ROHM's First Silicon Capacitors Leverage Semiconductor Technology to Provide Greater Miniaturization and Performance

White Paper

Market Trend and Development Background

In recent years, the growing sophistication of smartphones and other devices is increasing the need for compact, low-profile capacitors that support high-density mounting. Silicon capacitors in particular using thin-film semiconductor technology can provide higher capacitances in thinner form factors than existing multilayer ceramic capacitors (MLCCs). What's more, advantages such as superior temperature characteristics and resistance to capacitance changes (even in high temperature environments) are expected to drive demand in the future. In response, ROHM developed the BTD1RVFL of compact, high performance silicon capacitors that leverage original semiconductor processing technology cultivated over many years. (Photo 1)

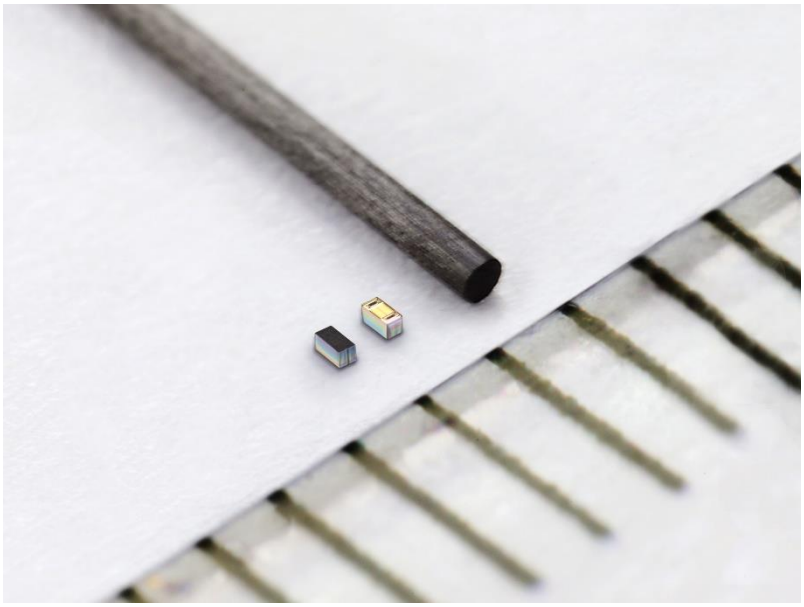

Photo 1. BTD1RVFL Silicon Capacitor (comparison with 0.5mm mechanical pencil lead)

Silicon Capacitors

Capacitors are devices that store electric charge in an insulating material called a dielectric sandwiched between electrodes. Silicon capacitors use silicon oxide or nitride as the dielectric. (Fig. 1)

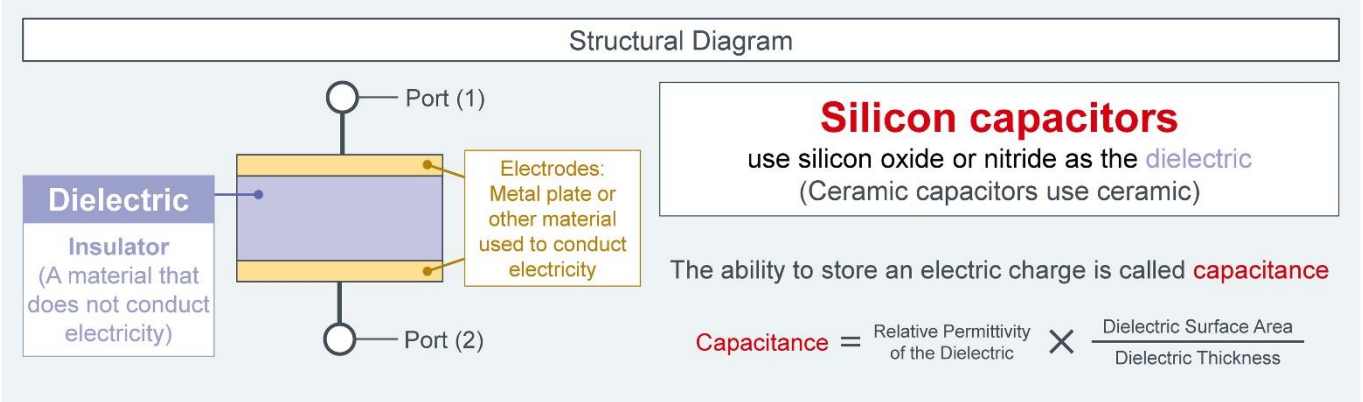

Figure 1. Capacitor Structure

The capacitance is proportional to the surface area of the electrode/dielectric. Silicon dielectrics,

which are easy to process and form into thick layers, allow for an increase in the surface area of the dielectric per unit substrate area by forming trench structures within the device. This makes it possible to achieve both greater miniaturization and increased capacitance. Other advantages over MLCCs include superior high-frequency and temperature characteristics.

