Optimization of the profile and material of wire contacts for an IR photodetector

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Abstract. The study is devoted to the influence of the choice of geometry and materials of wire contacts on the reflection coefficient and thermal characteristics of the photodetector and the quality of the device design. The process of diffusion of materials of wire contacts and contact pads on a photodetector crystal is investigated. The studies were carried out on samples that are rather small in size (250x250x400 µm). During the experiment, 4 main types of loop geometry were selected (main loop, reverse loop, double reverse loop, long loop). The loops were formed using a gold wire 25 µm in diameter. The quality of microwelds was investigated in 3 ways: shear and pull-off tests, optical observation using a scanning electron microscope (SEM), and contact resistance measurement. The aim of the work is to create a high-quality design of an IR photodetector, which allows achieving a high sensitivity (at least 0.5 A / W), a large dynamic range (at least 40 dB) and low indicators of dark current values. The developed technology ensures high quality of the photodetector design. Due to the low costs of this technological process (wire material, the number of operations required for installation), relative to other technologies, which allows maintaining high performance in the technical component of the photodetector, the installation method may be of practical interest in production.

1. Introduction
Microwave (MW) photonics is a rapidly developing area of high-speed communication systems with a spectral range of 1.3–1.55 µm. One of the key components of radiophotonics is high-speed photodetectors.[2] Many radio-photon systems today use PIN-type photodiodes. The desirable characteristics of photodetectors are high sensitivity, wide dynamic range and large bandwidth, but in practice these parameters cannot be achieved simultaneously due to the physical foundations of the photodiode operation and design solutions. It should be noted that in terms of designs and evolving technologies that allow compromise solutions to achieve high bandwidth and high operating power, there are a large number of solutions. Optimization of technologies for creating a photodetector design is one of the main solutions to ensure high technical characteristics of the device.

2. Description of the model
For the study, 4 types of loop geometry were formed on a TPT HB16 semi-automatic microwelding unit. Micro-welds were formed using ultrasonic vibrations. The qualities of the "ball-wedge" microwelding were investigated. Figures 1, 2 show 2 types of formed geometric loops used to create a photodetector.
Figure 1. (a) – Loop menu formation parameters; (b) – diagram of the loop geometry and the direction of movement of the tool.

Figure 2. (a) – Reverse loop formation parameters, (b) - a diagram of the loop geometry and the direction of the tool movement.

Figure 3 shows a series of successful microweldings of 4 types of loop geometry.

Figure 3. Series of microweldings with different loop geometries: (a) – base loop, (b) – reverse loop, (c) – double reverse loop, (d) – long loop.
3. Results and discussion

Three main research methods are used to analyze the quality of a structure: shear test, optical observation with a scanning electron microscope and contact resistance measurement.

The study according to the first method was carried out using a special tester, on which a force of 0.03 grams was set. The quality hinge profile describes the break at the center of the wire connection. As a result of testing, we obtained 80% of the loops with a wire break in the center.[1]

Figure 4 shows the compounds tested in SEM. An analysis of the diffusion process of the first and second points of microwelding was carried out.

![Figure 4. Examples of connections of two points of microwelding a ball and a wedge.](image)

As a result of the research, it was revealed that a high-quality design solution for creating photodetector components in the IR range is the choice of the basic geometry of the loop, which slightly exceeds the dimensions of the photodetector crystal. Table 1 shows the parameters and test results of the practical part of the study.

| Technological process number | First microwelding point | Second point of microwelding | Test result |
|------------------------------|--------------------------|-----------------------------|-------------|
|                              | Ultrasound Time Clamping | Ultrasound Time Clamping    |             |
| 1                            | 180 180 200             | 180 200 200                 | separation of the wedge (second point of microwelding) |
| 2                            | 200 180 200             | 200 200 200                 |             |
| 3                            | 220 180 220             | 200 200 200                 | separation of the wedge 50 % |
| 4                            | 220 180 220             | 220 200 220                 |             |
| 5                            | 220 180 220             | 220 200 220                 |             |
| 6                            | 220 180 220             | 220 200 240                 | break in the center of the wire connection |

We considered the contribution of wire bonding, microstrip discontinuities and microstrip-coaxial junction for accurate modelling of reflection coefficient of the matched and biased PD chips. The layout of the PCBs was optimized to minimize reflection coefficient from the PD output. The critical parameters for high-frequency operation were wire-bonding length.

In figure 5 shows the reflection coefficient R from the MB. In the figure, we see a matched board-todie design with bandwidth up to 20 GHz.
Figure 5. Reflectance value of a board without a crystal and a board with a crystal. After mounting the crystal on the board, the indicator changed by 0.5 dB. Changes up to 3 dB are allowed.

4. Conclusion
Thus, optimization of design solutions (formation of certain wire profiles and material selection), optimization of technological solutions in the process of mounting wire contacts made it possible to create a better design of a photodetector from a structural point of view (analysis of the diffusion process of materials, creation of a consistent design) and technical (achieving a reflection coefficient below -10 dB).

References
[1] Harman G Wire bonding in microelectronics. Third edition. McGraw Hill. 2010
[2] Kurushin A A Solution of multiphysics microwave problems using CAD COMSOL-M., One-Book, 2016. 376 pages.