SAW components

April 2004

Tiny and sophisticated

Photo: One to X

Outstanding filter properties make surface acoustic wave components indispensable throughout wireless communications. The miniaturization that they have undergone in recent years has only been made possible by permanent improvements in packaging technology.

Acoustic waves propagated over the chip surface of any SAW component must be protected by a cavity. Any solid touching the surface would impair or even fully suppress their filter properties.

Flip-chip package

Earlier SAW filter designs used packages made exclusively of metal, plastic or ceramic. These were electrically connected to the chip by bond wires. In mobile phones, these technologies were gradually replaced by flip-chip packages whose compact dimensions save considerable space on the circuit board. They must satisfy tough requirements in terms of cost, performance and quality.

Two generations of flip-chip packages are currently manufactured at EPCOS. Both use solder bumps to connect the chip electrically to a ceramic baseplate. In the first generation of these chip-size SAW packages - CSSP for short - the PROTEC process patented by EPCOS was used for passivation. PROTEC forms a cavity above the chip that allows undisturbed propagation of the surface acoustic waves. The cavity is produced on the wafer in two photolithographic steps. A polymer wall is first built around the filter structures, and the process is repeated to place a roof over it. The wafer level package can then be modified further with the aid of extrusion coating or underfilling. In the second CSSP generation (CSSPlus), a polymer laminate film is applied to the chip to seal the cavity between chip and baseplate.

SAW filter structure

The basic structure of a SAW filter is shown in → 1.

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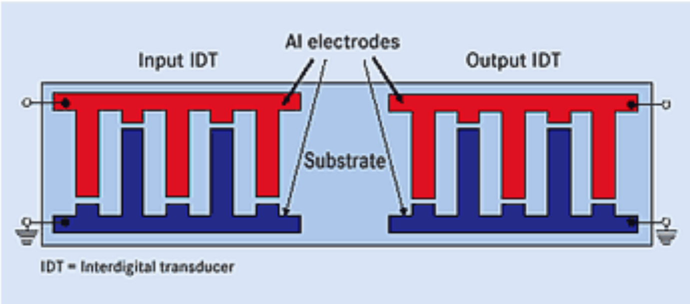
1 | Schematic view of a SAW filter



1 Substrates of quartz (SiO_2), lithium tantalate ($LiTaO_3$) or lithium niobate ($LiNbO_3$) are used.EPCOS obtains them from its subsidiary CTI in Palo Alto, California. In real filters, the width of the digital structures is about 50 µm.

A thin structured metal film is first deposited on a piezoelectric substrate. Substrates of quartz (SiO_2), lithium tantalate ($LiTaO_3$) or lithium niobate ($LiNbO_3$) are used for most applications. The interdigital transducer at the input transforms the electrical signal into surface acoustic waves, which are only propagated at particular frequencies. These are converted back into electrical signals in the output transducer. SAW technology can be used to implement outstanding bandpass filters and high-quality resonators. The period of the interdigital structure is inversely proportional to the center frequency. RF filters in mobile phones are used for frequencies up to 2 GHz, corresponding to an individual finger width of less than 0.5 µm. The accuracy of the finger width and metalization thickness must be within the nanometer range. For propagation of surface acoustic waves, the package must contain a cavity. This means that standard semiconductor packages cannot be used.

SAW package requirements of mobile phones

As well as containing a cavity, SAW packages must satisfy various requirements:

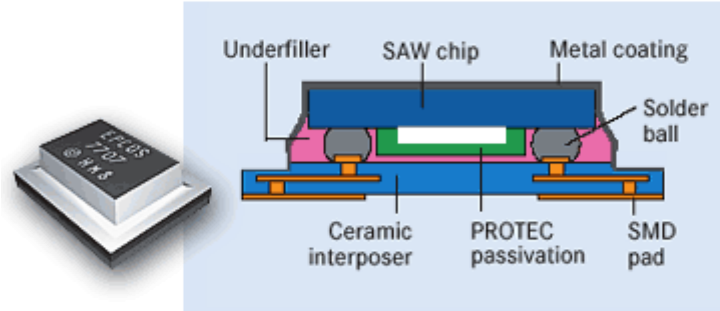
- The package temperature must have a negligible effect on the electrical properties of the filter throughout the temperature range from -30 to +85 °C. As the insertion loss of the filters must remain small,
- the package must not cause any additional attenuation.
- Most SAW filter applications operate in unbalanced mode at the input and balanced mode at the output. The package must not only support this combination but ideally even improve the quality of the output signal at the balanced terminal. To ensure long service life, the filters must undergo
- accelerated reliability tests and temperature cycling or storage in damp heat.

SAW filters in the flip-chip package are not only much smaller than conventional filters with bond wires, but the filter performance of RF filters is also significantly improved. However, electromagnetic crosstalk caused by bond wires impairs the transfer function, especially in the stopband. Flip-chip packages not only improve typical test data, but also help minimize tolerances in volume production. The electrical connections between substrate and package are more reproducible than with conventional wire bonding. Better reproducibility ultimately leads to improved specifications. Short leads within the package minimize insertion losses.

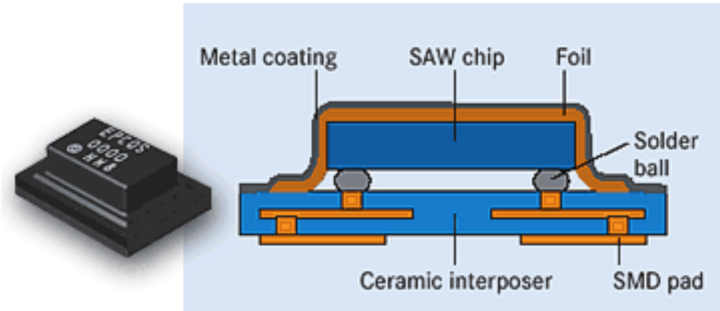
CSSP technology

Flip-chip technology is commonly used for RF SAW filters. Packages made with two fundamentally different technologies are currently available. The first uses packages similar to conventional SMD types in which ultrasonically bonded gold beads connect chip and package. The second type, known as CSSP technology, was developed by EPCOS and uses solder for electrical connections → 2.

