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Features Of The Wedge Welding Process In Microelectronics On The FEK Delvotec 6400

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Abstract — **The paper examines the features of the wedge welding process in microelectronics on the FEK Delvotec 6400 installation and analyzes the main stages of forming wire interconnections between contact pads of electronic components. The principles of automatic positioning, forming welded contacts and quality control of connections are studied, and the main technological parameters that affect the reliability and durability of microelectronic products are determined. The results obtained confirm the effectiveness of using the FEK Delvotec 6400 for high-precision automated wedge welding in modern microelectronic production.**

Keywords — wedge welding, FEK Delvotec 6400, microelectronics, wire bonding, wire interconnections, CCD alignment, ultrasonic welding, contact pad, process automation

I. INTRODUCTION

Modern microelectronics is characterized by a constant decrease in the size of components and an increase in the density of electronic assemblies, which places increased demands on interconnection formation technologies. [1,2] One of the most common methods of creating electrical contacts between the crystal of a semiconductor device and the leads of the case is wedge bonding. [3,4] This technology is widely used in the manufacture of integrated circuits, power electronics, sensor modules, hybrid microcircuits and special-purpose electronic devices. [5,6]

The relevance of the study is due to the need to improve the quality and reliability of wire connections, since even minor deviations in welding parameters can lead to defects, deterioration of electrical characteristics and a decrease in the product's service life. Modern automatic microwelding installations, in particular the FEK Delvotec 6400, provide high positioning accuracy and control of technological parameters, which allows for a stable process of forming interconnections in the production of microelectronic components. [7,8]

Let's analyze the latest publications within the framework of research on the wedge welding process in microelectronics on the FEK Delvotec 6400.

In the work of Groth A. and Hempel M., the influence of related technological operations on the quality of wire connections is investigated and an approach to the analysis of the degradation of wire bond contacts after ultrasonic welding of other elements of an electronic product is proposed. The authors established the relationship between the parameters of ultrasonic exposure and the decrease in the mechanical strength of already formed interconnections, which allows for timely detection of hidden defects and increased reliability of electronic modules [9]. But from the point of view of researching the features of the wedge welding process in microelectronics on the FEK Delvotec 6400, this approach cannot be directly used as the main research method, since it is focused mainly on analyzing the consequences of the influence of adjacent technological operations after the completion of the welding process and does not consider the features of automatic positioning, wire loop formation, wedge welding parameter control and the functioning of the CCD+PRU system, which are key components of the FEK Delvotec 6400 technological process. In the article, Song Y., Wang Z., Yi J., Tang S. and Luo J. investigated the current state of development of interconnection technologies for power semiconductor devices and developed a comprehensive review of promising solutions, including wire bonding, ribbon bonding, sintering technologies and new approaches to creating highly reliable electrical contacts. The approach proposed by the authors makes it possible to assess the prospects for the development of interconnection technologies for power electronics, increase thermal efficiency and ensure higher reliability of new generation electronic modules [10]. However, this approach cannot be used directly, as the work is mainly of an overview nature and considers a wide range of interconnection technologies without a detailed analysis of the welding head kinematics, automatic alignment algorithms, contact formation sequence, and control parameters of a specific FEK Delvotec 6400 installation.

In the study Meshki Zadeh P., Brand S. and Dehghan-Niri E. modern methods for assessing the structural integrity of microelectronic housings using Scanning Acoustic Microscopy (SAM) technology were investigated and a systematic approach to detecting internal defects, delaminations, cracks and hidden damage in microelectronic components was proposed. This method makes it possible to perform non-destructive quality control of finished products and increase the reliability of assessing the reliability of electronic modules at different stages of the life cycle [11]. However, within the framework of these studies, the proposed approach cannot be used as the main tool for analyzing the technological process, since it is focused on post-operational control of the structural integrity of products and does not take into account the parameters of the direct formation of the welded joint, ultrasonic exposure modes, wedge tool motion trajectories and welding process control algorithms.

