600 - 273^{-4} = 20 - 273^{-4} - \text{K}^4 = 32.5 \text{kW/m}^2 = 40 - 273^{-4} - 20 -$$

The conduction heat flux through the gas in the gap with L = 0.2 mm follows from Fourier's law,

$$q_{cond} = k \frac{T_h}{L} \frac{T_w}{0.0436 \text{W/m}} \times \frac{600 - 20 \text{ K}}{0.0002 \text{ m}} = 126 \text{ kW/m}^2$$

The initial time rate of change of the wafer can be determined from an energy balance on the wafer at the instant of time the heating process begins,

$$\dot{E}_{in}$$
 \dot{E}_{out} \dot{E}_{st} \dot{E}_{st} cd $\frac{dT_w}{dt}$

where Eost 0 and Ein qual or quant Substituting numerical values, find

Continued

PROBLEM L41 (Cont.)

(b) Using the foregoing equations, the heat fluxes and initial rate of temperature change for each mode can be calculated for selected gap separations L and range of hot plate temperatures T_h with $T_w = 20\,$ C.



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Table of Contents Heat Transfer Incropera 5th Edition Solution

- 1. Understanding the eBook Heat Transfer Incropera 5th Edition Solution
 - The Rise of Digital Reading Heat Transfer Incropera 5th Edition Solution
 - Advantages of eBooks Over Traditional Books
- 2. Identifying Heat Transfer Incropera 5th Edition Solution
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
- 3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Heat Transfer Incropera 5th Edition Solution
 - User-Friendly Interface
- 4. Exploring eBook Recommendations from Heat Transfer Incropera 5th Edition Solution

- Personalized Recommendations
- Heat Transfer Incropera 5th Edition Solution User Reviews and Ratings
- Heat Transfer Incropera 5th Edition Solution and Bestseller Lists
- 5. Accessing Heat Transfer Incropera 5th Edition Solution Free and Paid eBooks
 - Heat Transfer Incropera 5th Edition Solution Public Domain eBooks
 - Heat Transfer Incropera 5th Edition Solution eBook Subscription Services
 - Heat Transfer Incropera 5th Edition Solution Budget-Friendly Options
- 6. Navigating Heat Transfer Incropera 5th Edition Solution eBook Formats
 - o ePub, PDF, MOBI, and More
 - Heat Transfer Incropera 5th Edition Solution Compatibility with Devices
 - Heat Transfer Incropera 5th Edition Solution Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Heat Transfer Incropera 5th Edition Solution
 - Highlighting and Note-Taking Heat Transfer Incropera 5th Edition Solution
 - Interactive Elements Heat Transfer Incropera 5th Edition Solution
- 8. Staying Engaged with Heat Transfer Incropera 5th Edition Solution
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Heat Transfer Incropera 5th Edition Solution
- 9. Balancing eBooks and Physical Books Heat Transfer Incropera 5th Edition Solution
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Heat Transfer Incropera 5th Edition Solution
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Heat Transfer Incropera 5th Edition Solution
 - Setting Reading Goals Heat Transfer Incropera 5th Edition Solution
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Heat Transfer Incropera 5th Edition Solution

- Fact-Checking eBook Content of Heat Transfer Incropera 5th Edition Solution
- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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