IIB-8 Electrical Measurements of Devices Fabricated in Pulsed Arc Lamp Rapid-Zone-Recrystallized Silicon on Insulator—

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Zone-melting-recrystallized (ZMR) silicon on insulator (SOI) typically employs graphite strip heaters or other low power density melting sources with relatively slow scanning speeds [1]. The results of thermal modeling simulations suggest that high quality SOI can also be obtained by high power density, line-source *rapid zone recrystallization* [2]. The advantage to rapid recrystallization is the shorter high temperature duration, with less damage to existing structures or impurity distributions in the sample and greater applicability to 3-D IC's. To date, only line-source electron-beams [3] have been used for rapid recrystallization. This paper presents electrical measurements from active devices fabricated in SOI material processed in a rapid zone recrystallization system using a pulsed arc lamp line source.

The seeded polysilicon coated sample is rapidly preheated (above 1000°C, in room air ambient) and scanned by a linear translation table under the zone; speed is of the order of 35 $\mathrm{cm \cdot s^{-1}}$. (By comparison, strip heater ZMR systems typically operate at 100 $\mathrm{W \cdot cm^{-2}}$ with scan speeds of 1 $\mathrm{mm \cdot s^{-1}}$.) The lamp energy is collimated by a plate optic to a 0.5-mm line with 8-$\mathrm{kW \cdot cm^{-2}}$ power density. A single lamp pulse melts the top film and the sample then cools by radiation. The sample is above room temperature for less than 15 s. The experimental apparatus and materials properties are reported elsewhere [4]. Three-inch Si wafers with 0.5-μm-thick seeded SOI islands (50 μm by 2.5 cm) were prepared by this method. MOSFET's, resistors, capacitors, lateral junction diodes, Schottky diodes, and MESFET's were fabricated; standard CMOS LOCOS process technology was employed.

Measurements reveal electron mobilities averaging 670 $\mathrm{cm^2 \cdot V \cdot s}$ in implanted channels (15 percent higher than in bulk monitor samples). Unpassivated backchannel leakage averaged 80 nA $\cdot$ $\mu\mathrm{m}^{-1}$. Minority-carrier lifetimes over 10 μs (comparable to line e-beam recrystallized samples) exceed the values commonly seen in ZMR material. The electrical results confirm the material quality suggested by SEM, TEM, and Nomarski observations. Reproducible results were obtained in FET's down to 1-μm effective channel length. The process, with significantly higher throughput than one requiring a vacuum, has application to high-speed, dense, radiation-hard CMOS.

[1] See, for example, *Semiconductor-on-Insulator and Thin Film Transistor Technology*, A. Chiang, M. W. Geis, and L. Pfeiffer, Eds., Materials Research Society, Pittsburgh, PA, 1986.
[2] K. Kubota, C. E. Hunt, and J. Frey, *Appl. Phys. Lett.*, vol. 46, no. 12, p. 1153.
[3] See, for example, J. A. Knapp and S. T. Picraux, *J. Appl. Phys.*, vol. 53, p. 1492.
[4] C. E. Hunt and J. Frey, *Proc. 18th Conf. Solid State Devices and Materials*, Tokyo, p. 561, 1986.

IIIA-1 High-Frequency GaInAs/InP Multiple Quantum Well Buried Mesa Electroabsorption Optical Modulator—

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Multiple quantum well (MQW) p-i-n modulators, which are based on the quantum confined stark effect, have been demonstrated in the GaAs/AlGaAs system [1]. These devices work by shifting the exitonic absorption edge toward longer wavelengths when an external electric field is applied perpendicular to the plane of the MQW's. We describe the fabrication and performance for the first time of a GaInAs/InP MQW p-i-n electroabsorption buried mesa optical modulator with low insertion loss and high modulation bandwidth.

