Advanced Microelectronic Packaging and Fiber Optics Technologies for the Military, Defense & Security Industries

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Abstract

As modern military systems become increasingly compact, autonomous, and software-driven, the need for robust microelectronic integration and secure optical communication grows exponentially. In this context, advanced microelectronic packaging, fiber optic technologies and DIE bonding are no longer optional, because they are mission critical. At Tresky GmbH, we specialize in providing state-of-the-art DIE Bonder solutions and manufacturing services that cater to the unique needs of these sectors.

The importance of DIE Bonding and Advanced Microelectronic Packaging for defense

In the modern defense industry, highly specialized electronics are the backbone of almost all military platforms, from fighter aircraft and drones to guided missiles, sensor and communication systems and portable soldier systems. A key technology in the manufacturing of these high-performance electronics is DIE bonding, i.e. the precise and permanent connection of bare semiconductor chips (“DIEs”) with carrier substrates, printed circuit boards or housings. This connection must be mechanically stable, thermally conductive and electrically reliable, especially under the extreme operating conditions of military systems.

The performance of electronic components is non-negotiable. Military systems often operate in extreme conditions, including high temperatures, humidity, and mechanical stress. DIE Bonding technologies, such as thermocompression bonding, epoxy bonding, eutectic bonding and sintering, are employed to create robust connections that can withstand these harsh environments. The choice of bonding method can significantly impact the thermal performance and overall reliability of the packaged device.

DIE Bonders from Tresky Automation are designed to deliver precision and efficiency in the bonding process, ensuring that components are securely attached and function optimally under extreme conditions. This capability is vital for applications ranging from communication systems to weaponry, where any failure could have significant consequences.

DIE Bonding: Highest reliability and outstanding performance under extreme operating conditions

Military applications are characterized by high requirements, such as extreme temperatures, strong vibrations, constant pressure changes and electromagnetic influences, which place enormous stress on electronic assemblies. This is where the special importance of DIE bonding comes into play. Depending on the application and environmental conditions, different materials are used for high-temperature-resistant eutectic connections, silver sinter pastes for high-performance components with high thermal conductivity applications. In all cases, the connection must be mechanically stable, durable and thermally efficient, especially in

safety-critical systems such as active protection systems, navigation computers or flight control units.

High-performance components, including power amplifiers, radar modules, and laser systems, produce significant amounts of heat during their operation. This heat generation is a critical concern, as excessive heat can lead to overheating and potential failures of these components. To ensure reliable performance and longevity, it is essential to dissipate this heat efficiently.

One effective method for heat dissipation involves transferring the heat directly from the semiconductor through the die-attach connection. This connection can be made on thermally conductive substrates, such as aluminum nitride or copper, which are known for their excellent thermal management properties.

In addition, the use of advanced materials like silver sinter pastes enhancing thermal conductivity. These materials can achieve thermal conductivities exceeding 200 to 250 W/mK, making them particularly well-suited for high-performance military systems where reliability and efficiency are paramount. By utilizing such high-conductivity materials, the thermal management of these components can be significantly improved, thereby reducing the risk of overheating and ensuring optimal performance in demanding applications.

DIE bonding plays a major role in the miniaturization of modern defense electronics, enabling the development of advanced systems that require both high functionality and compact design. In applications such as Unmanned Aerial Vehicles (UAVs), guided missiles, portable radios and soldier assistance systems, there is an increasing demand for maximum performance within the smallest possible footprint. This need for miniaturization drives the adoption of innovative assembly technologies, such as direct chip assembly, which eliminates the need for traditional housing technologies.

Through packaging technologies like chip-on-board (CoB) and system-in-package (SiP), manufacturers can create compact, highly integrated assemblies that combine multiple functionalities into a single module. For instance, bonding technology facilitates the integration of several DIEs (semiconductor chips) into one cohesive unit, allowing for efficient signal processing, communication, and power supply management, all within a space-optimized design. This integration not only saves physical space but also enhances the overall performance and reliability of the systems.

