CMOS p-well process. The mismatch occurring due to the leakage suppression cannot be compensated by ratioing the corresponding drain areas, because of the temperature dependence and magnitude of the mismatch. Compensation methods dealing with the leakage mismatch are currently under investigation.

Acknowledgments: This work was supported financially by the Natural Sciences & Engineering Research Council of Canada under grants A7776 and A3382, and by the Alberta Microelectronic Center.

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14th June 1989

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VARIABLE PHASE SHIFT OF SPATIALLY PERIODIC PROTON-BOMBARDED SCHOTTKY COPLANAR LINES

Indexing terms: Microwave devices and components, Transmission lines, Semiconductor devices and materials, Phase shifters

Experimental results on periodic coplanar Schottky-contact transmission lines on semiconducting GaAs, prepared by proton implantation, are presented. It is shown, that this technique reduces the propagation constant and increases the characteristic impedance, whereas the phase velocity further depends on the applied bias voltage. An additional significant result is the simultaneous increasing of the quality factor.

Introduction: Active travelling-wave devices such as voltage dependent phase shifters are currently under investigation for several applications.[1–3] Here Schottky-contact transmission lines are advantageous, because the thickness of the distributed depletion layer can be varied by an applied DC bias voltage. However, the large value of the capacitance per unit length gives rise to an extreme reduction of the wavelength, a diminution of the characteristic impedance and an enhancement of the attenuation factor. To reduce the losses without losing the slow-wave characteristics, Fukuoka and Itoh[4] and Jäger[5] proposed coplanar waveguides on a periodically doped semi-insulating substrate. The resulting dispersive and filter effects due to the periodicity are not intended but exist at higher frequencies. In this letter we present, to our knowledge, the first experimental results of a monolithic periodic structure[4,5] produced on a semiconducting substrate by spatial proton bombardment.

Coplanar structure and implantation: The basic structure of the experimental coplanar Schottky contact transmission line is sketched in Fig. 1. An n-GaAs substrate with doping concentration N_D of 5×10^{16} cm^{-3} is used. Before the implantation process the substrate is covered by a suitable photoresist pattern (Shipley 1350J). This pattern consists of stripes of width a separated by unprotected areas of width b. Then protons (H^+) are implanted with an energy of 300 keV and a total dose of 1×10^{14} cm^{-2}. Using standard techniques a periodic coplanar Schottky contact transmission line is formed with $w = 140\,\mu$m and $s = 40\,\mu$m, where the aluminium centre conductor is reverse biased. The period p is given by the sum of the length a of the protected region and the length b of the implanted region. The period $p = a + b$ is $600\,\mu$m and

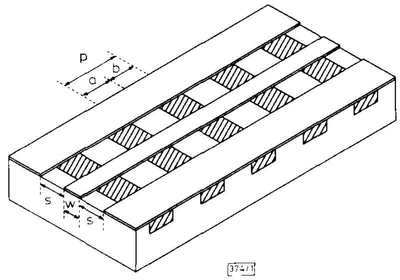

Fig. 1 *Sketch of periodically proton-bombarded Schottky coplanar line*

the ratio $r = a/p$ of the length a of the protected region to the period p varies from $r = 0$ (totally implanted line) to $r = 1$ (not implanted line). By control samples it has been verified that the implantation process changes the electrical properties of the rectifying contact as expected from published data,[6] i.e. the specific resistance of the implanted regions is increased by a factor 10^6.

Experimental results: The transmission line parameters of the periodic coplanar waveguides were characterised by conventional network analysis where measurements were carried out at reverse bias voltages V_0 of 1·5 and 5·0 V. In Fig. 2 the phase constant β of each line as a function of frequency f is presented. As can be seen, β of each line increases as a function of frequency and decreases for an increasing length b of the implanted regions at a given frequency. It should be mentioned that these results are also valid for $V_0 = 5{\cdot}0$ V.

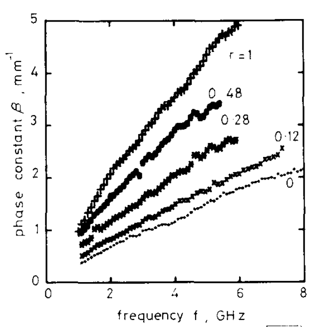

Fig. 2 *Phase constant β of implanted coplanar structures as function of frequency f*

Parameter is ratio $r = a/p$; $V_0 = 1{\cdot}5$ V

The voltage dependence of the not-implanted line ($r = 1$) is that of the well known Schottky coplanar lines[2,3] used as variable phase shifters. In particular, the phase constant and the attenuation constant α, which is not shown here, decrease when the bias voltage is increased. It should be pointed out that these results also hold for all partially implanted lines and that the totally implanted line exhibits no voltage-dependent propagation constant. To elucidate the voltage dependence of the partially implanted lines and to determine the influence of the local implantation on the transmission line properties more quantitatively, the measured values have been evaluated at constant frequencies. As a result, in Fig. 3a the phase constant β is plotted against the ratio r for both bias voltages at a fixed frequency. Clearly, the phase constant decreases at constant frequency and bias voltage with decreasing ratio r or, equivalently, with decreasing length a of the active regions. Moreover, this diagram shows that the voltage sensitivity is decreasing when the length b of the implanted regions is enhanced. At $r = 0$, the phase constant is independent of the applied voltage. Concerning technical applications

