FULL MONOLITHIC SAMPLING HEAD IC

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ABSTRACT

In this paper we describe a full monolithic sampling head IC with a bandwidth of up to 26GHz. It consists of Resonant Tunneling Diodes [RTDs] for a sampling pulse generator and Schottky barrier diodes for a sampling bridge. The RTD is made using an InGaAs/AlAs pseudomorphic superlattice system. For this type RTD, we obtained a peak to valley ratio of 9 at 202°C with switching voltages up to 1.5Voltp-p.

The Schottky barrier diode is made from an $(InGaAs)_{0.5}(InAlAs)_{0.5}$ mixing crystal. The RTD and Schottky barrier diodes are monolithically constructed on a Fe-doped InP substrate.

INTRODUCTOIN

A diode sampling bridge is a very important device for high speed waveform analyzers, network analyzers, and other microwave measuring instruments. The operating frequency of a diode sampling bridge is limited by its gating times (aperture times of the diode bridge). For diode bridge gating, step recovery diodes (SRD s) are generally used; however, their risetimes are limited to about 30ps.

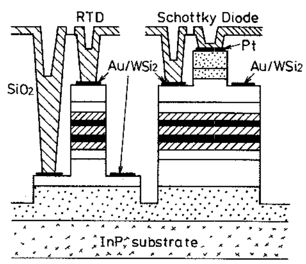
Recently, many researchers have been investigating switching speeds below 20ps for RTDs (resonant tunneling diodes). Switching voltages can be controlled by the carrier concentration and the barrier structure [1] [2]. We used the RTDs as a sampling strobe pulse generator. For this practical application, we selected an InGaAs/AlAs pseudomorphic superlattice system for room temperature operation[3]. Using this generator, we fabricated a high performance, fully monolithic sampling head IC on a Fe-doped InP substrate.

FABRICATION AND DESIGN

Figure 1 shows a cross sectional view of the new sampling head IC's layer-structure. Each semiconductor's layer is grown by MBE (ANELVA 620) at 470°C on a Fe-doped InP substrate (Sumitomo Electric Industries LTD). At each hetero-interface, the growth is interrupted at 2 minutes for atomic scale smoothing.

Composition[Nd/cm³]	Thickness [Å]
$n-(InGaAs)_{0.5}(InAlAs)_{0.5}$	3000
$n^+-(InGaAs)_{0.5}(InAlAs)_{0.5}$	500
$n^+-InGaAs(1\times10^{19})$	4000
$n-InGaAs(1-2\times10^{17})$	1000
u-InGaAs(spacer)	~15
u-AlAs(barrier)	~30
u-InGaAs(well)	~41
u-AlAs(barrier)	~30
u-InGaAs(spacer)	~15
$n^+-InGaAs(1\times10^{18})$	1000
$n^+-InGaAs(1\times10^{19})$	4000
u-InAlAs	5000
InP(substrate)	400[μm]

a) Layer Structure



b) Cross Sectional View

Figure 1 Cross-Sectional View

For sampling strobe pulse generators, the RTD carriers (outside of the double barrier region) are asymmetrically doped. High switching voltages are obtained at the anode side by this asymmetrical

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doping, as the carrier concentration of the anode side is low.

The Schottky diode cut-on voltages are controlled by the mixing ratio of the mixing crystals $(InAlAs)_{1-X}(InGaAs)_X$, which lattice-match to an InP substrate.

Figure 2 shows the sampling circuit. This circuit is a four diode bridge type. The diodes have a Cjo of about 50 fF and a series resistance of about 5 Ohms. For MIM capacitors, sputtered Ta_2O_5 is used. For resistors, sputtered TaWSi-N is used. The transmission lines of the input and the strobe pulses are a CPW and CPS respectively. The common line widths of the CPW are nearly equal to those the CPS. The signal line widths of the CPW are very narrow compared with the widths of the CPW common lines and the CPS lines (the signal line widths of the CPW are reduced to one-tenth those of the CPS line widths). With this technique, this characteristic impedances of the CPW and the CPS are maintained at 50 Ohm. The CPS is terminated in a short circuit. The round-trip time of the bridge from the CPS short point determines the strobe pulse width. This circuit has a CPW instead of a sampling hold capacitor.

