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(54) Apparatus for heating semiconductor wafers.

(57) Radiation heating of a semiconductor wafer employs first and second pluralities (30; 32) of spaced and skewed elongate parallel lamps (1 to 10: 11 to 20). Lamps in each plurality are grouped beginning with the innermost lamps and extending to the outermost lamps. Each group of lamps in one plurality of lamps are interconnected with a group of lamps in the other plurality of lamps whereby the interconnected groups of lamps are simultaneously and equally energized. Lamp voltage is modulated in accordance with a preestablished table for each size of wafer and temperature cycle. Alternatively, temperature sensors (38) can be employed to provide feedback to a computer controlled modulator. The lamps in the different groups can be selected to have different steady state power intensities for a given voltage thereby to establish a desired temperature gradient.

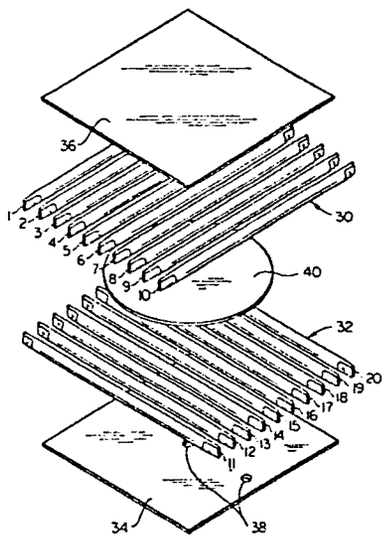


FIG_1

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APPARATUS FOR HEATING SEMICONDUCTOR WAFERS

This invention relates generally to apparatus for heating semiconductor wafers.

High intensity lamp heaters are now available for heat treating semiconductor wafers. For example, the Heat-Pulse™ system manufactures and sold by AG Associates, Palo Alto, California permits fast ramping of temperatures to 1100°C, and the maintenance of this temperature for a period of 10 seconds or so for the rapid annealing of ion implanted semiconductor wafers. The temperature is then quickly lowered thereby minimizing the movement of dopant ions in the crystal lattice structure. The same apparatus could be used for phosphorous doped oxide reflow, metal silicide formation, annealing, and other semiconductor applications.

When heat treating semiconductor wafers at a temperature of 1100°C or above, uniformity of heating is important to prevent thermally induced stresses and resulting slippage in the crystal structure. Heretofore, banks of lamps above and below the wafer all aligned in parallel have been used to heat the wafers. The current in each lamp is controlled to try and maintain some uniformity of temperature with the apparatus. However, maintenance of uniform temperature has not been possible due to the reradiated heat near the edges of the wafer, thus leding to a temperature gradient near the edges of the wafer. Attempts at overcoming this problem have included use of a supplementary lamp with generally circular configuration which surrounds the wafer in close proximity to the wafer edges. In addition to the increased complexity of the lamp heating array, an obvious limitation of using the supplementary lamp is the restriction of the lamp to one diameter size of wafer. However, in actual practice wafers of varying diameters, from 7.5 cms (3 inches) to 15 cms (6 inches) must be accommodated.

According to this invention there is provided apparatus for heating semiconductor wafers, a first plurality of lamps; and comprising a second plurality of lamps, said second plurality of lamps being spaced from said first plurality of lamps whereby a semiconductor wafer can be positioned therebetween; characterised by means electrically connecting groups of lamps in said first plurality of lamps and means electrically connecting groups of lamps in said second plurality of lamps; and means electrically interconnecting each group of electrically connected lamps in said first plurality of lamps with a group of electrically connected lamps in said second plurality of lamps whereby the interconnected groups of lamps are simultaneously and equally energized.

The invention provides a high temperature lamp heating apparatus which is readily controllable in heating wafers of various diameters, and which minimizes any temperature gradient along the wafer edges.