Moreover, DIE bonding is critically important in high-frequency and radar applications, where systems are designed to operate in the GHz frequency range. These applications, which include reconnaissance, target tracking, and electronic warfare, impose stringent requirements on electrical performance, signal integrity, and the minimization of parasitic effects. To meet these demands, precision in the micrometer range is essential when positioning the DIEs. The use of specialized substrate materials further aids in reducing signal losses, ensuring that the systems function optimally.

In particular, the quality of the DIE-attach connection is vital in radar systems equipped with Active Electronically Scanned Arrays (AESA), transmit-receive modules, and satellite communication units. Any deficiencies in the bonding process can lead to significant

performance degradation, affecting the system's ability to accurately process and transmit signals. Therefore, ensuring a robust and reliable DIE bonding process is crucial for the overall effectiveness and efficiency of modern defense electronics, enabling them to meet the rigorous demands of contemporary military operations.

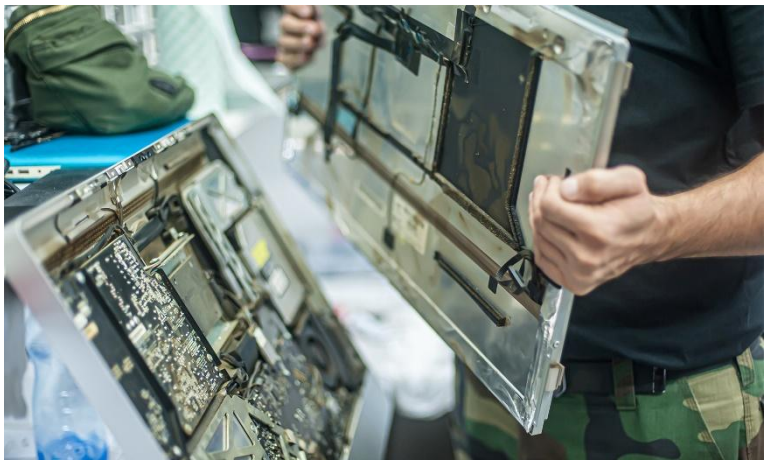

Figure 1: The DIE bonding process is crucial for modern defense electronics

In addition to all these technical requirements, DIE bonding in military electronics production is also subject to strict standards and testing processes. Standards such as MIL-STD-883[1] or ECSS[2] demand maximum reliability and long-term stability. Each individual bond is tested using X-ray inspection, shear strength test or thermocycling, among other things, to practically rule out failures during use. Compliance with these standards is of vital importance, especially in safety-critical applications such as ignition modules, fire control computers or communication interfaces.

For this reason, DIE bonding must be of the highest quality, which is why special systems such as DIE bonders from Tresky are used. Furthermore, these processes are constantly evolving, which is why the expert and process knowledge of these machine manufacturers is indispensable for a reliable DIE bonding process in the defense industry.

In total, DIE bonding is far more than just a production step. The process is a central component of modern military electronics and plays a key role in determining the performance, compactness, robustness and service life of systems that must function under the most extreme conditions. Without these reliable processes, many of today's advanced defense products, from radar-guided missiles to compact drone platforms, could not be realized.

[1] The MIL-STD-883 standard establishes uniform methods, controls, and procedures for testing microelectronic components suitable for use in military and aerospace electronic systems. It also defines basic environmental tests to determine resistance to the damaging effects of natural elements and conditions for military and aerospace operations. In addition, the standard specifies which mechanical and electrical tests, processing and training procedures and other controls and limitations are deemed necessary. The aim is to ensure a uniform level of quality and reliability suitable for the intended applications of these components.

[2] The European Cooperation for Space Standardization (ECSS) is an initiative founded in 1993 by ESA, national space agencies and the space industry. One of its aims was to create uniform standards for European space travel. The standards published by the ECSS cover the topics of project management (with the various project phases), product assurance, space technology and sustainability for space projects.

DIE Bonding from Tresky: A wide range of advantages for specific defense applications

1. Reliability under extreme conditions

Armament products such as fighter jets, missiles and submarines are exposed to extreme temperatures, vibrations, pressure differences and electromagnetic stress. DIE bonding ensures a thermally and mechanically stable connection between the chip and the carrier, which guarantees long-lasting function even under extreme conditions.