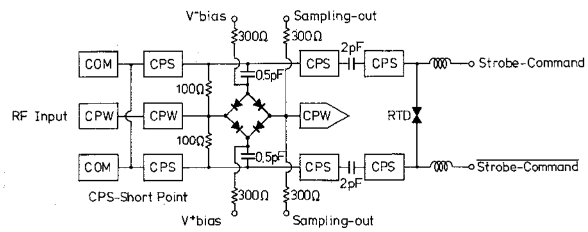


Figure 2 Sampling Head IC Circuit

Figure 3 shows a microphotograph of the full monolithic sampling head IC.

RESULT AND DISCUSSION

Figure 4 shows the I-V characteristics of this conventional RTD vs temperature. This data shows the P/V ratio is 9 at 202 °C. From this experiment, the InGaAs/AlAs pseudomorphic surperlattice system is considered a good selection for this practical application at room temperature.

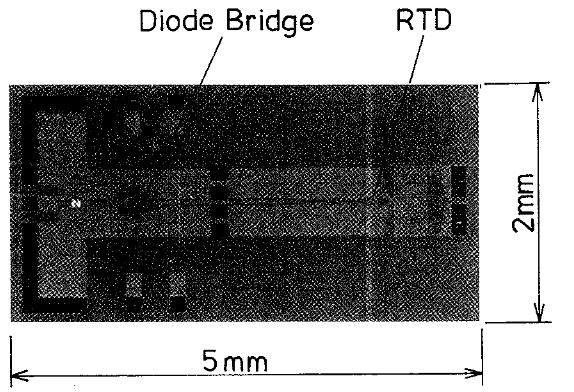


Figure 3 Microphotograph of Sampling Head IC (10ps Type)

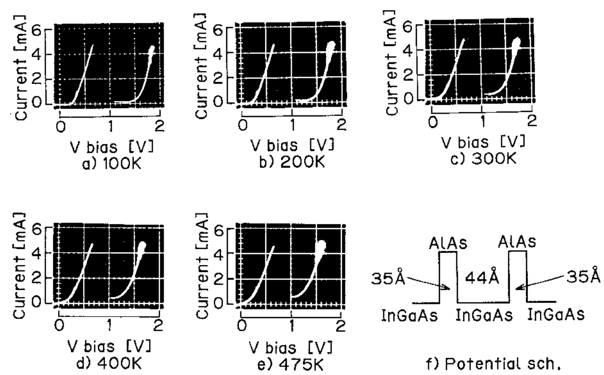


Figure 4 RTD Temperature Characteristics

Figure 5 shows the I-V curve of the $Pt-(InAlAs)_{1-X}(InGaAs)_X$ Schottky diode. This data shows that the cut-on voltages are about 0.4Volts and the leakage currents are below 100nA at -1Volts for a mixing ratio of 0.5.

Figure 6 shows the I-V characteristics of the asymmetrically doped RTD and the conventional doped RTD with their potential diagrams. At this low doping, the RTD needs high external voltages for the same intrinsic voltages of the barrier structure as the conventional type of RTD. This data shows that the switching voltages of the strobe pulse with