Thus, the analysis of the presented publications showed that modern research is focused mainly on issues of reliability of interconnections, development of promising technologies of electronic assembly and methods of non-destructive quality control of finished products. At the same time, insufficient attention is paid to the comprehensive study of the direct technological process of wedge welding on automated installations of the FEK Delvotec 6400 type, including issues of automatic positioning, control of welding parameters and digital support of the production process, which confirms the relevance and practical significance of further research in this direction.

II. ANALYSIS OF THE WEDGE WELDING PROCESS IN MICROELECTRONICS ON FEK DELVOTEC 6400

Wedge welding is a type of thermocompression or ultrasonic welding in which a metal wire (gold, aluminum, or copper) is pressed against the contact pad using a special tool – a wedge. [12] The formation of the welded contact occurs under the influence of mechanical pressure, ultrasonic vibrations and, if necessary, local heating. The general scheme of the wedge welding process is shown in Fig. 1.

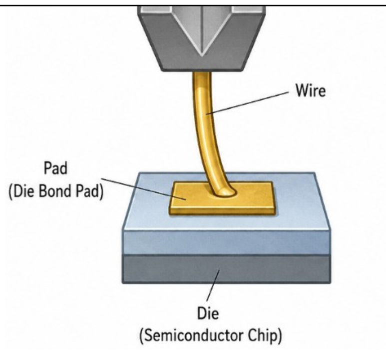

Fig.1 - Forming the first welded contact

The first stage involves welding the wire to the crystal contact pad. After forming the first contact, the system moves the tool to the second connection point, forming a wire loop of the required geometry. [13] Next, a second contact is formed on the housing lead or another contact pad. The interconnection formation scheme is shown in Fig. 2.

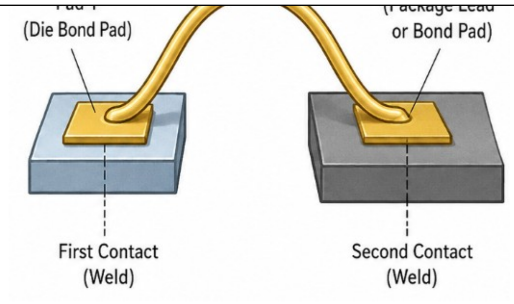

Fig.2 - Forming a wired interconnection

The FEK Delvotec 6400 installation is equipped with a high-precision X-Y-Z-P coordinate positioning system, a digital process control system and a machine vision module based on a CCD camera. Before welding, the system performs automatic recognition of the product reference marks and correction of the work program coordinates, which ensures high accuracy of tool guidance to the contact pads. [14]

The general structure of the welding process on the FEK Delvotec 6400 is presented in Fig. 3.

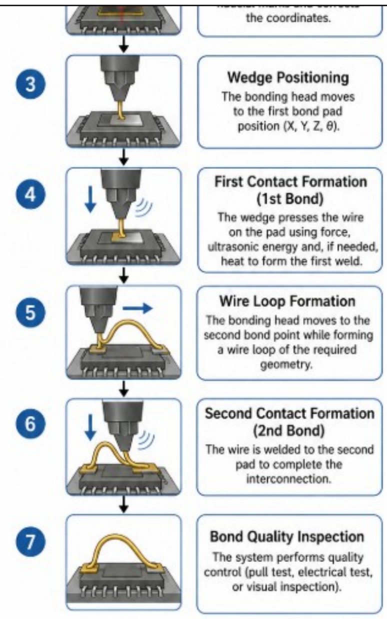

Fig.3 - General structure of the welding process on the FEK Delvotec 6400

Let us describe the purpose of each step of the welding process on the FEK Delvotec 6400: [15,16]

Step 1. Loading the welding program - at this stage, a technological program is loaded into the FEK Delvotec 6400 control system, which contains the coordinates of the welding points, wire parameters and modes of wedge welding operations.

Step 2. Automatic alignment (CCD + PRU) - the vision system uses a CCD camera to search for reference marks on the product, determine their actual position and automatically correct the coordinates of the work program to ensure high positioning accuracy.

Step 3. Wedge positioning - the welding head automatically moves to the specified coordinate of the first contact area and sets the wedge tool in the required working position relative to the surface of the product.

Step 4. Formation of the first contact - the wedge tool presses the wire to the contact pad and, under the action of mechanical force, ultrasonic vibrations and technological heating, forms the first reliable metal connection.