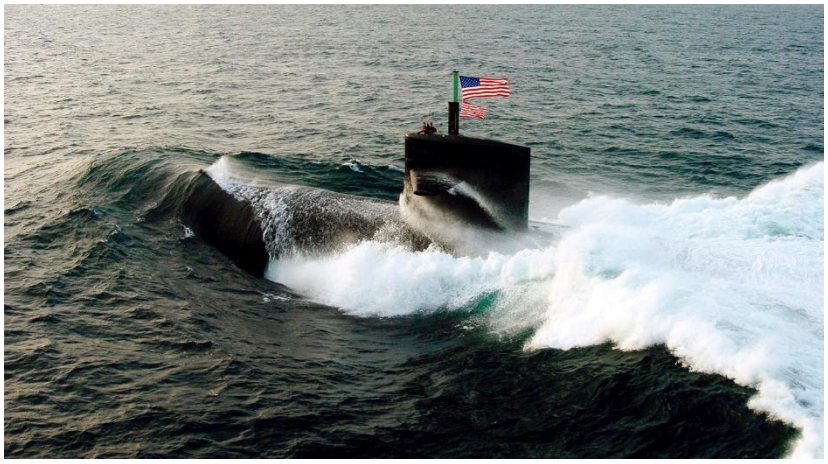

Figure 2: Submarines, for example, are exposed to extreme temperatures, pressure and extreme conditions

2. Miniaturization and high integration density

Modern military systems require compact, highly integrated electronics, for example in missiles, drones or portable soldier systems. DIE bonding enables the direct attachment of semiconductor chips to substrates without conventional packaging, which reduces size and improves system performance.

3. Thermal management

High-performance components, such as those used in radar and communication systems, generate large amounts of heat. Heat can be efficiently dissipated from the chip using suitable DIE attach materials (e.g. silver or epoxy-based). This is a decisive factor for the service life and functional reliability of military electronics.

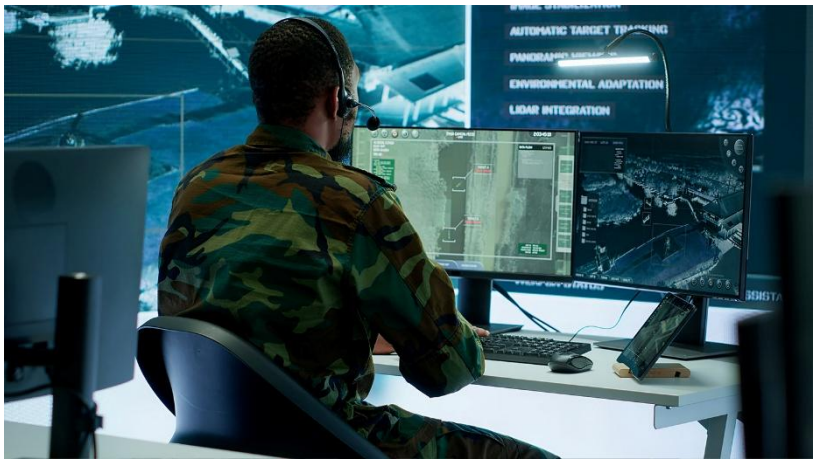

Figure 3: DIE-Attach materials can efficiently dissipate heat from the chip so that radar and communication system, for example, can operate for a long time without malfunctions

4. Applications for high-frequency and radar systems

Microwave and millimeter wave technologies are used particularly in electronic warfare, communications and reconnaissance. These require precisely positioned and permanently installed chips in which DIE bonding not only contributes to fastening, but also to ensuring electrical performance (impedance, attenuation).

Figure 5: AWACS reconnaissance aircraft primarily use microwave radar technologies for air surveillance, target tracking and early warning

5. Integration in power electronics and drive systems

Power semiconductors play a central role in electronically controlled drive systems for tanks and other systems. DIE bonding ensures the safe assembly of these components and guarantees the necessary current carrying capacity and temperature resistance.

