STUDY OF DESIGN, TECHNOLOGY AND CHARACTERIZATION OF GALLIUM NITRIDE BASED HIGH POWER HETEROSTRUCTURE FET FOR MICROWAVES[1]

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ABSTRACT

The low contact resistances and Schottky contacts with low leakage current [1-5], are important aspects of AlGaN/GaN FET's influencing gain and thermal behavior. This paper discusses the use of Coplanar waveguides in AlGaN/GaN power amplifiers if no via-hole technology is available or if a hybrid solution is pursued. To carry enough current in the output stage of an amplifier the signal line should have a large metal cross- sectional area (> 5 x 50 m^2*). The result shows that CPWs with large dimensions show non-quasi-TEM behavior related to propagation of parallel plate modes.*

INTRODUCTION

Towards the development of high-power amplifiers, the utmost importance lies on discrete HEMTs, along with it the matching circuitry is also very important. Amplifiers can be realized either in a hybrid fashion, or in a monolithic fashion (MMIC) with all the elements on the same substrate. The following section discusses about the aspects of CPW in the development of compound elements like AlGaN/GaN, power amplifiers.

COPLANAR WAVEGUIDETECHNOLOGY

Introduction

The disadvantage of CPW is that this technology has not been implemented in commercial design environments with sufficient accuracy. Hence, most CPW elements like transmission lines have to be fabricated, measured and modeled.

This paper presented results on the fabrication and characterization of CPW transmission lines on an AlN substrate. AlN substrate was chosen for its superior electrical properties and can be used as a suitable carrier if flip-chip techniques are pursued.

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Experimental

Several CPW lines were processed on AlN samples with a thickness of 0.02 inch (figure 1). The CPW consisted of a Ti/Au e-beam evaporated bottom metal layer on which 2.5 m gold was plated to reduce losses. The mask contained a matrix of CPW lines with a signal line width ranging from 25 to 200 m and a spacing between the signal and ground lines of 10 to 320 m. The large widths of the signal lines were chosen because these lines need to be able to carry high currents (>1 A) if they are used in matching networks for high power amplifiers.

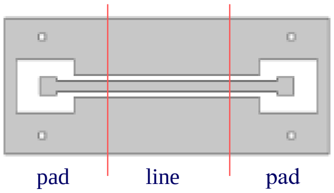


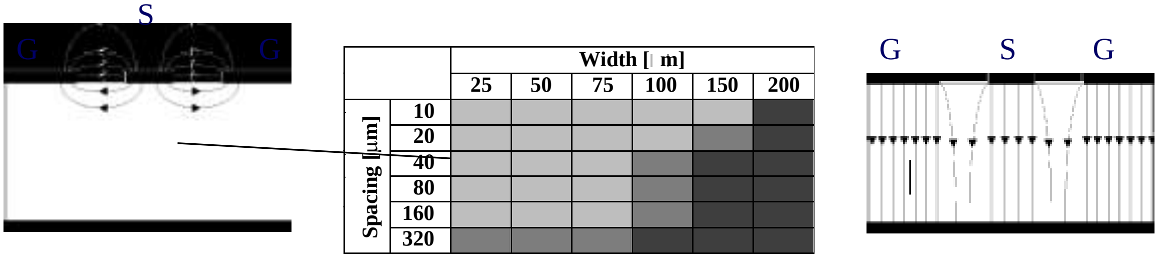
Figure 1: *CPW layout; the transmission line is connected to 2 contact pads.*

The characteristic impedance and propagation constant were extracted using S-parameter measurements up to 50 GHz in combination with a capacitance measurement of the transmission line [6,7]. The influence of the contact pads on the overall measurement was eliminated using the Line-Reflect-Line (LRL) de-embedding technique [7]. This technique was modified to account forth symmetrically out of the CPW. Furthermore, reciprocity was assumed ($S_{21}=S_{12}$). Using these modifications, it is possible to extract the transmission line parameters using only two CPW lines with different lengths.