Step 5. Formation of the wire loop - after creating the first contact, the welding head moves to the second welding point, simultaneously forming a wire loop of the specified geometry and height in accordance with the requirements of the technological process.

Step 6. Formation of the second contact - the wedge tool welds the wire to the second contact pad, completing the creation of an electrical interconnection between two points of the product.

Step 7. Connection quality control - after welding is completed, the system checks the quality of the formed connection by visual inspection and analysis of the compliance of geometric and technological parameters with the established requirements.

The main technological parameters of the process are the tool pressing force, power and duration of ultrasonic exposure, loop height, head movement speed, geometric parameters of the wire and material of the contact surfaces. The optimal selection of these parameters directly affects the strength of the connection, the electrical resistance of the contact and the durability of the product. To ensure process stability, the FEK Delvotec 6400 allows you to programmatically set and control all of these parameters for each individual connection. [17-19]

Conclusion

As a result of the conducted research, the features of the wedge welding process in microelectronics on the FEK Delvotec 6400 installation were analyzed and the main technological stages of forming wire interconnections, which ensure high quality electrical contacts, were determined. It was established that the use of the X-Y-Z-P automatic positioning system and machine vision based on a CCD camera allows to increase the accuracy of tool guidance and reduce the likelihood of defects during welding. It was shown that the optimal choice of parameters of ultrasonic influence, pressing force and geometry of the wire loop directly affects the mechanical strength and durability of the formed connections. The results obtained confirm the effectiveness of using the FEK Delvotec 6400 for automated production of modern microelectronic components and create the basis for further development of a digital twin of the wedge welding process.

References

[1] Luo, Z., Wang, X., Li, Y., Zhou, P., Chen, L., Bai, C., ... & Ji, H. (2026). Optimization and reliability of ultrasonic wedge bonding performance of copper wires on gold pads for MEMS devices. Microelectronics Reliability, 176, 115971. https://doi.org/10.1016/j.microrel.2025.115971

[2] Kahatapitiya, N. S., Saleah, S. A., Seong, D., Ravichandran, N. K., Han, S., Wijesinghe, R. E., ... & Kim, J. (2026). Optical Coherence Tomography for High-Precision Industrial Inspection in Industry 4.0: Advances, Challenges, and Future Trends. Laser & Photonics Reviews, 20(8), e02290. https://doi.org/10.1002/lpor.202502290

[3] Guan, R., Li, H., Ni, W., Huang, T., Wang, K., & Han, X. (2026). Kissing Bond Damage Identification and Evaluation in CFRP-Reinforced Steel Plates Using Mixed-Frequency Ultrasonic Guided Waves. Sensors, 26(5), 1531. https://doi.org/10.3390/s26051531

[4] Buchner, C., Riedle, B., Seidler, C. T., Huber, M. F., Eigenbrod, H., Von Ribbeck, H. G., & Schlicht, F. (2026). Comparing few-shot learning methods in various application scenarios for quality prediction in ultrasonic wire bonding. The International Journal of Advanced Manufacturing Technology, 1-19. https://doi.org/10.1007/s00170-025-17356-z

[5] Chu, C., Mou, J., Zhang, H., & Ding, J. (2026). Recent Advances in Green and Intelligent Electrochemical Sensing System for Environmental Monitoring. Advanced Sustainable Systems, 10(5), e70485. https://doi.org/10.1002/adsu.70485

[6] Wang, K., Xiao, S., Chen, P., Ji, X., Yan, C., Zhou, R., ... & Xu, W. (2026). VoltSiren: Exploiting Power Supply Vulnerabilities to Control IoT Devices. IEEE Internet of Things Journal. https://doi.org/10.1109/JIOT.2026.3667971

[7] Nevliudov I., Yevsieiev V., Horovyi K. Analysis of the FEK Delvotec 6400 Wedge Bonding System // Débats scientifiques et orientations prospectives du développement scientifique: c avec des matériaux de la X conférence scientifique et pratique internationale, Paris, 5 juin 2026. P. 89-92. https://doi.org/10.36074/logos-05.06.2026

