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When Piezostacks Without Housing Are the Better Solution

Opportunities and Limitations for Developers and Designers Based on CuX Piezostack Technology

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Introduction

Piezostacks are key components in a wide range of applications where precision, dynamics, and force in the smallest possible space are required – from industrial automation and precision optics to medical technology. While many piezostacks are typically supplied in a protective housing, there are specific application scenarios where the bare version – a piezostack without casing – is the better choice from a technological, economic, and design perspective.

This white paper explores the advantages, risks, and typical areas of application for unhoused piezostacks based on the proven CuX technology, offering developers practical guidance for decision-making.

What Are Piezostacks?

A piezostack is a stack-type actuator composed of multiple thin layers of piezoelectric ceramic, each alternately connected with metal electrodes. When an electric voltage is applied to this multilayer structure, a directional elongation of the entire stack occurs due to the inverse piezoelectric effect. The resulting mechanical displacement is directly related to the number of active layers, the overall height of the stack, and the applied voltage. In standard configurations, piezostacks are often integrated into a protective housing that offers mechanical protection, as well as partial electrical insulation and environmental shielding. However, for specific applications, particularly in OEM environments, the use of unhoused piezostacks, i.e., bare ceramic stacks without additional casing or encapsulation, can offer significant advantages.

What Are Unhoused Piezostacks?

Since unhoused stacks consist solely of the functional multilayer structure and a simplified contacting system, they allow for especially compact designs and minimal space requirements. They also provide direct access to the mechanical interface surfaces, which facilitates more flexible preloading and mounting solutions within complex device architectures. The open design further improves thermal coupling to surrounding structures, which enables more efficient dissipation of heat loss, an important factor in high-frequency or continuous operation. Economically, the omission of the housing offers additional benefits: eliminating extra manufacturing steps and reducing unit costs for materials. At the same time, the open structure allows for high integration flexibility into existing mechanical or electronic subsystems, particularly in modular OEM components or specialized solutions with custom housing designs. As a result, unhoused piezostacks represent an attractive option both technically and economically, provided that the surrounding conditions (e.g., protection from moisture and mechanical overload) are ensured by the application itself or by additional measures.

Typical Application Areas for Unhoused Piezostacks

Bare piezostack actuators are used when the application environment already provides

sufficient protection. They are also ideal for setups with specific mechanical, thermal, or design requirements that standard housings cannot accommodate. The following are four typical fields of application described in more detail:

OEM-Integration in Enclosed Systems

In many industrial OEM applications, some devices already include integrated enclosures or environmental shielding. In such cases, an additional piezostack housing is unnecessary. Typical examples include fully sealed assemblies, fluid-tight modules, or components already installed in protective housing with IP-rated sealing. In such cases, using unhoused stacks can significantly reduce the required installation space, while also lowering manufacturing effort. Moreover, direct access to the active structure enables more flexible mechanical coupling to surrounding components, particularly advantageous in applications with high demands on precision or force transmission.

Research, Development, and Prototyping

Unhoused piezostacks offer significant advantages during the development phase of actuator systems or devices. Because they are fully exposed and accessible, they enable fast mechanical and electrical integration, as well as flexible adjustment of parameters such as preload, mounting, electrical contacts, or driving electronics. This accelerates iterative design, testing, and optimization processes. For laboratories, R&D departments, and academic institutions, unhoused stacks are favored when it comes to feasibility studies, prototyping, or experimental setups where rapid implementation and adaptability are key.

Applications with Limited Installation Space or Specific Geometric Requirements

In highly integrated optical systems, miniaturized positioning units, or precision mechanical components, standard actuator housings can quickly reach their geometric limits. Particularly in precision-critical applications with tight tolerances or strict installation constraints, the volume of a conventional actuator housing can become a limiting factor. The unhoused stack can be directly embedded into the mechanical structure in a space-saving manner, simplifying the design and minimizing parasitic effects caused by additional interface layers (e.g., in force transmission).

High-Dynamic Systems with Significant Heat Generation

Piezo actuators generate considerable heat during high-frequency or continuous operation. In stacks with housing, heat dissipation is often slightly hindered by the additional thermal barrier of the casing. Unhoused piezostacks, on the other hand, provide direct thermal contact with surrounding materials, such as heat sinks, metal frames, or thermal masses within the system. This allows for more efficient heat dissipation, reducing thermal stress on the ceramic and thereby improving both performance stability and actuator lifespan. This is particularly beneficial in systems with high duty cycles or continuous operation (e.g., active vibration damping, adaptive structures, or precision micro-positioning), where thermal management is a critical factor.

