NASA TECH BRIEF
Lewis Research Center

High Temperature Gallium Phosphide Rectifiers

The problem:

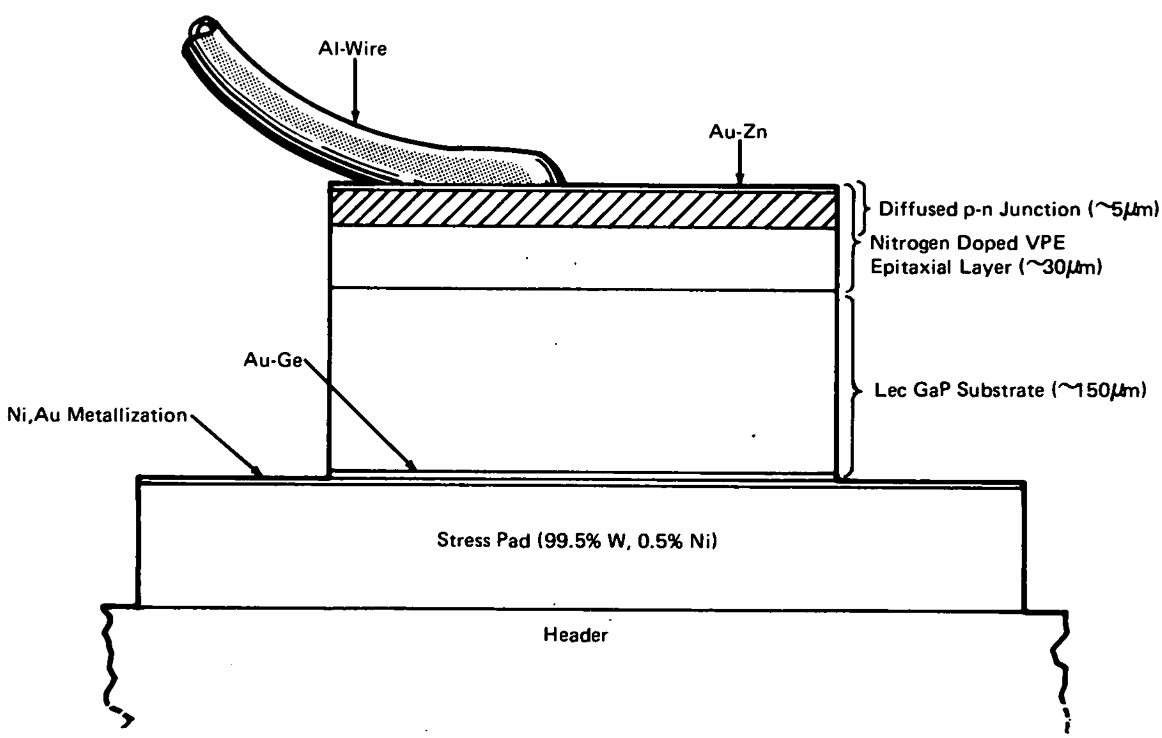
The potential of gallium phosphide (GaP) rectifiers for high-temperature applications has been known for some time, and rectifiers have been produced both with diffused junctions and with Schottky barriers. However, the development of stable high-power Schottky rectifiers has been complicated both by the stringent requirement of uniform surface preparation prior to metallization and by the tendency of the barrier metal to alloy with the GaP during high-temperature operation. Also, studies of large-area diffused-junction rectifiers revealed not only problems in fabricating a stable high-temperature device, but also a difficulty in achieving both high reverse breakdown voltages and low forward voltage drops in the same device.

The solution:

Refinement of GaP vapor phase epitaxial (VPE) growth techniques and the utilization of n/n+ GaP structures has resulted in the fabrication of Zn-diffused GaP p/n/n+ rectifiers which exhibit reverse avalanche voltages greater than 400 volts as well as forward voltages less than 3 volts at a forward current of 1.0 ampere for temperatures from 27 to 400°C.

How it's done:

Material used in the fabrication of these devices is prepared by the VPE growth of thin (approximately 30 μm), high resistivity layers on low resistivity liquid encapsulated Czochralski (LEC) substrates. The growth is carried out in an open tube system using phosphine



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(PH_3) with HCl gas transport of Ga. Both the PH_3, as a 5% mixture in H_2, and the HCl are ultra pure grade. The other reagents are 99.9999% Ga and H_2 purified by Pd diffusion. HCl at 3 ml/min standard temperature and pressure (STP) diluted with 50 ml/min of H_2 is passed over Ga at temperature close to 780°C to form GaCl vapor. The GaCl vapor is then mixed with the main H_2 stream at 450 ml/min including 10 ml/min of 5% PH_3 in H_2 mixture, at 930°C. From the mixing zone, the combined reactant gas stream is passed over the horizontally supported substrates located at 800°C to 850°C in a temperature gradient of 10°C/cm. Epitaxial layers are grown at a rate of approximately 10 microns/hr. The epitaxial layer thickness is in the range of from 25 to 35 μm and uniform to within ± 1 μm for a given wafer.

The epitaxial layers are doped with nitrogen, an isoelectric impurity, to a concentration of approximately 10^{19} molecules/cm^3, but are otherwise not intentionally doped.

Carrier densities in the nitrogen doped epitaxial layers as low as 3×10^{14}/cm^3 were observed by Au-GaP Schottky barrier C-V analysis. Epitaxial layers grown in the same reactors, but without nitrogen doping, have background carrier concentrations of approximately 10^{16}/cm^3.

Junctions are formed at a depth of approximately 6 μm in the thin epitaxial layer by a closed ampoule Zn diffusion using either a $ZnAs_2$ or metallic Zn source. Diffused wafers are lapped and polished on the substrate side to a final thickness of approximately 150 μm. A thin film of Au-Ge eutectic alloy is vacuum evaporated on the substrate side to improve the n-type side ohmic contact. A thin film of Al is then evaporated onto the p-type side to reduce spreading resistance in the p-type layer. The wafers are then diamond scribed and cleaved into chips.

In order to minimize thermally induced strain in the devices during high-temperature operation, the n-type sides of the chips are alloyed to Au-plated 99.5% W – 0.5% Ni stress relief pads (see figure) with Au-Ge preforms. The W-Ni stress relief pads have a thermal expansion coefficient which closely matches that of GaP. The chip-stress pad sub-assemblies are then alloyed to Au-plated headers and contacted with multiple Al ultrasonic bonds.

Notes:

1. These thin film devices can be used to temperatures in excess of 400°C which is far above the maximum operating temperature for Si devices.
2. This work represents a major improvement in GaP material and device technology, and makes possible the fabrication of GaP active components, such as transistors and monolithic light emitting arrays with a memory.
3. The following documentation may be obtained from:

   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)

   Reference: NASA CR-2098, Development of High Temperatures Gallium Phosphide Rectifiers
4. Technical questions may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B72-10673

Patent status:

NASA has decided not to apply for a patent.

Source: M. G. Craford and D. L. Keune of
Monsanto Company
under contract to
Lewis Research Center
(LEW-11804)