[8] Nevliudov I., Yevsieiev V., Horovyi K. Analysis of the Technological Process of Wedge Bonding Using FEK Delvotec 6400 in Microelectronics // Current scientific goals, approaches and challenges: Collection of Scientific Papers «SCIENTIA» with Proceedings of the VI International Scientific and Theoretical Conference, June 5, 2026. Dresden, Federal Republic of Germany: International Center of Scientific Research. P. 117-119. https://doi.org/10.36074/scientia-05.06.2026

[9] Groth, A., & Hempel, M. (2025). Cross-Correlation of Interconnection Technologies—A Case Study of Reduced Wire Bond Quality after Ultrasonic Welding. Journal of Materials Engineering and Performance, 34(6), 4546-4554. https://doi.org/10.1007/s11665-024-10313-z

[10] Song, Y., Wang, Z., Yi, J., Tang, S., & Luo, J. (2025, May). Research Process and Prospects of Power Device Interconnection Technology. In 2025 8th International Conference on Electronics Technology (ICET) (pp. 226-236). IEEE. https://doi.org/10.1109/ICET64964.2025.11102947

[11] Meshki Zadeh, P., Brand, S., & Dehghan-Niri, E. (2025). Recent Progress in Structural Integrity Evaluation of Microelectronic Packaging Using Scanning Acoustic Microscopy (SAM): A Review. Sensors, 25(24), 7499. https://doi.org/10.3390/s25247499

[12] Nadaf, H., Nabavi, S. F., & Farshidianfar, A. (2026). A comprehensive review of laser wobble welding for aerospace applications: materials, characteristics, and case studies. Advances in Materials and Processing Technologies, 12(2), 369-428. https://doi.org/10.1080/2374068X.2026.2630784

[13] Yang, L., Wang, Z., & Hu, X. (2026). Optical Transceiver Microsystem Based on Digital Prototyping and Optoelectronic Collaborative Simulation. International Journal of Optics, 2026(1), 9947711. https://doi.org/10.1155/ijo/9947711

[14] Yao, J., Zhou, H., Cao, J., Gao, X., Zhong, S., Dong, X., ... & Persic, J. Study on Bonding Performance of Palladium-Coated Copper Wires with Different Palladium Layer Thicknesses. Available at SSRN 6386070. https://dx.doi.org/10.2139/ssrn.6386070

[15] Al Sarraf, Z. S., & Younis, A. D. (2026). Investigation on the Mechanical Properties of Various Welded Materials by Ultrasonic Welding Technique–A Review. Journal of Applied Engineering Sciences, 16(1), 91. https://dx.doi.org/10.2478/jaes-2026-0012

[16] Rong, Y., Wang, Y., Deng, J., Li, W., Yang, L., Zhao, C., ... & Yao, J. (2026). Interfacial Bonding and Fracture Mechanism of Tempered Glass and Aluminium Alloy Direct Welding by Top-hat Nanosecond Laser. Ceramics International. https://doi.org/10.1016/j.ceramint.2026.01.037

[17] Nevliudov I., Yevsieiev V., Horovyi K. Model of the Technological Process of Wedge Bonding Based on FEK Delvotec 6400 in the Production of Hybrid Electronic Modules // In Proceedings of the XII International Scientific and Theoretical Conference, June 12, 2026. Chicago, USA: International Center of Scientific Research. P. 170-173. https://doi.org/10.36074/scientia-12.06.2026

[18] Yevsieiev V. Digital Twin in Modeling and Control of Collaborative Robots: Analysis, Comparison and Application Recommendations / V. Yevsieiev, S. Starikova // Computer-integrated technologies, automation and robotics 2026 : Proceedings of III st All-Ukrainian Conference, May 14-15, 2026. - Kharkiv .: [electronic version], 2026. - P. 89-92.

[19] Yevsieiev V. Evolution of approaches to intelligent microclimate control in industrial environments: A review of models for cyber-physical systems / V. Yevsieiev, I. Holod // Відкриті інформаційні та комп'ютерні інтегровані технології. – 2026. - № 107. – С. 104-122. https://doi.org/10.32620/oikit.2026.107.07