Detailed Advantages: Why Dispense with a Housing?

Depending on the applications, omitting housing in piezostacks offers a range of technical and economic advantages, which create a significant impact on system performance, integration depth, and cost structure.

One of the key benefits in terms of **miniaturization** is the elimination of the external protective housing, reducing the actuator to its technical minimum: the active piezoceramic structure and its electrical contacts. This allows for significantly more compact integration in space-constrained systems. Especially in applications with high component density or miniaturized modules, the resulting space savings can be a decisive advantage.

From a **cost optimization** perspective, the production of housings, including the related assembly and encapsulation processes, is both material- and labor-intensive. Unhoused stacks eliminate these steps entirely. In series production, this can lead to a substantial reduction in unit costs. Additional system-level savings may be realized through simplified assembly procedures and reduced material consumption.

In terms of **design freedom**, unhoused piezostacks give engineers maximum flexibility in mechanical integration. Both the type of preload and the mechanical coupling to mounts or load paths can be precisely adapted to the specific application. This is particularly beneficial in OEM systems where actuators must be deeply integrated into existing mechanical assemblies or where custom preload mechanisms are required.

Efficient thermal management is another important advantage. During operation, especially under dynamic conditions, piezostacks generate waste heat that must be dissipated reliably. In housed versions, the casing often acts as a thermal barrier, increasing internal thermal stress. Unhoused stacks, on the other hand, allow for direct thermal transfer to surrounding structures such as housing walls, heat sinks, or actively cooled components. This improves thermal stability and enables extended operation at high duty cycles.

In **mechanically demanding systems, direct force transmission** is crucial for efficiency and dynamic performance. Housing components can introduce undesirable deformation or damping effects that compromise force transmission. Unhoused stacks allow for a direct, rigid connection to adjacent structures, enabling more precise force delivery and improved mechanical repeatability, particularly in positioning or actuation tasks requiring sub-micron accuracy.

Conclusion

The use of unhoused piezostacks represents a deliberate technological choice that can offer significant advantages over conventional housed solutions, provided that system-level requirements for protection and preload are properly addressed.

Important Considerations: Risks and Limitations

Despite their advantages, unhoused piezostacks require careful and expert system integration, as the piezoceramic structure is inherently brittle, hygroscopic, and sensitive to both mechanical and electrical overload. Reliable moisture protection is essential, since prolonged exposure can compromise the ceramic's electrical insulation, making a sealed environment or protective coating mandatory. Additionally, mechanical preload must be applied externally to prevent tensile stresses and maintain long-term reliability. Handling and assembly demand particular care, as the ceramic can withstand compressive loads but is vulnerable to impacts. Furthermore, electrical connections must be safely insulated and securely implemented to avoid short circuits and arcing. As such, unhoused stacks are best suited for experienced developers who can ensure proper protection, mechanical preload, and system-level integration.

Conclusion: When Is the Use of Unhoused Piezostacks Appropriate?

Unhoused piezostacks are not a universal alternative to housed standard solutions. Rather, as a specialized component format, they offer clear advantages in specific application areas. They are particularly advantageous where installation space is limited, thermal management requirements are high, or the overall system already ensures sufficient environmental and touch protection. In applications with high integration density or the need for customized mounting and preload concepts, unhoused CuX piezostacks offer maximum design flexibility, enabling the realization of highly efficient, application-specific solutions.

About CuX Piezostacks

The CuX series was developed as a high-reliability multilayer piezostack actuator line for industrial, medical, and automotive applications. The unhoused actuators are particularly intended for OEM designs where integration into existing housing or mechanical structures is planned. A key technological feature of the CuX series is its patented internal architecture, which uses copper electrodes within the ceramic multilayer structure, a significant advancement over conventional silver-palladium (AgPd) electrodes. The CuX technology has been in use for over two decades in highly dynamic fuel injection systems in the automotive sector under demanding operational conditions.

From a technical standpoint, the CuX technology offers several benefits:

- Increased power density and energy efficiency due to improved electrical conductivity
- Enhanced moisture resistance through optimized materials and internal structure
- Significantly extended service life under cyclic and thermal stress

These characteristics make CuX piezostacks ideally suited for high-performance applications, such as nanopositioning, precision fluid valve control in process engineering, or active alignment systems in semiconductor manufacturing. Even in unhoused form, the actuators provide a robust and durable foundation for custom mechanical integration, provided that the surrounding conditions for protection, preload, and control are designed according to application-specific requirements.

Contact and Consultation

Are you planning to use an unhoused piezostack? Our experts are happy to advise you on suitable products, preload concepts, and protective measures tailored to your application, especially for bulk orders.

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