2 | SAW filter in CSSP technology



3 | SAW filter in CSSPlus technology



Right:Schematic sections.Left: Components with footprints of 2 × 2 mm (top) and 2 × 1..4 mm (bottom).

The active SAW structure on the substrate is protected by a small cavity formed by the PROTEC passivation. A baseplate made of high-temperature co-fired ceramic (HTCC) or low-temperature co-fired ceramic (LTCC) is used for the electrical connection between chip and circuit board. The contact between chip and baseplate is made via SnPb solder bumps with a diameter of 200 µm.

For soldering, a thin solderable film must be deposited on the chip. In CSSP technology, platinum and gold were selected for this purpose. In the next process step, an underfiller is applied between chip and baseplate. Copper and nickel layers applied later seal the package hermetically. The smallest components in CSSP technology have a footprint of 2 × 2 mm.

CSSPlus

The second generation of flip-chip packages, known as CSSPlus, is shown in → 3. The chips are soldered to a ceramic baseplate with lead-free solder bumps 100 µm in diameter. A cavity is then formed over the chip by application of a polymer laminate film. To ensure that the film adheres well to both ceramic baseplate and chip, a special process that uses high pressures and temperatures was developed. It also ensures constant film geometry in volume production. The film is removed from the edge of the components before metalization to prevent penetration of moisture. The package is then hermetically sealed by Cu and Ni films with a total thickness of 20 µm. CSSPlus production has been running since early 2002. The smallest footprint is 2 × 1.4 mm with a height of 0.7 mm. The chips are polished in a special process for use in components with a height of 0.6 mm, for which demand is growing.

Designing duplexers with CSSPlus

Miniaturization of SAW filters with CSSPlus technology saves considerable board space not only in discrete filters, but also in more highly integrated components, such as duplexers and front-end modules. EPCOS is already producing SAW duplexers in CSSP technology with footprints of 5 × 5 mm and 3.8 × 3.8 mm. To shrink components even further, SAW duplexers are also switching to CSSPlus. SAW duplexers with a footprint of 3 × 2.5 mm are currently being

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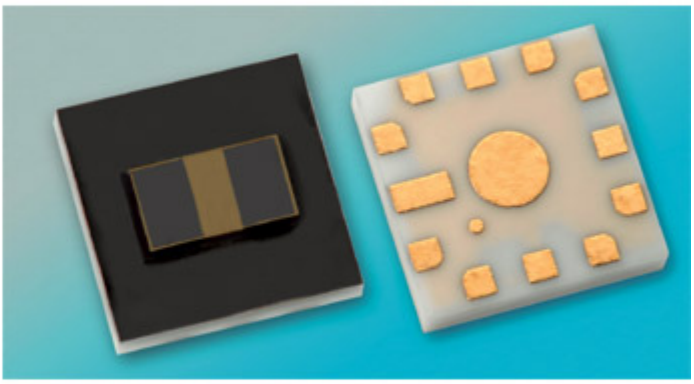
developed in CSSPlus → 4.

4 | SAW duplexers

4 SAW duplexers for CDMA mobile phones with footprints of 5 × 5 mm, 3.8 × 3.8 mm and 3 × 2.5 mm.

This new duplexer design is not only distinguished by a 50% smaller footprint, but its low insertion height of only 0.6 mm also supports integration into modules. New areas of application can thus be opened up, such as modules for the American CDMA mobile radio standard. Here a low-profile duplexer is essential to meeting customer specifications for overall dimensions of modules that contain further filters and power amplifiers as well as the actual duplexer. EPCOS is currently the only components manufacturer that can offer this kind of miniaturized duplexer. But CSSPlus technology is not restricted to SAW components. It can also be used to package film bulk acoustic wave resonator (FBAR) filters and duplexers → 5.

5 | FBAR duplexers



5 FBAR duplexer with footprint of 5 × 5 mm for future PCS mobile phones.

For reasons of technology, the transmit and receive filters are located on separate silicon chips in FBAR duplexers. Two FBAR chips are therefore mounted on the ceramic baseplate and a polymer laminate film is applied to both. Common to the components described is the base material of LTCC. In contrast with filters based on HTCC, numerous passive components can be integrated in LTCC, thus providing the functionality of integrated duplexers.

CSSP3

But miniaturization has by no means reached the end of the road. Over the next few years, the 1513 standard with a footprint of 1.5 × 1.3 mm will become established. Work is already in progress on a new generation with a footprint of only 1.4 × 1.1 mm. Both will be known as CSSP3.

Outlook

Miniaturization of SAW filters not only saves considerable board space, but is also essential to integration of filters into LTCC modules. So as well as complete front-end modules implemented in LTCC, modules integrating all filters can be developed for multiband and multimode handsets in the future.

GLOSSARY | DUPLEXERS

Duplexers are used in mobile phone systems that permit simultaneous transmission and reception of signals (CDMA,UMTS).They contain a transmit filter and a receive filter (on the same chip in SAW duplexers) and are located right after the antenna at the front end of the handset. The special properties required from duplexers, such as high power compatibility and high attenuation in the stopband,make special demands on the packaging technology,such as good thermal coupling with the substrate,high reproducibility of electrical connections between substrate and package,and good shielding toward the outside.