RESULTS

The behavior of the measured CPWs can be divided in two different regimes: the (desired) quasi-TEM and non-quasi-TEM regime where non-quasi-TEM behavior results in distortion for high frequencies.

The non-quasi-TEM regime can be attributed to parallel plate modes that become dominant for large CPWs. In this case the metal chuck acts as one of the plates. Figure 2 illustrates for the non-quasi-TEM behavior.



Spacing [μm]	Width [m] 25	50	75	100	150	200
10	░	░	░	░	░	▓
20	░	░	░	░	▒	▓
40	░	░	░	▒	▓	▓
80	░	░	░	▒	▓	▓
160	░	░	░	▒	▓	▓
320	▒	▒	▒	▓	▓	▓

Figure 2: *Illustration of the dominant modes and electric field lines for different CPW dimensions. The deviation from the ideal quasi-TEM is represented by different shades of gray with dark being the worst.*

A test was performed to reduce the effects of the parallel plate modes by placing several non-processed samples between the chuck and the actual sample. Quasi-TEM behavior was restored further supporting the idea of parallel plate modes. Tests with Au plated backsides showed the same results as the non-plated samples indicating that the sample-chuck combination acts like a conductor backed CPW.

Extracted and Z0

Figure 3 shows the effective dielectric constant, eff, which is proportional to the propagation constant, divided by the frequency, for a typical CPW. For frequencies below 10 GHz dispersion-like effects can be seen. For higher frequencies the dielectric constant can be approximated by a constant value. This value was used for the calculation of the characteristic impedance as illustrated in figure 4. Taking into account the non-quasi-TEM behavior shown in figure 10 we can conclude that quasi-TEM CPWs can be realized within the impedance range of 30-120. The inductance values that can be realized with these lines, which is important for matching purposes, lie in the range of 0.2 – 0.9 nH/mm.

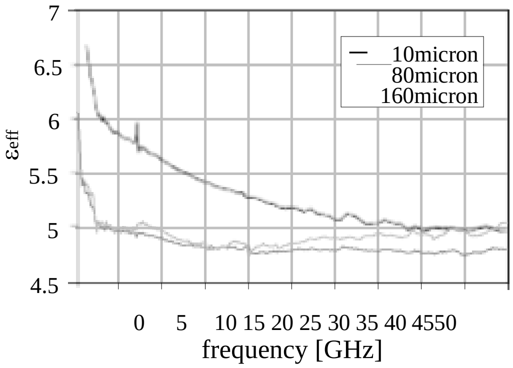


Figure 3: *Effective dielectric constant versus frequency for a CPW (signal width = 75 m, spacing = 80 m, length = 3200 m).*

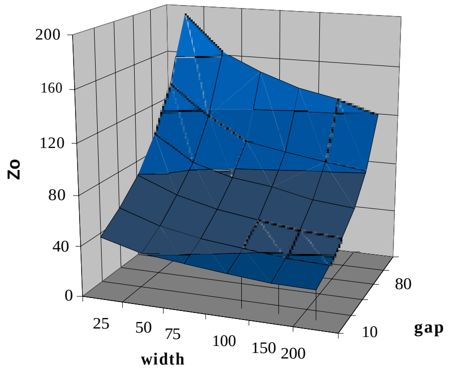


Figure 4: *Characteristic impedance for different CPW dimensions.*

CONCLUSIONS

The paper presented results on coplanar waveguides on AlN. These waveguides need to have signal lines with a large metal cross section in order to withstand the large currents that flow for instance in the output stage of an amplifier. It was shown that CPWs with very large signal-to- ground spacing's or large signal line widths (or both) showed non-quasi-TEM behavior related to propagation of parallel plate modes. It was shown that the influence of this mode decreases with increasing substrate thickness, as expected. In the quasi-TEM regime CPWs can be realized with characteristic impedances in the range of 30-120 with an inductance up to 0.9 nH/mm.

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