A Novel System for Systematic Microwave Noise and DC Characterization of Terahertz Schottky Diodes

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***Abstract*—An automated system is developed to evaluate a large number Schottky diodes for terahertz applications with respect to their dc and noise characteristics using a highly sensitive noise measurement technique for one port devices. An extensive RF switching matrix allows noise characterization of one port devices at selected frequency points over a bandwidth from 2 to 8 GHz. The measurement principle also accounts for the impedance mismatch between the system and the device under test (DUT). Furthermore, the setup includes an automated three-axis nanopositioning system capable of consecutively contacting many Schottky diodes arranged in a honeycomb array. The highly accurate positioning of the DUT allows to create reproducible contacts with the diodes using electrochemically etched whisker tips. The smooth contacting procedure enables several hundred contacts with the same whisker tip. With this system, we evaluate the statistical distribution of dc and noise parameters of Schottky diodes with an anode diameter of 1 μm within one honeycomb chip. The system helps in optimizing the production parameters of Schottky diodes for terahertz frequencies.**

***Index Terms*—Terahertz (THz), Schottky diodes, noise.**

I. Introduction

FOR FREQUENCIES exceeding 1 THz, the development of Schottky diodes with submicron diameter has become an important issue. One of the most critical parameters of these diodes is their junction capacitance, which has to be in the femto-Farad range in order to make the diode an effective mixing element. The diode size must be reduced in order to keep the junction area as small as possible [1]. Diodes for frequencies between 500 and 1000 GHz usually have diameters in the range from 0.8–1.2 μm and capacitances in the fF range. Higher frequencies require anode diameters in the 0.5–0.25-μm range [2], [3]. These diodes are usually arranged in a honeycomb array as shown in Fig. 1. The diodes in a honeycomb structure have a common cathode on the rear side, while the circular anodes are structured on the front side with a Pt-GaAs Schottky contact which is covered by a thin layer of gold. The anodes are etched into the SiON passivation layer so that small holes of about 300 nm in depth are created to guide the whisker tips. The anodes are contacted with electrochemically etched whisker tips.

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Pushing the upper limit for these devices toward higher frequencies is inevitably connected with reducing the diode size. This mainly causes three different problems. The production of the diodes has to be optimized for very small anode diameters in order to achieve diodes with acceptable mixer performance. The excess noise [4], [5] emitted from the diodes increases with increasing current density and contributes the major part to the overall noise [6] of the diode. Contacting diodes with anode diameters of 0.5 μm or less becomes increasingly difficult.

In order to optimize the production parameters of the Schottky diodes for minimum noise and ideal dc characteristics, a systematical evaluation of these parameters is needed. Although earlier studies have investigated these parameters, no data is available on the statistical distribution of the quality of Schottky diodes within one honeycomb array. The contacting procedure in a real terahertz-mixer system does not allow to choose a specially selected diode. Usually, the whisker is blindly placed somewhere on the chip enabling an electric contact with a randomly chosen diode. Considering this procedure, it becomes even more important to get insight into the statistical variations of diode parameters within one chip, instead of characterizing only a few randomly chosen devices.

The system introduced here combines sensitive noise characterization at IF frequencies with dc measurements and accurate nanopositioning. The three-axis positioning system moves the diode samples relative to the whisker tips and contacts one diode after another. To our knowledge, this is the first system capable of automatically contacting Schottky diodes with anode diameters as small as 1 μm and measuring their dc and noise parameters at selected frequency points distributed over a bandwidth of more than one octave. The whole contacting and measurement procedure is fully automated and all instruments are controlled from one computer. The positioning unit can be moved with a minimum step width of 50 nm. The very carefully controlled contacting procedure makes it possible to use the same whisker tip for contacting many hundred diodes.

II. Theory of Noise Measurement

As opposed to two-port devices such as amplifiers, whisker contacted diodes are one-port devices which can not be characterized with the well-known Y factor method. We, therefore, present an extended theoretical derivation of a measurement method proposed by [7]. The basic circuit diagram is shown in Fig. 2. The noise of an electronic noise source (NS) is coupled