To maintain a generally uniform temperature across a wafer of any size, the lamps in each plurality are energized in groups of two or more, with a group in one plurality being interconnected for energization with a group in the other plurality whereby the two groups of lamps can be simultaneously and equally energized. Preferably the lamps are so connected to provide a plurality of heating zones extending outwardly. For example, the lamps in each group can have the same position from opposite ends of the plurality of which they are part. Since the groups of lamps are independently controlled, heat near the edge of a wafer can be increased to minimize temperature gradients in the wafer.

The electrical power to the lamps can be controlled in accordance with preestablished lamp current for obtaining a desired temperature for a specific size of wafer. Alternatively, sensors can be provided to sense the temperature of the heated wafer and provide feedback for automatically controlling the lamp groups. Additionally, a desired temperature gradient profile can be established by adjusting the relative power of the groups of lamps through judicious selection of the individual lamps as to power rating.

The invention will now be described by way of example with reference to the drawings, in which:-

Figure 1 is an exploded perspective view of an apparatus in accordance with the invention;

Figure 2 is a side view of the apparatus of Figure 1;

Figure 3 is a top schematic view of the two pluralities of lamps of Figure 1 illustrating the positioning of a wafer therebetween and the energization of the lamps in pairs;

Figure 4 is a schematic diagram illustrating the energization of two pairs of lamps of the arrangement of Figure 2; and

Figure 5 is a functional block diagram of control circuitry for controlling the pluralities of lamps in an apparatus as shown in Figure 1.

Referring now to the drawings, Figure 1 is an exploded perspective view of one embodiment of heating apparatus in accordance with the invention. A first plurality of elongate lamps shown generally at 30 and numbered 1 - 10 are provided above a wafer 40, and a second plurality of elongate lamps shown generally at 32 and numbered 11 - 20 are provided below the wafer 40. The lamps 1 to 20 may be conventional tungsten halogen lamps. A light reflector 34 is positioned below the plurality of lamps 32, and a light

reflector 36 is positioned above the plurality of lamps 30. Two temperature sensors 38 are positioned in reflector 34 for sensing the temperature of the heated wafer 40. Suitable sensors are optical pyrometer thermometers manufactured and sold by I. R. Con, Inc. of Skokie, Illinois.

Figure 2 is a side view of the apparatus of Figure 1, and further illustrates the positioning of the wafer 40 between the pluralities of lamps 30 and 32. One of the sensors 38 is positioned beneath the center of the wafer 40 and the other sensor 38 is positioned near the edge of the wafer 40.

Figure 3 is a top plan view of the two pluralities of lamps with the wafer 40 positioned therebetween and in alignment with an orthogonal criss-cross arrangement of the lamps of the two pluralities. As shown, the lamps in each plurality are paired beginning with the outermost lamps 1, 10 and 11, 20 and working inwardly to the innermost pair of lamps 5, 6 and 15, 16. Corresponding pairs of lamps in the two pluralities are then connected together in parallel for simultaneous and equal energization. For example, as shown in Figure 3 the two lamps 3, 8 in the top plurality 30 of lamps are connected with the corresponding pair of lamps 13, 18 of the bottom plurality 32 of lamps with the four lamps being connected in parallel for simultaneous energization by power control unit 42.

In one mode of operation, power through the lamps is controlled by phase modulating a voltage having a constant peak amplitide, or controlling the duty cycle thereof. The voltage applied to the pairs of lamps can be preestablished for each size wafer and for a particular heat treatment. For example, heat treating of a 10cm (four inch) diameter wafer where the temperature is ramped up to 700°C in three seconds, maintained in a steady state for ten seconds, and then ramped down in three seconds can be in accordance with the following table:

RAMP TABLE

Normalized intensity = 1 = 30% peak

		3 sec. Ramp Up	10 sec. Steady Rate	3 sec. Ramp Down		
				1 sec.	2 sec.	3 sec.
Group	1	1	.80	.7	.4	0
	2	1.1	.80	.7	.4	0
	3	1.2	.85	.75	.43	0
	4	1.3	.90	.8	.45	0
	5	1.5	1.0	.9	.50	0

This loop system using predetermined current for the lamps may provide an annealing temperature of 700°C plus or minus 7°C for the ten second steady state. For other sized wafers and for other temperature annealing patterns the normalized current intensity will vary.