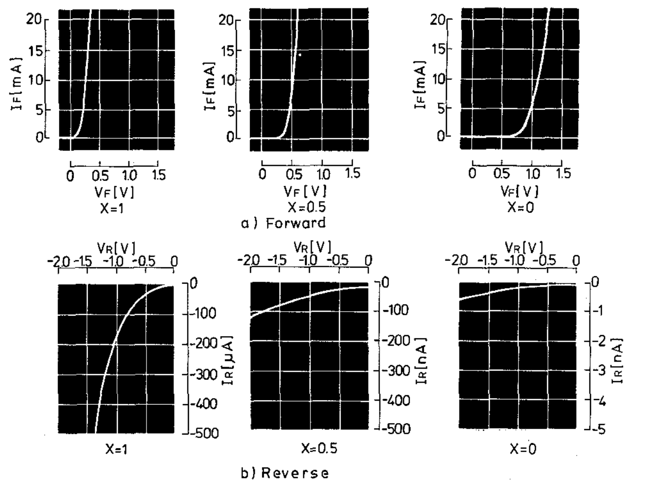
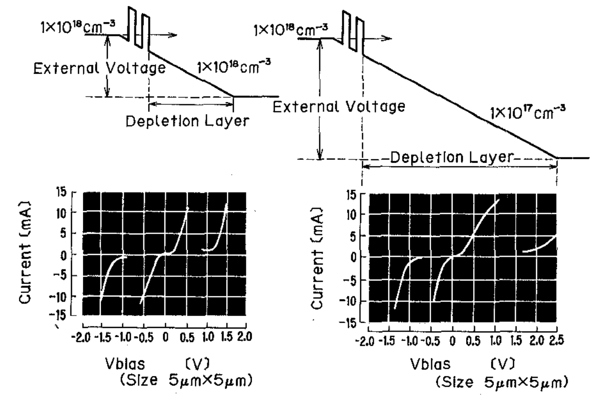
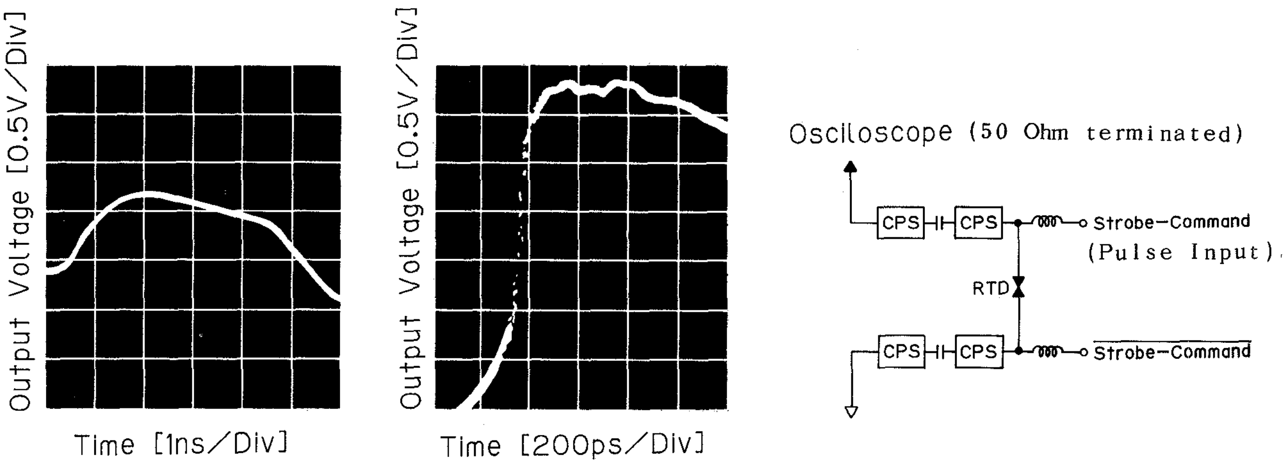


Figure 5 Curves of Pt-$(InGaAs)_X(InAlAs)_{1-X}$ Schottky Diode



a) Conventional Type b) Large Swing Type

Figure 6 Large Voltage Swing RTD



a) No Switching State
Input Pulse ±3V, 4ns
at 50 Ohm Load

b) Switching State
Input Pulse ±5V, 4ns
at 50 Ohm Load

c) Test Circuit

Figure 7 Pulse Drive Operation of Large Swing RTD

this RTD are up to 1.5Voltp-p at the anode side. The large voltage swing RTD has a high power comsumption, so we consider the pulse drive operation prevents thermal or avalanche breakdown. Figure 7 shows the pulse drive operation characteristics of the large voltage swing RTD. In the switching state, the output voltages of this RTD are sufficient to drive the Pt-$(InAlAs)_{0.5}(InGaAs)_{0.5}$ Schottky diode bridge of the sampling head IC.