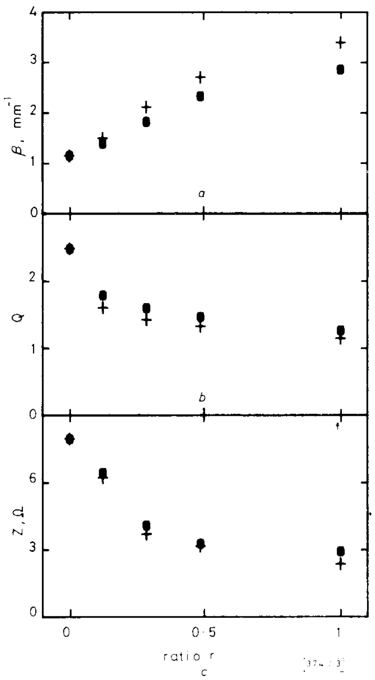

Fig. 3 *Measured values of (a) phase constant β, (b) quality factor Q and (c) real part Z of characteristic impedance at 4 GHz*

Bias voltage V_0 is parameter: (+) 1·5 V, (●) 5·0 V

of the transmission lines as variable phase shifters the attenuation per wavelength is recognised as the significant parameter.[7] However, one has to take into account that the wavelengths of the different structures are modified by the spatial proton bombardment. Therefore the 'quality factor' $Q = \beta/2\alpha$ of transmission lines, defined as the ratio of reactive to resistive power, seems to play a key role. In Fig. 3b this quality factor is depicted against the ratio r for both bias voltages. Although the absolute values are not very large, it is obvious that the quality factor is increased by the implantation process from 1·3 to about 2·5, which is in the order of 100%. In Fig. 3c the real part Z of the characteristic impedance as a function of the ratio r shows another typical influence of implantation. As can be seen, Z is enhanced at constant frequency and bias voltage by an increasing length b of the implanted regions. It is obvious that Z is enlarged by implantation from less than 3 Ω to approximately 8 Ω, which is more than 150%.

The microwave properties of the ion-bombarded semiconductor sections can be determined by using common transmission line theory. Here we consider the totally implanted line ($r = 0$). Neglecting dispersive and resistive effects, in a first-order approximation the phase constant β and the real part Z of the characteristic impedance are given by $\beta = \omega\sqrt{(L'C')}$ and $Z = \sqrt{(L'/C')}$, respectively, where L' denotes the inductance per unit length of a coplanar line and ω is the angular frequency. Under slow-mode conditions the capacitance per unit length C' of the totally implanted line can be assumed to be the distributed capacitance of the centre conductor, whereby the plate distance is given by the implantation depth d. This depth d can easily be calculated using the data of Figs. 3a and 3c, $\beta = 1{\cdot}15\,\text{mm}^{-1}$ and $Z = 7{\cdot}96\,\Omega$, and $\varepsilon = 12{\cdot}9$ for the relative dielectric constant. The resulting value of $d = 2{\cdot}78\,\mu$m at 300 keV implantation energy matches very well with the value of the ion penetration depth of 1 μm per 100 keV, as published in Reference 6.

Conclusion: As a distinct influence of implantation it has been shown that the properties of coplanar Schottky-contact transmission lines can be improved essentially by periodic proton bombardment. In particular, the following most important features of periodically implanted Schottky coplanar lines are found experimentally: the phase constant β is decreased, the quality factor Q is increased, and the real part Z of the characteristic impedance is enlarged by increasing the length of the implanted regions when frequency, bias voltage and period are kept constant. Slow-wave characteristics, especially external control of phase shift are still present if only parts of the material are implanted.

Acknowledgments: Implantation was carried out using the 360 keV particle accelerator of the Institut für Kernphysik der Universität Münster. We are especially grateful to Dr. B. Cleff and his team for their kind assistance in implantation technology. We also thank the Deutsche Forschungsgemeinschaft for financial support.

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30th June 1989

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FREQUENCY-SELECTIVE SURFACE USING APERTURE-COUPLED MICROSTRIP PATCHES

Indexing terms: Antennas, Microstrip, Antenna arrays, Radar cross-sections

A new type of frequency-selective surface using aperture-coupled microstrip patches is described. The geometry uses two back-to-back arrays of microstrip antennas with coupling apertures in the common ground plane, and provides a narrow passband response that may be useful for radome and RCS reduction applications. Calculated results demonstrate the operation of the structure, and are verified with measurements using a waveguide simulator.

Introduction: Frequency-selective surfaces are useful as subreflectors for dual-frequency reflector antennas, and as antenna radomes for radar cross-section (RCS) control.[1] Here we report a new type of frequency-selective surface (FSS) that uses two back-to-back arrays of microstrip patches with small coupling apertures in the common ground plane (see Fig. 1).