Abstract

This work aims to choose a material, design, fabricate and characterize thin-film resistors that are as linear and time-invariant as possible, offering a low resistance, for developing on the InP-based circuits technology up to 500 GHz.

A wide range of theoretical studies about the electrical properties of semicon- ductors and metals as resistors was done to achieve this goal. After carrying out the comparison, high n-doped InGaAs came out as one of the best options for this purpose among the semiconductors because of its high doping density; it offers rel- atively high conductivity. It also offers a relatively low-temperature dependency in comparison to other semiconductors. In the case of metals, NiCr was chosen, which provides even higher conductivity and even lower temperature dependency when compared to semiconductors.

A design was carried out with the help of High Frequency Simulation Software from Ansys for both material choices and embedded in a coplanar waveguide struc- ture. This simulation used a wave port and a lumped port as excitations. Also, OPEN and SHORT calibration standards were designed to validate the GSG 3D model used for the purpose of the future de-embedding process.

For this work, InGaAs-based resistors were fabricated using epitaxial growth. In order to fabricate a resistor with better properties, NiCr was looked into, using the physical vapor deposition fabrication technique available in the BHE department. As part of the development process, a technology for in-situ control of the conductivity of the vapor-deposited NiCr layers was created, consisting of a Python script and

a Keithley multimeter connected to the reference sample. This technique provided real-time monitoring of the deposited NiCr alloy on the sample.

The process started with evaporations using a bare tungsten filament as a heater, which offers high-temperature resistance as well as a high melting point. The fil- ament was destroyed, showing an intermetallic mixing with the source material. Afterward, two different passivation layers were used, but they offered no further improvement regarding the interaction problem, although the source material (NiCr alloy) was evaporated. Extra research was conducted deeply to find alternative methods to improve the process due to the massive challenges of fabricating NiCr- based thin film resistors using the thermal evaporation technique, and boron-nitride crucibles were used. On the one hand, boron-nitride provides no chemical interac- tions with the source material, and on the other hand, because its thermal conduc- tivity is so high, it can be efficiently heated without risk of evaporation. However, as it is an electrical insulator, it requires an additional heater that could not survive the high temperatures during the evaporation process and was destroyed, yielding no successful evaporations. Options for further improvement are modifying the evapo- ration parameters using multiple experimental runs with coated tungsten filaments or using a feeding system during the evaporation. Another option is replacing the glass reference sample with a different material or size. Nevertheless, coated and bare tungsten offered the best results, producing two NiCr samples used for further characterization of the resistors.

Characterization was divided into two parts: DC and RF for both NiCr and InGaAs resistors. In the DC characterization, we separated the contact and sheet resistance very precisely for InGaAs and NiCr. a measured temperature dependence was developed, which confirmed a very low thermal coefficient for NiCr.

Both materials are possible choices for designing a resistor for THz applications. NiCr offers higher thermal stability, but it needs further investigation regarding possible oxidation. For this reason, it is easier to use InGaAs at this moment.

RF characterization from 50 MHz until 67 GHz was conducted for both ma- terials. For InGaAs, it was successfully characterized with the help of OSM and de-embedding process, but in the case of NiCr, because the OPEN SHORT struc- tures of CPW were not available on the samples, an additional version of OPEN

SHORT structures was designed via EM simulation for de-embedding. These results could be improved with suitable GSG structures. The off-site on-wafer RF measure- ments for the frequency range up to 500 GHz using mTRL as calibration procedure resulted in less parasitic inductance in serie, between 4 *pH* and 2.5 *pH*, and more stable resistance results. At the end of this work, these results are available for InGaAs up to 500 GHz.