Laser Processing of Semiconductors and Hybrids

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Laser Processing of Semiconductors and Hybrids

Edward J. Swenson
Chairman/Editor

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LASER PROCESSING OF SEMICONDUCTORS AND HYBRIDS

Volume 611

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Sessions
Session 1—Hybrid Laser Trimming

Session 2—Microelectronic Laser Welding, Soldering, and Marking

Session 3—Semiconductor Processing

Session 4—Laser and Nondestructive Testing

LASER PROCESSING OF SEMICONDUCTORS AND HYBRIDS

Volume 611

INTRODUCTION

This conference represents an overview of practical applications of lasers in the production of microelectronic circuits. As circuit geometries have decreased, laser-based processing procedures have become more important and flexibility requirements have increased.

While hybrid circuit trimming and general laser processing are expected to remain the major laser markets, significant growth is projected for direct, on-chip processing. This projection is being supported by intensive research into new processes as well as refinement of existing processes.

The first session provided papers on the traditional areas of laser hybrid trimming, both passive (611-01) and functional (611-02) as well as a novel new approach to creating fast-turnaround hybrid masks by utilizing a standard laser trimming system (611-03).

The second session on microelectronic laser welding, soldering and marking started with an excellent overview of pulsed Nd:YAG spot welding in the microelectronics area (611-04). The scientific approach to laser/material interactions by a variety of analytical techniques provides extremely good insight into the optimum techniques for laser spotwelding. The marking of passive components, packaged devices and other microelectronic parts by laser (611-05) is a popular area of activity. In addition, this session included some new insight into using Nd:YAG for micromachining of ceramic and metal microelectronic parts (611-06).

The third session dealt with semiconductor processing with lasers. Currently, the area with the most activity is in laser programming of redundant DRAMS (611-07). A new approach of using lasers to produce gate arrays received considerable attention (611-08). An area of growing interest is laser assisted etching of electronic materials (611-09). Also of note is the work done to further the art of functional laser trimming of thin-film resistors on integrated circuits (611-10).

The fourth session dealt with nondestructive testing using lasers. New techniques for defect diagnosis by scanning laser image generation were reviewed (611-11). And, the technique of inspecting solder connections with lasers was covered (611-12).

The breadth and depth of papers presented at this conference indicates the growing use of lasers in microelectronic production... tools that are well suited to the constantly shrinking sizes and accuracies required and the flexibility and programability needed in today's automated manufacturing environment.

Edward J. Swenson
Electro Scientific Industries, Incorporated

LASER PROCESSING OF SEMICONDUCTORS AND HYBRIDS

Volume 611

Contents

LASER PROCESSING OF SEMICONDUCTORS AND HYBRIDS

Volume 611

Session 1

Hybrid Laser Trimming

Technology review of high-speed, thick-film laser trimming

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Introduction

Thick-film hybrid circuits continue to dominate the hybrid circuit market because of their design flexibility, power handling capabilities and low production costs. In their simplest form, thick-film circuits consist of high purity alumina substrates with screen printed, fired resistors and conductors. The resistor materials are usually oxides of ruthemium with conductors of platinum/gold, palladium/gold, or palladium/silver.

A critical element of thick-film circuit production is high-speed laser trimming of the thick-film resistors. The laser trimming technique essentially involves micro-machining resistive material in order to adjust resistance values accurately to a desired nominal.

This adjustment is necessary because the "as processed" values of thick-film resistors normally can be in a spread of plus or minus fifteen percent or more. After laser trimming, a typical desired resistor tolerance would be plus or minus one percent. This is acceptable for most applications of thick film resistor networks or thick film hybrids. Applications for such circuits include electronic ignition and fuel control devices for automotive products, tone generators and filters in touchtone telecommunications systems as well as a host of other industrial and consumer uses.

A brief historical overview

Systems designed to perform micro-machining of thick-film resistors are known as laser trimmers. They bring together a very wide range of engineering disciplines including laser and optics, digital and precision analog electronics, computing and software, and electro-mechanics.