Otherwise the temperature sensors 38 shown in Figure 2 can provide a feedback for computer control of the lamp currents. Figure 5 is a functional block diagram of control apparatus in which the sensors 38 are employed. Signals from the temperature sensors 38 are suitably conditioned at 44 and applied through a multiplexer 46 to an analog to digital converter 48. The digital signals from converter 48 are then applied to a microprocessor 50 which is suitably programmed to respond to the sensed temperature and control timers 52 and phase controllers 54 in energizing the pluralities (banks) of lamps 56. This closed system employing the temperature sensors 38 can more readily vary the temperature profiles used in heat treating a wafer. Greater control can be realized by employing more than two temperature sensors.

In alternative modes of operation, a single center sensor can be employed for dynamically controlling the central group of lamps. The other groups of lamps can have a predetermined offset from the intensity of the central groups with the other groups automatically changing as the central group is changed in intensity.

Using the two sensors 38 the central sensor can control the central group of lamps, while the temperature differential between the two sensors controls the offset of the outer groups of lamps.

In another mode of operation, the groups of lamps can have different steady state intensities for a give voltage thereby establishing a desired temperature gradient. Each wafer size can be provided with a specific gradient which is not dependent on electronic control.

Heating apparatus utilizing high intensity CW lamps as described above can provide accurate control of the temperature in a wafer, and maintian desired temperature gradients therein. Use of the temperature sensors and feedback provides greater versatility in controlling the temperature profiles in heat treating a wafer; otherwise a proper selection of lamps can provide a desired temperature gradient without need for electronic control.

Claims

1. Apparatus for heating semiconductor wafers, comprising by a first plurality (30) of lamps (1 to 10); and a second plurality (32) of lamps (11 to 20), said second plurality (32) of lamps (11 to 20) being spaced from said first plurality (30) of lamps (1 to 10) whereby a semiconductor wafer (40) can be positioned therebetween; characterised by means electrically connecting groups of lamps (eg. 3 and 8) in said first plurality (30) of lamps (1 to 10) and means electrically connecting groups of lamps (eg. 13 and 18) in said second plurality (32) of lamps (11 to 20); and means (42) electrically interconnecting each group of electrically connected lamps (3 and 8) in said first plurality (30) of lamps (1 to 10) with a group of electrically connected lamps (13 and 18) in said second plurality (32) of lamps (11 to 20) whereby the interconnected groups of lamps (3 and 8; 13 and 18) are simultaneously and equally energized.

2. Apparatus as claimed in Claim 1, characterised in that the lamps (1 to 10; 11 to 20) in each plurality (30; 32) are elongate and parallel, with the lamps of one plurality being skewed with respect to the lamps of the other plurality.

3. Apparatus as claimed in Claim 2, characterised in that the lamps (1 to 10) of the first plurality (30) are arranged orthogonally with respect to the lamps (11 to 20) of the second plurality (32).

4. Apparatus as claimed in any preceding claim, characterised in that the lamps (3 and 8; 13 and 18) in each group are connected in parallel.

5. Apparatus as claimed in Claim 4, characterised in that the lamps (3, 8, 13, 18) in interconnected groups are connected in parallel.

6. Apparatus as claimed in any preceding claim, characterised in that each group of lamps (3 and 8; 13 and 18) consists of two lamps.

7. Apparatus as claimed in Claim 6, characterised in that the lamps (3 and 8; 13 and 18) in each group have the same position from opposite ends of the plurality (30 or 32) of which they are part.

8. Apparatus as claimed in any preceding claim, characterised by control means for controlling the power supplied to the interconnected groups of lamps whereby a desired temperature can be maintained when heating a wafer (40) between said first plurality (30) of lamps (1 to 10) and said second plurality (32) of lamps (11 to 20).