Features of ROHM's First Silicon Capacitors (BTD1RVFL)

ROHM's newest capacitors, which have achieved the industry's smallest size for surface-mount mass produced products, are offered in the 01005-size (0.016inch × 0.008inch) / 0402-size (0.4mm × 0.2mm) (ROHM May 22, 2024 study). Mounting area is reduced by approximately 55% compared to the general 0201-size (0.024inch × 0.012inch) / 0603-size (0.6mm × 0.3mm). (Fig. 2)

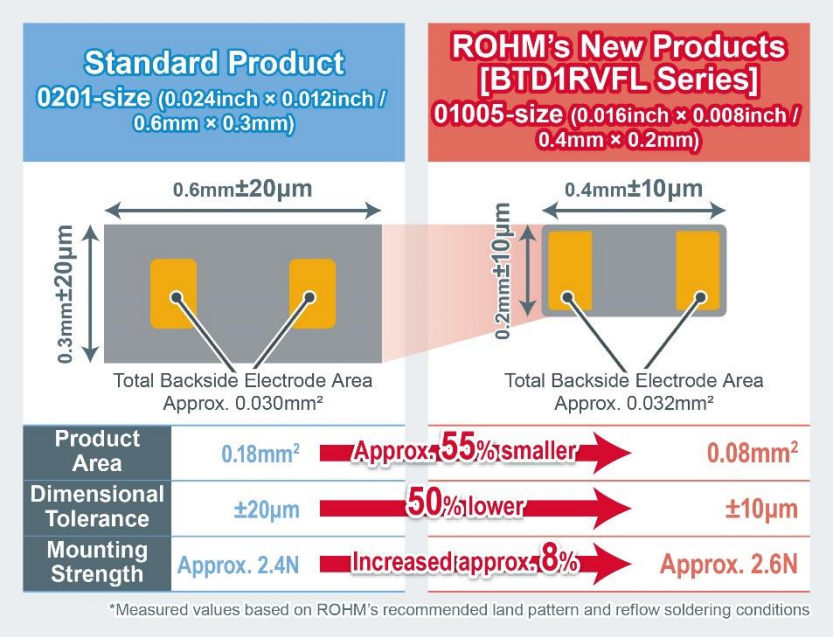

Figure 2. Comparison of Package Size and Mounting Strength

RASMID™ (ROHM Advanced Smart Micro Device) is ROHM's proprietary microfabrication technology that enables processing at the submicron level to form the exterior. This eliminates chipping at the edges of the package, improving dimensional tolerance to within ±10μm - 50% smaller than standard products. Reducing variations in product size makes it possible to narrow the distance between components when mounting on the substrate.

Improved package dimensional accuracy has also succeeded in designing the edge of the backside electrode (which serves as the bonding surface with the substrate) closer to the device periphery. This translates to a total area of the backside electrode of approximately 0.032mm², which accounts for approx. 40% of the device's bottom area, resulting in a mounting strength of around 2.6N (about 8% higher than that of general-purpose 0201-size / 0603-size products).

In addition, a TVS diode is built in for high ESD resistance that not only contributes to reducing

the number of circuit design processes, such as for surge countermeasures, but also eliminates the need for an external TVS diode.

The synergistic effects of high-density mounting resulting from device miniaturization and high dimensional precision, along with the integrated TVS diode, allow designers to reduce board space for communication and other circuits. (Fig. 3)

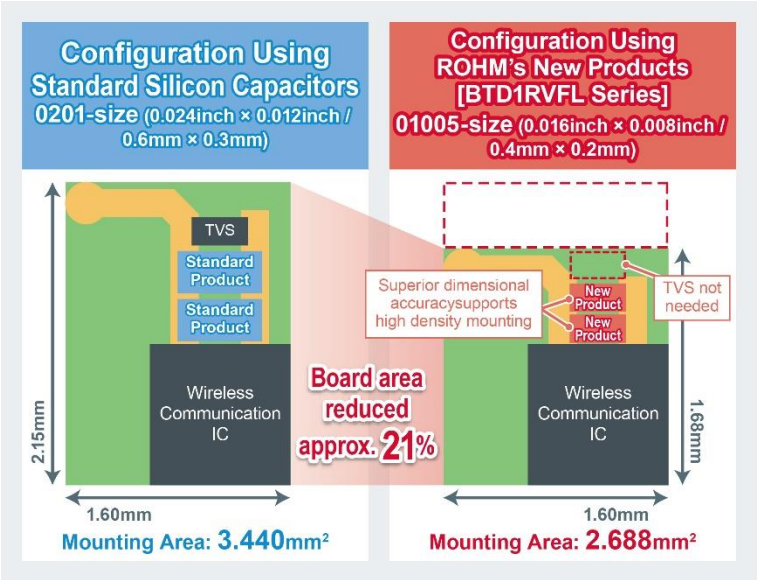

Figure 3. Comparison of Mounting Area in a Communication Circuit

Mass production of two silicon capacitors, the BTD1RVFL102 with 1,000pF capacitance and the BTD1RVFL471 with 470pF capacitance, began in August 2023 at a monthly rate of 500,000 units. In the future, ROHM plans on expanding the lineup to seven models by developing five more products in different capacitances.