Many of the early systems in the late 1960s were manually controlled and designed only for very low volume production, since they were set up to trim only one resistor on a circuit at a time. Rates of one resistor per second were considered fast, especially when compared to the alternative method, a refined form of sandblasting.

The first automatic laser trimmers in 1970 were capable of trimming entire circuits in a single pass. These systems could achieve trim rates on the order of ten resistors per second. With such systems, manufacturers now possessed the kind of tool needed to produce high volumes of precision resistor networks and hybrids.

Today, laser systems exist that can trim resistors at rates of up to 200 resistors per second. To create systems that can trim at this rate without degrading the performance of the trimmed resistor requires a very thorough knowledge of the trimming process and laser/material interaction.

Trimming thick-film resistors

Laser trims in a resistor take the form of cuts in the resistor material at some angle to the current flow. The most simple form of trim known as the plunge cut is shown in Figure 1. Just how the trim mechanism works can be seen by comparing the current flow lines in an untrimmed resistor with a trimmed resistor (Figure 2). The rate of change of resistance with distance trimmed becomes almost exponential with this trim technique. It is, in fact, the fastest way of getting a resistor to value.

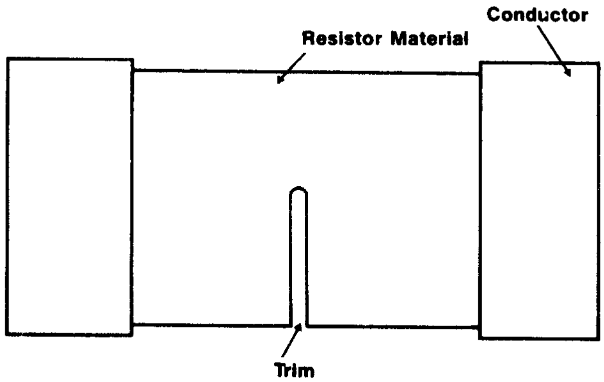

Figure 1. Sample of plunge cut.

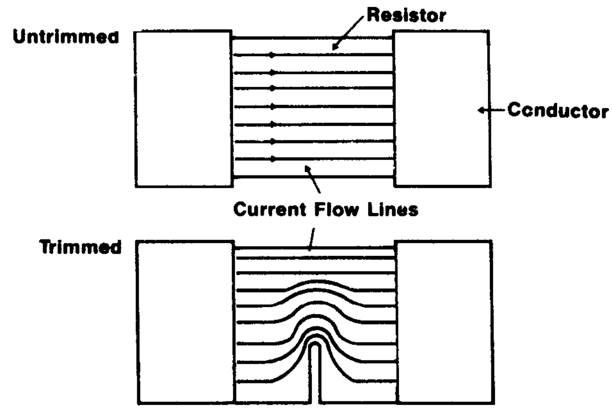

Figure 2. Illustration of current flow lines in trimmed and untrimmed resistor.

Other commonly used trims are shown in Figures 3 and 4. The L-cut and the U-cut are both trims that achieve slower rates of change of resistance with distance trimmed after their initial segments. These trims are often used to trade off speed against accuracy and stability.

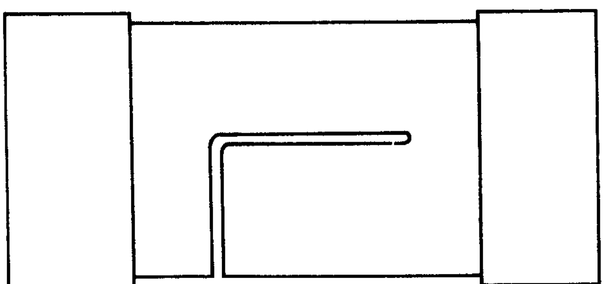

Figure 3. L-cut.

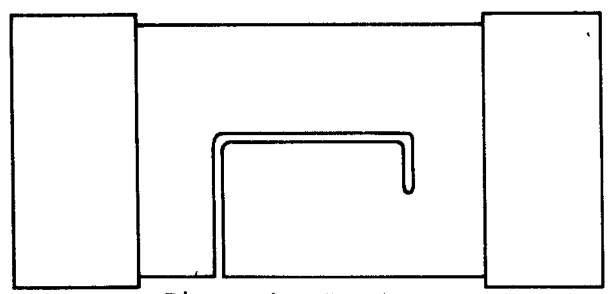

Figure 4. U-cut.