The AC characteristics of this full monolithic sampling head IC (with its round trip time set at 10ps, 20ps, 30ps, 40ps and 50ps with the photomask design) is shown in Figure 8. The data of Figure 8 is normalized to 0dB at 1GHz. The sampling frequency is 30MHz and the beat-down frequency is about 150kHz. The widths of the sampling strobe command pulses are 3ns.

Figure 9 shows the sampling output vs the round-trip times at 1GHz. The same

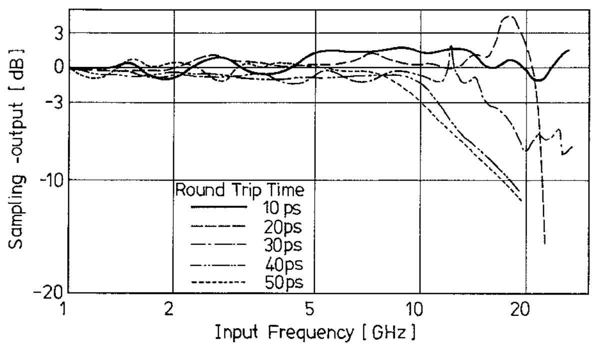


Figure 8 AC Characteristics of Sampling Head IC

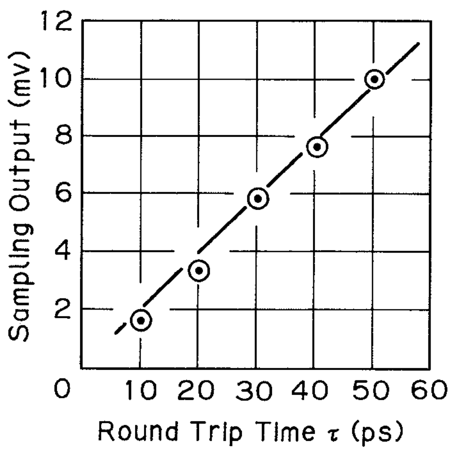


Figure 9 Sampling Output vs Round Trip Time

test fixture was used to account for the constant stray capacitor. The sampling output is proportional to the round-trip time, as predicted by sampling theory. From this data, the RTD's switching times are considered to be less than or equal to 10ps.

Figure 10 shows the sampling head IC microwave package and its chip carrier. This chip carrier is made using a sintered AlN plate (Sumitomo Electric Industries LTD). The use a sintered AlN carrier for the DC operation of our RTD prevented termal breakdown. Thus, all our experiments with the RTD were made using a sintered AlN chip carrier without on-wafer testing.

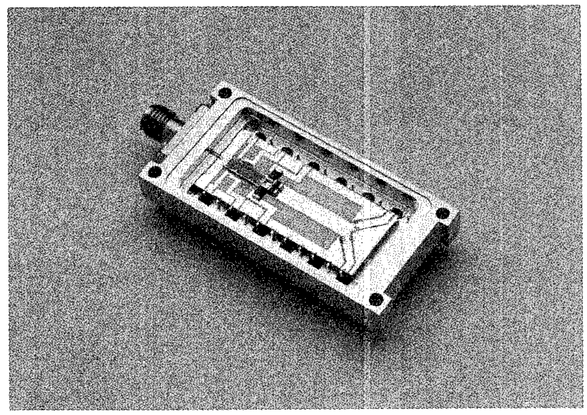


Figure 10 Sampling Head IC Microwave Package

CONCLUSTION

We obtained a full monolithic sampling head IC with a bandwidth of up to 26GHz. It consisted of a large voltage swing RTD and Schottky barrier diodes (Pt-$(InAlAs)_{0.5}(InGaAs)_{0.5}$). This value was limited by the test fixture (the synthesized oscillator).

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