The material is grown by atmospheric-organometallic vapor phase epitaxial (atmos-OMVPE) which has been shown to be capable of producing narrow abrupt quantum wells [2]. The device is fabricated in two atmos-OMVPE steps: first a MQW (GaInAs = 100 Å, InP = 100 Å, 100 cycles) of about 2-μm thickness is grown, on a p-InP substrate and then covered sequentially by an n^- and n^+ InP layer; second, after etching a 40-μm mesa, semi-insulating (SI) Fe doped InP is regrown and the mesa buried. The mesa is then contacted with a ring allowing light to pass through the center. Because most of the contact and bonding are over the SI-InP, parasitic capacitance is minimal and high-frequency operation was obtained.

Typical mesa's had reverse breakdowns of 30–40 V and dark currents of less than 1 μA. The insertion loss was less than 4.5 dB mostly due to reflections at the air-semiconductor interface and p-substrate absorption. The maximum modulation depth was 25 percent at 1.62 μm, while non-SI-InP regrown mesa's of 200-μm diameter exhibited 45 percent. The 3-dB small-signal modulation bandwidth for the buried mesa was 5.3 GHz at 1.621 μm at bias voltages around 7 V. This modulation bandwidth is, to our knowledge, the highest yet reported for an electroabsorption modulator.

[1] T. H. Wood, C. A. Burrus, D. A. B. Miller, C. S. Chemla, T. C. Damen, A. C. Gossard, and W. Wiegman, *Appl. Phys. Lett.*, vol. 44, p. 16, 1984.
[2] B. I. Miller, E. F. Shubert, U. Koren, A. Ourmazd, A. H. Dayem, and R. J. Capike, *Appl. Phys. Lett.*, vol. 49, p. 1384, 1986.

IIIA-2 Observation of Large Absorption Modulation in a Quantum-Well Field-Effect Device—

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Deep quenching of absorption ($\Delta\alpha > 10^4\ \mathrm{cm^{-1}}$) over a 90-meV spectral range brought about by field induced carriers has been observed directly for the first time at room temperature in a special AlInAs/GaInAs/AlInAs single quantum-well (SQW) MODFET for a modest gate voltage change from −0.6 to 1.5 V. The effect is well suited for several important and novel optoelectronic applications.

The modulation doped $\mathrm{Al_{0.48}In_{0.52}As/Ga_{0.47}In_{0.53}As/AlInAs}$ SQW (10 nm) structure was grown by MBE on an InP:Fe substrate. The recessed gate (1.6 μm long by 200 μm wide) MODFET's [1] exhibit a maximum g_m of 116 mS/mm with $V_{th} = -0.5$ V. An extension of the gate electrode was included in the design to form a 100 μm × 100 μm optical test pad over a contiguous part of the FET mesa.

Optical measurements were carried out in the 1.0- to 1.7-μm range using the focused output from a monochromater. Photocurrent spectrum taken at zero bias shows characteristic absorption steps due to 2D subbands. To investigate the effect of gate bias on the absorption spectrum, the light was focused onto the optical test pad through the substrate, reflected off the Cr/Au electrode and was detected by a PbS photodetector. The gate-voltage induced modulation in the reflected light was measured using a lock-in amplifier.

The measured difference spectrum clearly shows a large change at the position of $n_s = 1$ exciton peaks with a maximum $\Delta I/I$ of ~ 2 percent. This amounts to $\Delta\alpha \sim 10^4\ \mathrm{cm^{-1}}$ which corresponds to total quenching of the excitonic absorption [2]. This interpretation is supported by the abruptness of the edge of the difference spectrum and the appearance of two features at the expected positions of the heavy and light hole exciton peaks. Weaker structures are also observed near the $n_s = 2$ and 3 absorption edges. The results are very reproducible from device to device.

The observed absorption change is primarily due to the filling of the generalized phase space (including 2D excitonic states) by free carriers. The change is more pronounced than those produced by quantum confined Stark effect [3] and by photocarriers [4]. It is