Because of constraints introduced by the screen printing process, minimum resistor geometries are typically 600 microns square. However, it is not unusual to find resistors that have a dimension as low as 250 microns on one side only. These minimum dimensions, together with laser power density limitations, dictate a maximum desired cut (or kerf) width of around 70 microns. In most cases, kerfs of less than 40 microns are too small because of the possible danger of bridging or leakage across the trim.

Today, cuts are made almost exclusively with the focused beam of a neodymium doped yttrium-aluminum-garnet laser (Nd:YAG). The ND:YAG laser has a wavelength of 1.06 microns, and it was selected at a very early stage in laser system evolution for a number of reasons. First, it vaporizes resistor material easily while leaving most substrate materials relatively undamaged. In addition, because of its wavelength, it is easily focused to the required spot size. The Nd:YAG laser is also available in the range of powers appropriate for thick-film trimming.

While the trim is taking place, a resistance measurement system connected to the resistor constantly monitors its value. When the required target resistance is reached, cutting is terminated.

A typical high-speed laser trimming system

The main subsystems in a laser trimmer are the beam positioning subsystem, the resistance measurement unit, and of course, the Nd:YAG laser itself. Figure 5 is a block diagram of a typical high-speed system. The beam positioner, laser, and measurement system are carefully synchronized during the trimming operation to ensure clean kerfs and accurate resistance values. Some synchronization can be achieved by the host control computer, but in very high-speed applications, hardware event lines may be employed to control the process. (See Measurement System.)

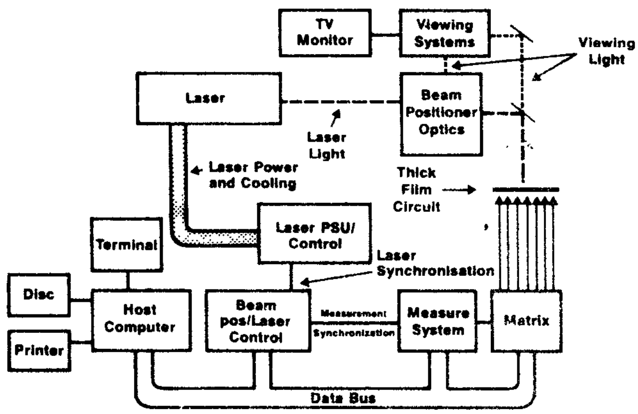

Figure 5. Block diagram of typical high-speed laser trim system.

In modern systems where maximum trim rates are the goal, each of the subsystems has its own intelligent controller, enabling the processes to operate concurrently. For example, the beam positioner can be moving into position for a trim, while the resistance measurement system is checking the value of the last resistor processed. Data may be transferred from the host computer to the subsystems while trims are taking place. This ensures that the system runs at a capacity, limited only by the physical hardware. Thus, the host computer takes on more of a supervisory role and is primarily used for data analysis and the user interface.

Each of the above subsystems can be examined individually to illustrate exactly what features are required in a high-speed trimming environment.

The laser

The Nd:YAG laser used for the process is often the most neglected and loosely specified subsystem in the trimmer. Performance requirements of this laser can be seen by looking in more detail at the actual mechanics of the cutting operation. While the trims look like continuous cuts in the resistor material, they actually consist of a series of overlapping holes where material has been vaporized by pulses from the q-switched laser. It is the specification of these pulses that is the important factor in determining the suitability of a laser for trimming purposes -- both in terms of pulse width and energy per pulse.

For example, the laser pulse width can affect the stability of the trimmed resistor. Too short a pulse will not adequately vaporize the resistor material, while too long a pulse allows time for heat to spread into the resistor material surrounding the kerf. In this area, the material can melt and resolidify, sometimes cracking in the process. This can cause instability in the resistor in the form of resistance drift or excessive noise generation.