6. High reliability for safety-critical systems

Many military applications are safety critical. Failures are not an option. Assemblies manufactured using DIE Bonding can be subjected to rigorous testing and inspection procedures, such as X-ray, thermography and shear strength testing, to ensure maximum reliability.

Contract Manufacturing Hub: For reliable prototyping and small series production

In the prototyping phase, when producing small series or batch size 1, many companies, even in the defense industry, hesitate to invest in their own DIE-Bonder. Often the final design process has not yet been completed, so that downstream changes to the product or even the manufacturing processes are possible.

Nevertheless, there is often a desire to have these prototypes and small series produced as quickly as possible and without any loss of quality. With a great deal of technical know-how and many years of experience, Tresky can take over the production of prototypes and small series for you from the first piece onwards on our systems.

Tresky has access to the following processes in its Contract Manufacturing Hub:

- DIE Attach for precise attachment of semiconductor chips
- Eutectic Bonding for robust and durable connections
- Ultrasonic Bonding for efficient connections with high strength
- Sintering for superior material properties through high-temperature processes for power electronics
- Flip Chip Bonding for direct connections for improved electrical performance
- Epoxy Bonding for versatile adhesive connections for various applications
- DIE Sorting for reliable classification and selection of semiconductor chips

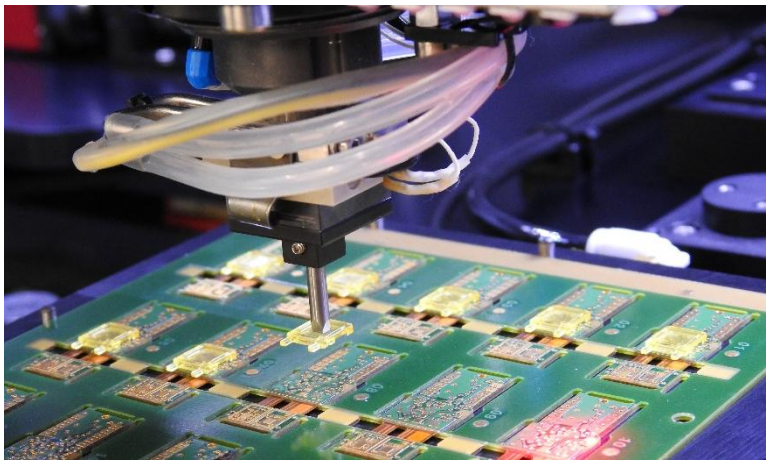

Figure 1: DIE Attach is a central process in the manufacture of high-performance electronics

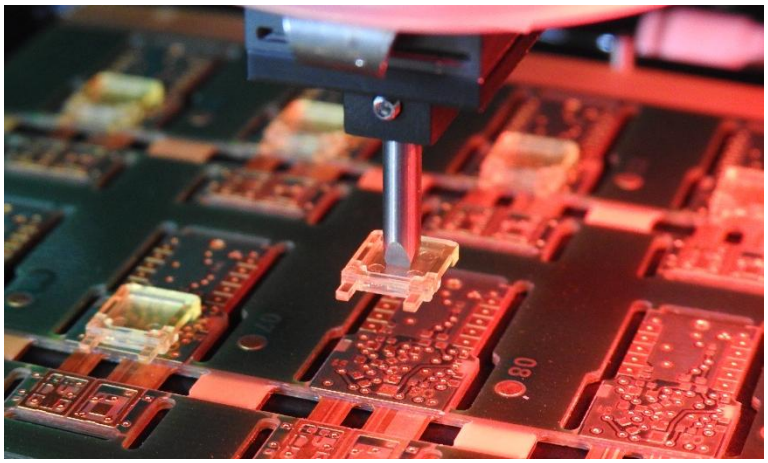

Figure 2: DIE Attach is important for electrical functionality as well as thermal and mechanical stability

Fiber Optics Technologies: Indispensable component of modern defense systems

Fiber optic technologies play a central role in the development and operation of modern armament products. Their ability to transmit large amounts of data in real time and at high speed makes them particularly valuable for networked battlefields and highly complex military systems. In communication networks, sensor technology and weapon systems, optical fibers enable fast, secure and reliable data transmission, even under extreme conditions.