9. Apparatus as claimed in Claim 8, characterised in that said control means includes a voltage source and modulation means for modulating the duty cycle of voltage applied through interconnected groups of lamps.

10. Apparatus as claimed in Claim 9, characterised in that said modulation means is controlled in accordance with preestablished duty cycles of current through said interconnected groups of lamps.

11. Apparatus as claimed in Claim 9 or Claim 10, characterised by temperature sensing means (38) for sensing the temperature of a wafer (40) and computer control means (50) responsive to the sensed temperature for controlling said modulation means.

12. Apparatus as claimed in any preceding claim, characterised in that the lamps in each group of lamps are selected to have different steady state power intensities for a given applied voltage thereby to establish a desired temperature gradient.

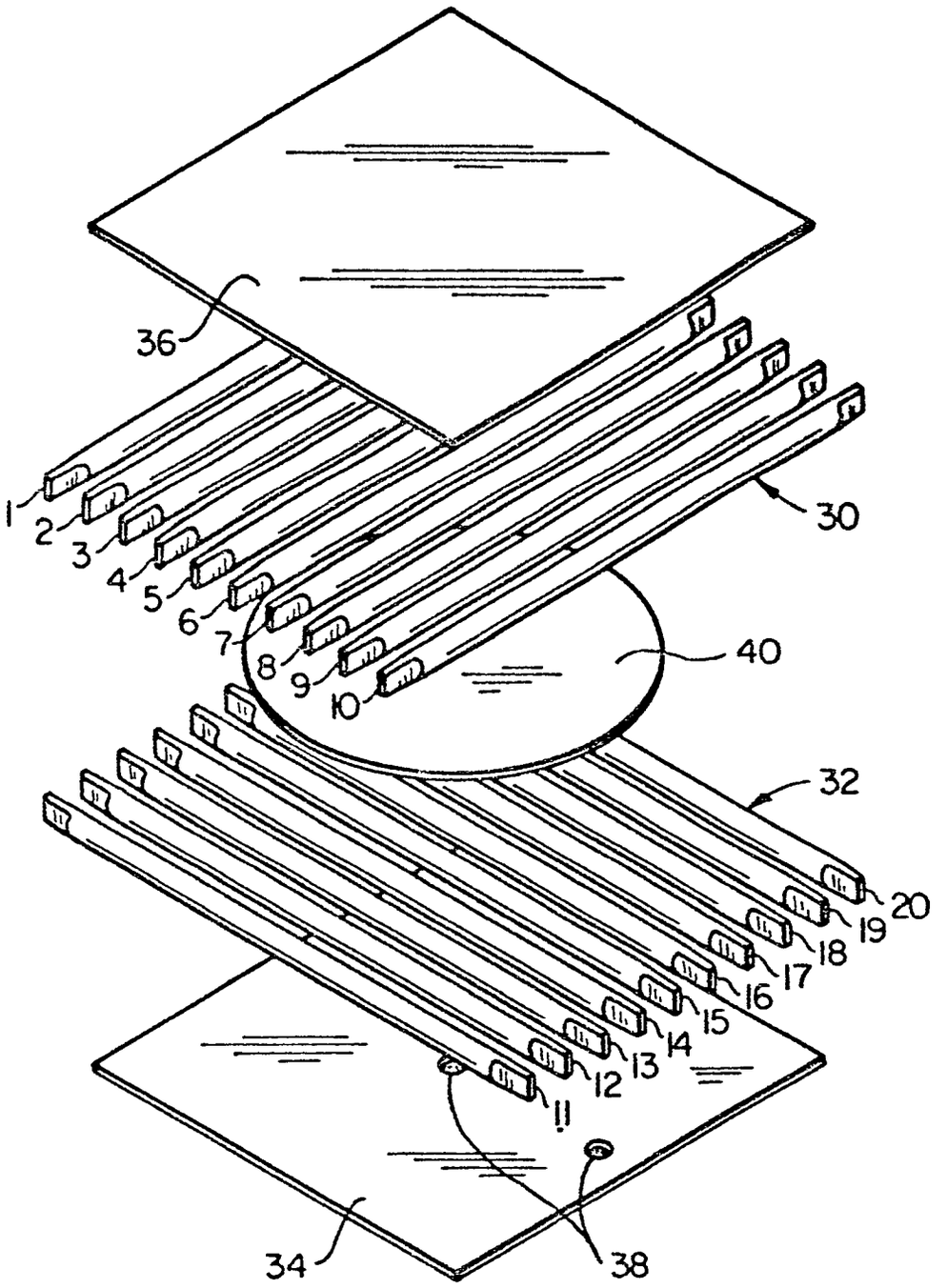

36
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34
38

FIG_1

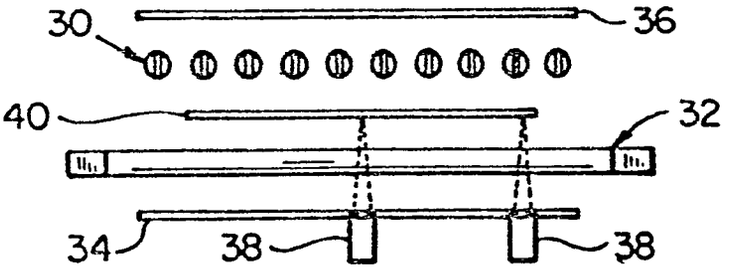

30
36
40
32
34
38
38

FIG_2

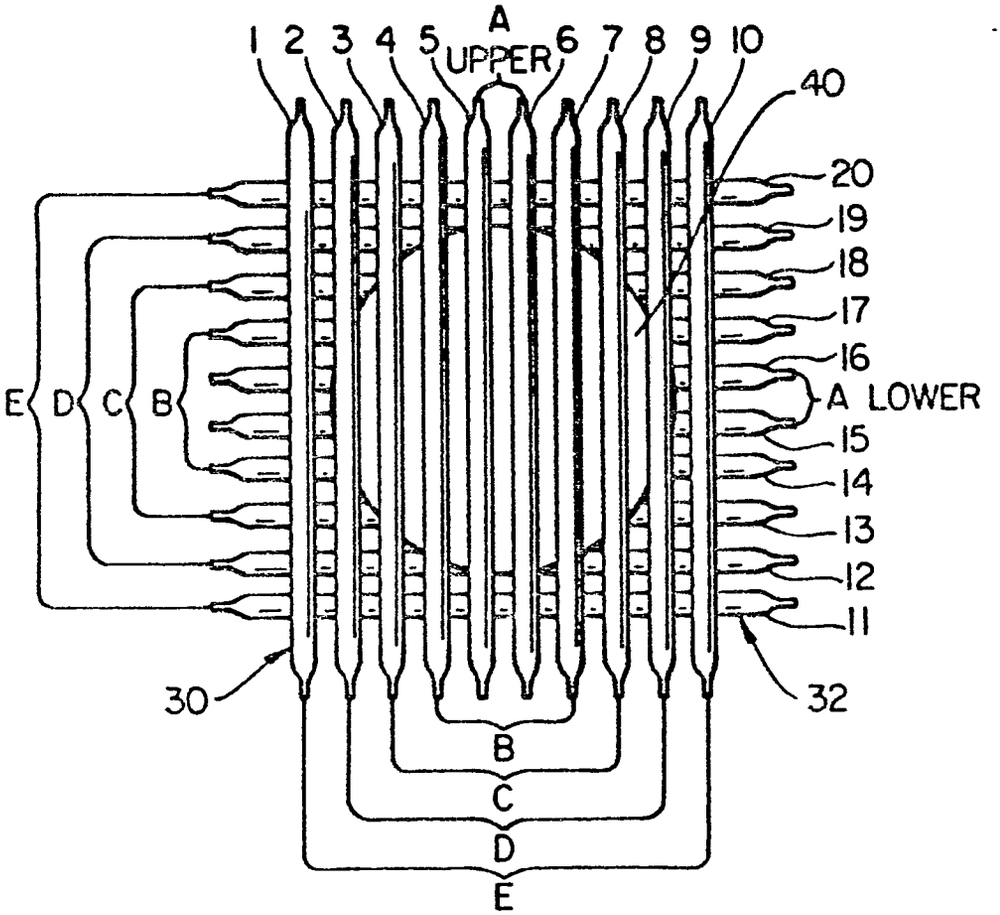

A
1 2 3 4 5 UPPER 6 7 8 9 10
40
20
19
18
17
16
A LOWER
15
14
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12
11
E D C B
30
32
B
C
D
E

