(12) UK Patent Application (19) GB (11) 2 070 328 A

(21) Application No **8101628**
(22) Date of filing **20 Jan 1981**
(30) Priority data
(31) **8002205**
(32) **23 Jan 1980**
(33) **United Kingdom (GB)**
(43) Application published
3 Sep 1981
(51) **INT CL^3**
H10L 21/26 21/263 21/268
(52) Domestic classification
H1K 11B2 3E1M 3E1T
3E5A 3F 9C3 9D1 9D2 9N2
9N3 MW
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(58) Field of search
H1K

(71) Applicants
The Secretary of State for Defence,
Whitehall,
London SW1A 2HB.
(72) Inventors
Keith Gordon Barraclough,
Anthony George Cullis,
Hugh Charles Webber.
(74) Agents
F.R. Robinson,
Procurement Executive,
Ministry of Defence,
Patents 1 A(4),
Room 1932,
19th Floor,
Empress State Building,
Lillie Road,
London SW6 1TR.

(54) Improvements in or relating to laser annealed electronic devices

(57) Selected regions of a slice of neutron transmuted semiconductor material are laser annealed to a submicron depth. Si or Ge starting material is irradiated with neutrons to produce compensating doping by transmutation. Selected regions of a slice are then laser annealed either by selective scanning with a small diameter spot, or by using a mask and a larger diameter spot. The surrounding unannealed matrix is semi-insulating. Further dopants may be implanted into parts of the slice before laser annealing.

SPECIFICATION

Improvements in or relating to laser annealed electronic devices

The present invention relates to the production of laser annealed electronic devices and particularly, though not exclusively, relates to the production of silicon integrated electronic devices by employing laser beam annealing.

Some applications of laser beam annealing are described in Science, Vol 201, 28 July 1978 and in the Boston Conference Proceedings, Academic Press 1979, S D Ferris, H J Leamy and J N Poole. It is known to laser beam anneal ion-implanted semiconductors to electrically activate the implanted dopant.

In known silicon semiconductor manufacture, an ingot of raw silicon is irradiated by neutron bombardment to produce neutron transmuted silicon containing P dopant having a resistivity of about $2 \times 10^5 \Omega$ cm which is then furnace annealed at 1000°C for an hour in an argon atmosphere to reduce the resistivity to about 28 Ωcm. These irradiation and furnace annealing steps are necessary to reduce unacceptable variations in the resistivity of the silicon starting material. The ingot is then etched and sliced into wafers.

The present invention provides a method for producing annealed electronic devices wherein the annealing is carried out to give conductivity regions in a semi-insulating matrix. The annealing may be spatially controlled.

According to the present invention a method for producing laser annealed electronic devices includes the steps of irradiating semiconductor material to produce a neutron transmuted semiconductor material, and laser annealing a selected region or regions in a slice of the transmuted material to a sub-micron depth.

The semi-conductor may, for example, comprise silicon or germanium.

Laser annealing is (may be) effected using a scanning laser beam having a spot diameter in the range 2-50 μm, or may be effected by masking part of the selected region and by directing a laser beam of large spot area at the selected region.

The regions of the neutron transmuted semiconductor material selected for laser annealing may be implanted with Group III or Group V elements, such as for example boron, prior to laser annealing, and p-n junctions formed by laser annealing the implanted regions.

Integrated circuits which include active devices such as diodes and related devices may be manufactured by using the above-mentioned steps. In particular, devices may be spatially isolated from adjacent devices within a semi-insulating neutron transmuted matrix.

The invention will now be described by way of example only.

Float-zoned 1000Ω cm n-type silicon was irradiated with a flux of thermal neutrons at an intensity of 9.65×10^{17} n/cm^2 which raised the resistivity of the silicon to $2 \times 10^5 \Omega$cm. Selected regions in the transmuted silicon were annealed by a Q-switched ruby laser using 30 nsec pulses of 694 nm radiation and a power level of about 1.5 - 2.0 J/cm^2. 4-point probe measurements and chemical step etching indicated that the annealed regions were typically 3000 Å deep and had a resistivity of about 50 Ωcm, n-type, indicating a high level of activation of P dopant atoms. Furnace annealed control samples had resistivities of typically 28 Ωcm, n-type. It was concluded that laser annealing produced relatively high levels of activation.

In a further experiment boron was implanted in 1 mm circular regions in irradiated transmutation doped silicon to give 10^{16} 60 keV-B$^+$/cm^2. These regions were then laser annealed as described in the first experiment above. Electrical measurements confirmed that p-n junctions had been formed at the boundaries of the implanted regions. Reverse breakdown voltages for these regions was greater than 130V with a leakage of about 200 μA for 100 V reverse bias. For a probe distance of 100 μm from the junction regions, the forward resistance was about 2.5 kΩ.

CLAIMS

1. A method for producing laser annealed electronic devices including the steps of irradiating semiconductor material to produce a neutron transmuted semiconductor material, and laser annealing a selected region or regions in a slice of the transmuted material to a sub-micron depth.

2. A method for producing laser annealed electronic devices as claimed in claim 1 wherein the semiconductor is silicon or germanium.

3. A method for producing laser annealed electronic devices as claimed in claim 2 wherein the laser annealing is effected by a scanning laser beam having a spot diameter in the range 2-50 μm.

4. A method for producing laser annealed electronic devices as claimed in claim 2 wherein the laser annealing is effected by directing a laser beam of large area at a partially masked region in a slice of the material.

5. A method for producing laser annealed electronic devices wherein the region or regions of the neutron transmuted semiconductor material selected for laser annealing may be implanted with Group III or Group V elements prior to laser annealing, whereby p-n junctions may be formed by laser annealing the implanted regions.

6. A method for producing laser annealed electronic devices substantially as hereinbefore described.

7. A method for producing integrated circuits which include a plurality of laser annealed electronic devices produced by any of the methods claimed in claims 1 to 5, wherein the devices are spatially isolated from each other by semi-insulating neutron transmuted matrix.

8. A laser annealed electronic device produced by any of the methods claimed in claims 1 to 6.

9. An integrated circuit produced by the method claimed in claim 7.

Printed for Her Majesty's Stationery Office by Croydon Printing Company Limited, Croydon, Surrey, 1981.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.