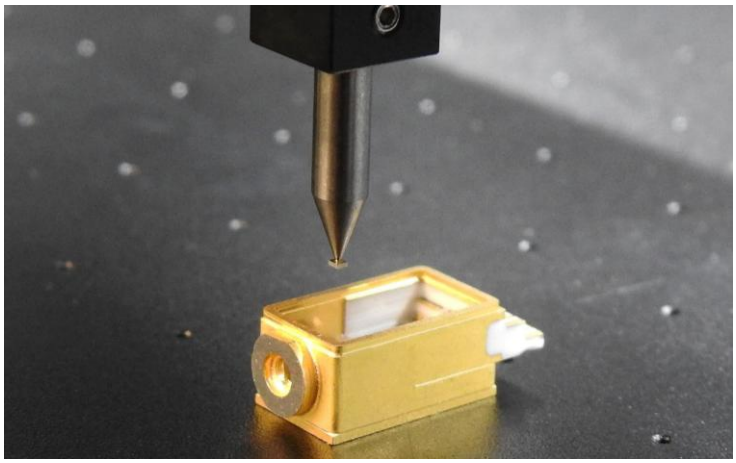

Figure8: Photonics Bonding - Technological miniaturization and functional integration in nano- and optoelectronics are crucial for future-oriented product innovations.

A decisive advantage of fiber optic systems is their immunity to electromagnetic interference. In military applications, where electronic interference or even electromagnetic pulses (EMP) could be used in a targeted manner, fiber optic cables offer significantly higher reliability than conventional copper cables.

Fiber optic systems are also used in precision weaponry and sensor technology. Target detection and infrared systems, LIDAR technology and fiber-optic guided missiles benefit from the low-interference and latency-free transmission of optical signals. Modern aircraft and armored vehicles are also increasingly using so-called "fly-by-light" [3] technologies. These systems replace electrical signal transmission with optical transmission, which increases reaction speed and reduces susceptibility to manipulation.

Figure 3: Modern aircraft, like the Lockheed Martin F-35 using "fly-by-light" technologies

In stationary facilities, command posts or mobile operations centers, fiber optics are the basis for secure and fast communication. Fiber optic systems also enable the real-time transmission of high-resolution sensor data in drones and reconnaissance aircraft. In addition, fiber optic cables offer a high degree of protection against interception, as they are much more difficult to tap or manipulate than conventional cables. In this context, future-oriented applications such as quantum communication via fiber optics are also being researched to develop completely tap-proof transmission technologies.

Overall, fiber optic technologies are now an indispensable component of modern defense systems. They improve the performance, security and reliability of military applications and thus make an important contribution to technological superiority in the defense sector.

Tresky's manufacturing services extend to the production of components that support fiber optics technologies. The precision bonding capabilities of these DIE Bonders ensure that optical components are integrated seamlessly, enhancing their performance and reliability in critical applications.

[3] In aviation, light signals are used via fiber optic cables to transmit measured values and control commands. Conventional electrical signals are only used in the sensors, actuators and computers. However, data is transported over longer distances via light signals. The advantages are the reduced cable weight and the insensitivity to electromagnetic interference, e.g. EMP weapons or radio technology. The disadvantage is the additional weight of the optical-electrical converters. For this reason, communication via light signals is not used in civil aviation. However, the use of fly-by-light is becoming established in military aircraft, such as the Northrop B-2 or the Lockheed Martin F-35, as it is particularly resistant to interference and eavesdropping.

Conclusion

As the military, defense, and security industries continue to advance, the demand for reliable and high-performance technologies will only grow. At Tresky GmbH, we are committed to providing cutting-edge DIE Bonder solutions that meet the stringent requirements of these sectors. Our expertise in advanced packaging and fiber optics technologies positions us as a key partner in the development of innovative solutions that enhance operational capabilities and ensure mission success.

Are you developing next-generation defense systems? Let's discuss how our DIE bonding and packaging solutions can support your mission. Contact our team to discuss your current challenges.

Contact

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