**PACKAGE ID -** 001183MLTPL00 MACWAFER

**KWIC TITLE -** Therml & Gravitational Stress in Si Wafers; Lim. on Process Htg & Cool. Rates

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**LIMITATION CODE** -COPY **AUDIENCE CODE -** LIM

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**DESCRIPTION -** The MacWafer code determines maximum allowable processing temperatures and maximum heating and cooling rates for thermal processing of silicon semiconductor wafers in single and multiple wafer furnaces. The program runs interactively on Macintosh, PC, and workstation computers. Execution time is typically 20 seconds on a Macintosh 68040 processor operating at 33 MHz. Gravitational stresses and displacements are first calculated based on the user's input of a support system consisting of a ring beneath the wafer and/or arbitrarily placed point supports. The maximum operating temperature is then deduced by comparing the calculated gravitational stresses with the temperature-dependent wafer strength. At lower temperatures, the difference between wafer strength and gravitational stress is used to determine the allowable thermal stress, and hence the allowable radial temperature difference across the wafer. Finally, an analytical model of radial heat transfer in a batch furnace yields the maximum heating or cooling rate as a function of the allowable temperature difference based on the user's inputs of wafer spacing and furnace power. Outputs to the screen include plots of stress components and vertical displacement, as well as tables of maximum stresses and maximum heating and cooling rates as a function of temperature. All inputs and outputs may be directed to user-named files for further processing or graphical display.

**PACKAGE CONTENTS -** Media Directory; Software Abstract; Media Includes Source Code, Executable Module;

**SOURCE CODE INCLUDED? -** Yes

**MEDIA QUANTITY -** 1 3.5 Diskette

**METHOD OF SOLUTION -** Gravitational stresses and displacements induced by the weight of the wafer are determined by solving the fourth-order elliptic partial differential equation that governs elastic deformation of thin plates. The particular solution for an arbitrary support system is constructed by superposing analytical solutions applicable to ring and point supports. A nonlinear equation solver is used to determine the load fractions carried by

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**METHOD OF SOLUTION -(CONT)** the individual supports. Thermal stresses are also determined analytically by evaluating known integral solutions for the case of an axisymmetric temperature field that varies quadratically with distance from the wafer center. The total stress is obtained by addition of thermal and gravitational stress tensors. To determine whether slip dislocations may occur, the wafer surface is scanned to find the maximum shear precipitated oxygen concentration. Iterative root-finding algorithms are used to determine the maximum operating temperature (at which the maximum gravitational stress is equal to the temperature-dependent yield stress) and, at lower temperatures, the allowable temperature difference between wafer edge and center. For temperatures less than the maximum, the allowable temperature difference is used to deduce the maximum heating or cooling rate of stacked wafers based on an analytical model of radial heat transfer that includes conduction through the silicon wafer and radiation heat transfer between opposing wafer faces as well as radiant exchange between wafer surfaces and furnace walls.

**COMPUTER -** MLT-PLTFM

**OPERATING SYSTEMS -** Macintosh, PC, or workstation

**PROGRAMMING LANGUAGES -** FORTRAN

**SOFTWARE LIMITATIONS -** Only those of standard FORTRAN

**SOURCE CODE AVAILABLE (Y/N) -** Y

**UNIQUE FEATURES -** To our knowledge, MacWafer is the only computer code which is specifically designed to analyze gravitational and thermal stresses in semiconductor wafers. Because this purpose is so specific, the user interface and solution procedures are highly specialized and optimized beyond those available in general purpose finite-element and finite-difference codes. As a result, the solution procedures are fast enough to permit interactive use on a Macintosh and PC computers. In addition, the interactive interface is sufficiently self-explanatory that there is no need for a user's manual. All required code inputs are displayed on the screen along with the initial default values that may be interactively altered by the user. The code is also unique in performing all of the iterative trial-and-error searches required to directly yield the results needed by equipment designers and process engineers. For example, the code calculates the maximum allowable temperature and heating rates, rather than simply indicating whether or not plastic deformation will occur for user guesses of these optimal operating conditions.

**RELATED SOFTWARE -** No auxiliary software is required.

**OTHER PROG/OPER SYS INFO -** Suggested memory allocation is 4 MB

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**HARDWARE REQS -** Executables will be available for popular Macintosh and PC computers

**TIME REQUIREMENTS -** About 20 CPU seconds is required for a complete analysis of a typical configuration on a Macintosh 68040 (with math coprocessor) operating at 33 MHz. This includes: calculation of stresses and displacements at 300 points, display of stress and displacement pictograms, field searches for maximum stresses, and iterative determination of maximum operating temperature and maximum heating and cooling rates at 100 temperatures in the range of interest.

**ABSTRACT STATUS -** Submitted 8/8/97. Released AS-IS 10/27/97

**SUBJECT CLASS CODE -** HIT

**KEYWORDS -**
COMPUTER PROGRAM DOCUMENTATION
M CODES
STRESS ANALYSIS
HEAT TRANSFER
TRANSIENTS
DEFORMATION
ELECTRONIC EQUIPMENT
PROCESS CONTROL
COMPUTER-AIDED MANUFACTURING

**EDB SUBJECT CATEGORIES -**
990200

**SPONSOR -** DOE/DP

**PACKAGE TYPE -** AS - IS