FIG_3

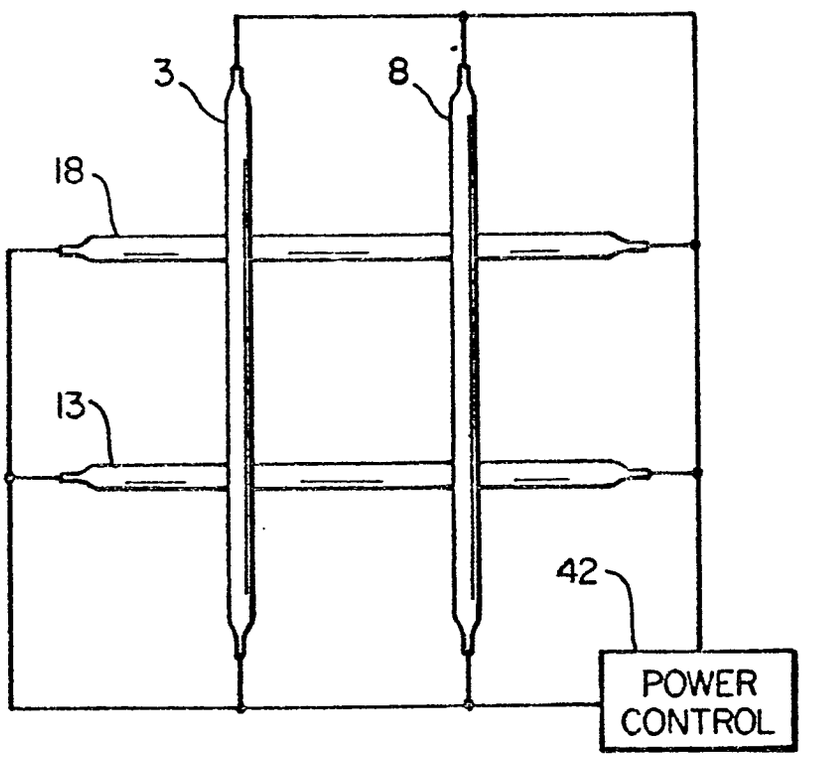

3
8
18
13
42
POWER
CONTROL

FIG_4

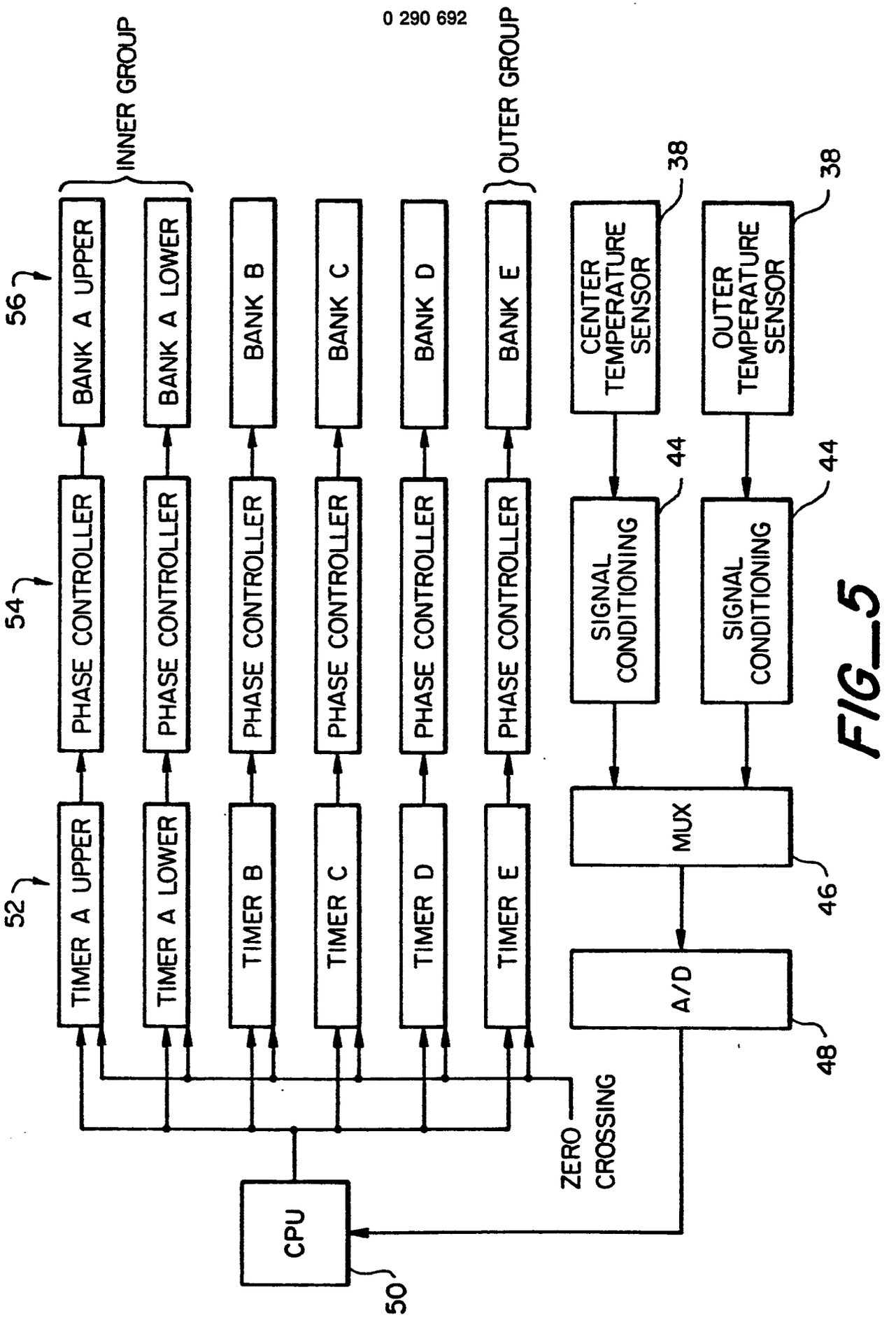

INNER GROUP
OUTER GROUP
56
54
52
BANK A UPPER
BANK A LOWER
BANK B
BANK C
BANK D
BANK E
PHASE CONTROLLER
TIMER A UPPER
TIMER A LOWER
TIMER B
TIMER C
TIMER D
TIMER E
CENTER TEMPERATURE SENSOR
OUTER TEMPERATURE SENSOR
38
SIGNAL CONDITIONING
44
MUX
46
A/D
48
CPU
50
ZERO CROSSING

FIG_5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 87 30 4297

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	US-A-3 836 751 (E.R. ANDERSON)		H 05 B 3/00 C 30 B 25/10 F 27 B 17/00 C 30 B 31/12
A	EP-A-0 119 654 (PHILIPS)		
A	US-A-4 508 960 (TETSUJI ARAI)		
A	US-A-4 533 820 (HIROSHI SHIMIZU)		
A	US-A-4 493 977 (TETSUJI ARAI)		

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

C 23 C
C 30 B
F 17 B
H 05 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23-02-1988	COULOMB J.C.

CATEGORY OF CITED DOCUMENTS

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