Sawing Silicon

The Art & Science of Wafer Dicing

BY PETER MCCABE

step 3

Wafer sawing is the last back-end operation in which a processing error can convert an entire $50,000 wafer into thousands of pieces of expensive scrap. Proper dicing of wafers requires experience, judgement, and high-performance equipment. Successful sawing requires selecting the correct saw blade from dozens of possibilities and finding the proper combination among dozens of control settings. Wafer thickness and composition, the width of the saw streets, and the desired die size must be considered when selecting sawing parameters. The wrong blade or the wrong combination of parameters can destroy the wafer.

The continuing shrinkage of semiconductor devices toward smaller feature size and higher density is raising the hurdle of sawing. Wafers are designed to hold as many die as possible. Producing a wafer is a fixed cost, so more die per wafer equates to lower cost per die. Each die is separated from its neighbors by narrow "streets," which are the cut lines for singulating the die. The narrower the streets, the more die — and the more challenging the sawing.

While several new singulation technologies are being developed or in limited use, most silicon wafers, which comprise more than 90% of wafer volume, are sawn with a diamond saw blade. Selecting the proper saw, diamond blade, and mounting tape are three keys to success.

Dicing Saws

Silicon dicing saws offer a wide variety of models with many options. Options include manual or fully automated operation; single-blade or multi-blade cutting; cutting in one direction only or bi-directional; blade mounting on a 2- or 4-in.-diameter hub; cooling water flow from a single jet or from multiple jets; and spindle rotational speeds ranging from 1,000 to 60,000 rpm. Figure 1 shows an operating saw, showing the rotating saw blade and the spray of cooling water.

Post-saw cleaners, which remove the residual silicon dust, may be a part of the saw or standalone equipment. Automatic blade "dressing," to maintain the cutting surface, may be included in the saw.

A semiconductor manufacturer may routinely saw large quantities of wafers. Manufacturers have the advantage of a limited family of products and materials, however, so that they can standardize their sawing equipment and processes. As a wafer service provider, every month we must saw wafers with hundreds of different part types from any of 30 wafer manufacturers. We use two types of saws to deal with this variety: semiautomatic and fully automated machines.

The semiautomatic saw dices single wafer orders that have low to moderate sawing complexity. This saw has one cooling jet, a single blade on a 2-in. hub, and a maximum spindle speed of 40,000 rpm. The operator programs the saw and must monitor the sawing, intervening as needed.

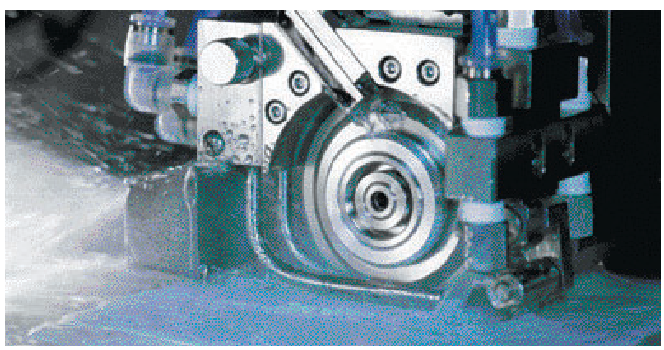

Figure 1. Close-up of an operating saw, with cooling water spraying at the top of the rotating blade and the wafer. Photo courtesy of Disco.

A higher-performance, fully automated machine is well suited for volume batch processing. Fifty wafers can be loaded into the saw, which has six cooling water jets, a single-blade, 2-in. hub, and a maximum single speed of 60,000 rpm. When full pattern recognition is enabled, the wafers are diced without operator intervention.

The high cooling capacity provided by the 6-nozzle cooling water system also make this the saw of choice for small die with dimensions in the 0.010- to 0.030-in. range. A wafer of such small devices, such as diodes, has many more closely spaced streets than a wafer of large die. The number of cuts per wafer greatly increases. Resulting localized heat buildup is a frequent cause of die cracking and die chipping.

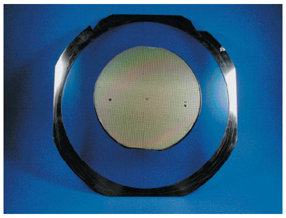

Figure 2. A wafer mounted to a sawing frame with blue tape, in preparation for sawing.