Future Developments

The products are offered in a compact, low-profile package suitable for smartphones and wearable devices where the housing and internal components are becoming smaller and thinner. They also contribute to decreasing the size of applications such as small IoT devices and optical transceivers when used as a decoupling capacitor.

And as increased demand is anticipated for compact, low-profile components in high-frequency applications like smartphones and wearables driven by the ongoing advancement and enhanced functionality communication standards, ROHM is actively developing high-frequency models with the goal of shipping samples by September 2024. ROHM pursues specifications compatible with ultra-thin devices (i.e. smart cards, RFID tags) as well as ultra-high-speed, large capacity transmission equipment such as optical transceivers, with hopes to expand the application scope beyond decoupling capacitors to include use in high-frequency circuits.

At the same time, with trends such as the continuing electrification of vehicles, expanding wireless

communication coverage in maritime and aviation areas, and the increase in data centers, ROHM plans on developing products that leverage the high reliability characteristic of silicon capacitors to meet the growing demands in the automotive and industrial equipment sectors. However, the requirements for automotive and industrial equipment applications differ greatly than those for consumer devices not only in terms of reliability, but also withstand voltage, capacitance, size, and structure, prompting ROHM to develop a product lineup that support these diverse needs. (Fig. 4)

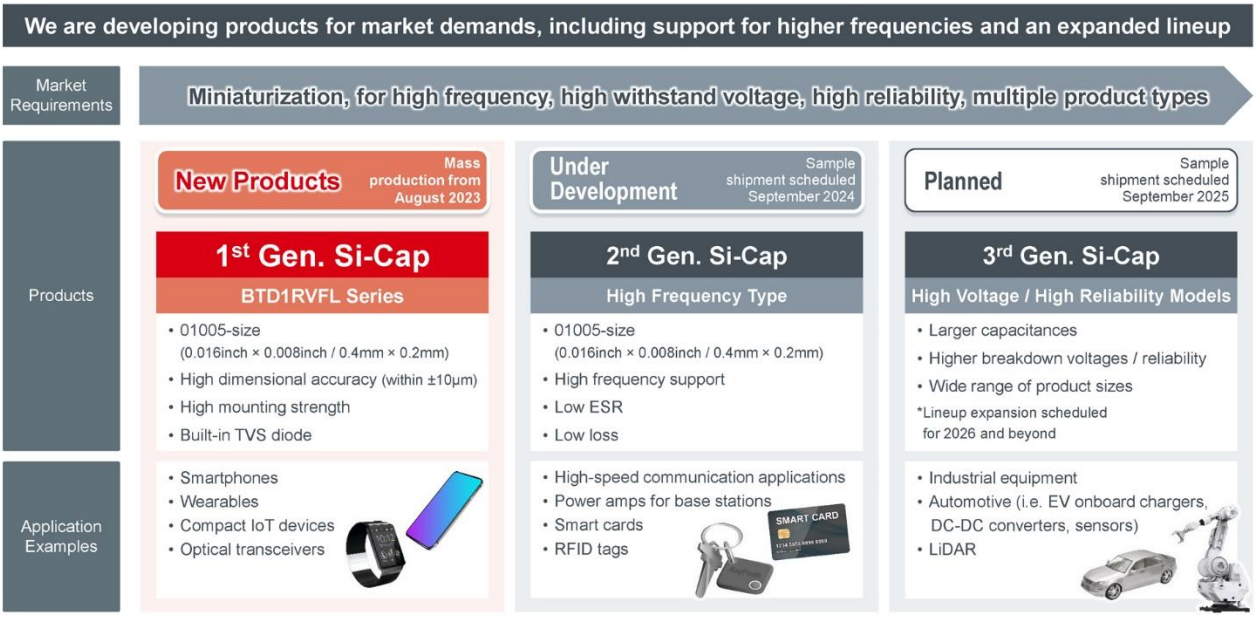

Figure 4. Future Development Roadmap

Conclusion

To create a sustainable society and enrich people's lives at the same time, it is necessary to improve the performance of conventional devices backed by the advancement of communications while introducing new services and applications that have never existed before. One high-performance device expected to support this is the silicon capacitor that combines high capacitance and excellent temperature characteristics in a compact, low-profile form factor. Going forward, in addition to the evolution of applications through the development of high-performance devices, ROHM will continue to work to expand the silicon capacitor market.

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