Dicing Blades

Diamond dicing blades are open-center disks made from a resin, nickel, or sintered metal that provides a matrix for the diamond chips. Blades for cutting ordinary silicon wafers comprise more than 90% of wafer production. Nickel-bond blades are a suitable choice for silicon wafers. Resin matrix or electroformed blades might be used for harder or softer materials. Nickel blades are selected for a specific cutting task based on blade width, grit size, and exposure. Blade width is determined by the width of the street to be cut. Grit size describes the size of the diamond chips on the blade. Typical grit size for silicon wafers ranges from 2 to 6 μm. On a wafer with a narrow street, a thin blade with a smaller grit size allows a smoother cut. “Exposure” measures the height of the exposed blade surface available to cut the material. For example, a 20-mil-thick wafer requires a blade with at least 25-mil exposure, because the blade must cut completely through the wafer and some distance into the supporting tape.

Mounting Tape

Mounting tape is used to securely mount the wafer to a metal frame for sawing. The key characteristics of mounting tape are its thickness and adhesion. Most of the tape used for wafer dicing is 80 to 95 μm thick. Adhesion must be adequate to hold each die firmly in place during cutting to support the singulated die until they are removed from the tape, and to release them easily during removal.

The two most popular mounting tapes used in the industry are blue film and UV film. Blue film is roughly 1/3 the cost of UV film, however, it’s limited to a fixed adhesion value in the 40- to 170-g range. When mounting, cutting, and removing the die from the film within 72 hrs, blue film is an economical choice. Leaving die on the blue tape longer than 72 hrs can result in a sticky backside, caused by remaining adhesive residues.

UV film has a variable adhesive strength: strong before UV exposure, weak afterward. For the added cost of the UV film, you gain a much higher adhesive force during sawing, and a permanent 90% lowering of the adhesive force when the film is exposed to UV after sawing.

Wafer Dicing Process

The first step in the dicing process is an evaluation of wafer thickness, street width, and the material, which might be silicon, silicon on sapphire, silicon germanium, or more exotic materials. The evaluation helps in choosing the best blade. A standard silicon wafer (20 mils thick and 4 mil streets), for example, can be sawn with a 1-mil-thick blade having a 2- to 4-μm grit and a 30-mil exposure.

After the evaluation and blade choice, the wafer is mounted with the adhesive film onto a metal wafer-cutting ring. First, a disk of particle-free paper is centered on the mounting chuck to protect the wafer’s face. Next, the wafer is positioned face down on the paper. Then, the wafer tape is stretched, sticky-side down, over the back of the wafer and the cutting ring, and pressed with a roller to smoothly and evenly distribute the tape. Excess tape is cut away from the edge of the ring. Figure 2 shows a wafer mounted on a cutting ring with blue tape, ready for dicing.

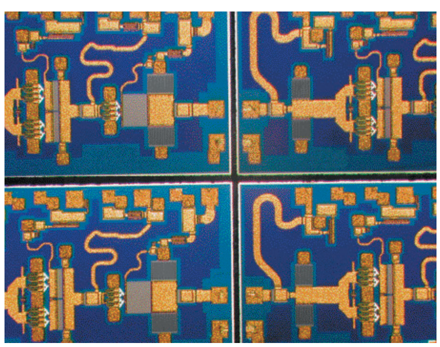

Figure 3. Portion of a diced wafer, still on the dicing tape. The dark cross is the tape below the wafer, visible through the sawn streets.

The ring-mounted wafer is loaded on the saw-dicing chuck for programming. The *X* and *Y* step centers are measured and stored. Following the theta angular alignment, a sample cut is made near the edge of the wafer for verification. Pattern recognition features are selected and stored if multiple wafers are to be cut. During dicing, the wafer is periodically checked for alignment and cut quality.

Following dicing, the wafer is moved to the cleaner to wash away residual dust so that it cannot adhere to bond pads. For saws with fewer cooling water jets, a surfactant may be used to bind with and help remove any remaining silicon dust. Figure 3 shows a portion of a diced wafer after cleaning.

Sawing Challenges

Sawing challenges include narrow streets, hard materials, and thin wafers. Street widths of less than 3 mils require narrow blades. Silicon wafers more than 25 mils thick require high forces. This combination puts stress on the saw blade that risks breakage. Breaking the blade during sawing invariably damages the wafer.

Thinned wafers, which are growing in popularity, do not present unusual sawing challenges. A 5-mil-thick wafer is less brittle and easier than a 10-mil-thick one. The challenges here are in handling the wafers and detaching the large, thinned die from the tape without cracking.

Conclusion

Most wafers can be cut using generic materials and standard set-up parameters. When sawing a new or unique type of wafer, a sample cut in the flat or along the edge will help you find the proper settings. Blade and saw manufacturers can help you develop customized processing. If you frequently cut a wide variety of wafers, try keeping a detailed journal that captures the details of each process and the struggles that you encounter and, hopefully, overcome.

In summary, wafer sawing remains both an art and a science. For best results, both high-performance equipment and the proper materials must be combined with expert human judgement and experience. **AP**

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