However, this heat-affected zone may be reduced by close attention to laser mode structure. TEM_{00} with its Gaussian power distribution across the beam provides the sharpest decrease of power density outside the focused area, hence minimizing peripheral damage. Unfortunately, the zone around the kerf edge is usually in the area where it can do the most harm, especially in high-speed trimming situations, where the plunge cut is used. The end of the trim is in the area of highest current density which is the area most sensitive to material damage.

Investigations have indicated that laser pulse widths of between 50ns and 200ns are ideal for most thick-film applications. Pulse widths longer than this can be used, but more care must be taken to optimize power parameters in order to avoid excessive instability.

Typical laser specifications are shown in Figure 6. Energy per pulse varies from 0.25 to 2.5 millijoules depending on repetition rate. Since even the highest peak power pulse of 20 Kw is not sufficient to completely vaporize material down to the substrate, the beam positioner is synchronized to overlap the pulses in order to produce a clean kerf. This overlap also helps to straighten edges of the trim that would become scalloped if the overlap was too small.

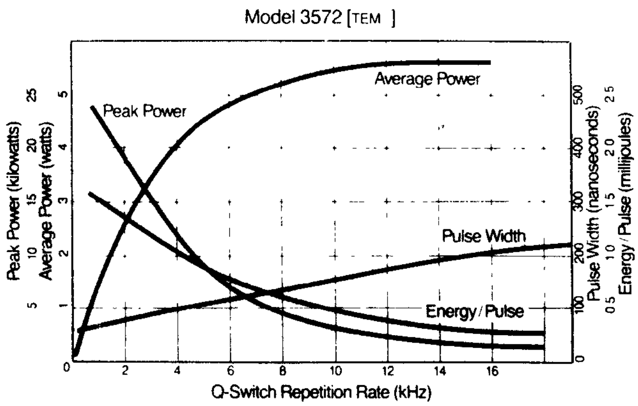

Figure 6. Typical laser specifications.

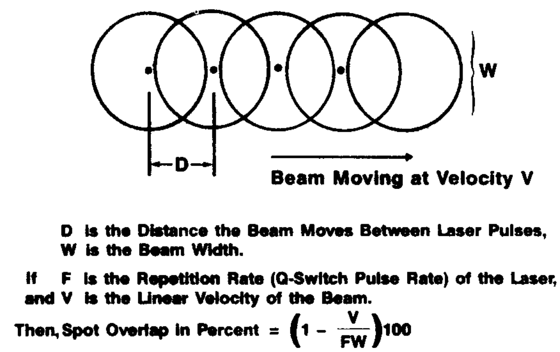

Figure 7. Relationship between overlap, focused spot size, scanning speed, etc.

The relationship between overlap, focused spot size, beam positioner scanning speed, and laser repetition rate are shown in Figure 7. In high-speed trimming, the laser can be cutting at linear speeds in excess of 300mm/sec. To provide an overlap of 80 percent with a spot size of 50 microns requires a laser repetition rate of 30Khz. Lasers must be designed to have an acceptable pulse width and sufficient energy per pulse, even at these high repetition rates. A high degree of pulse-to-pulse stability is necessary to ensure that the kerf width is consistent, since missing or low power pulses will cause bridging across the trim.

The beam positioner

Because thick-film circuits come in many shapes, sizes, and geometries from 0.25 inches square up to 6 inches square, the beam positioner has a number of conflicting requirements. Prior to performing a trim, it must be able to move the laser beam to anywhere in the entire field in the shortest possible time with a repeatability of around 12 microns. At the same time, it must have the high resolution performance necessary to control pulse overlap during trimming.

The positioning technique of choice for high-speed trimmers is the galvanometer beam deflection system. This technique uses two rotating mirrors mounted at 90 degrees to one another in order to deflect the laser beam over the trim field. The mirrors are mounted on the shafts of moving iron galvanometers which have built-in rotational feedback devices to enable them to be driven by third order control systems.

The feedback system is designed to provide fast step response for point-to-point beam movement, along with accurate tracking of the drive waveform necessary to make some of the more complex cut geometries. Long-term repeatability can be achieved by temperature controlling the galvanometers to stabilize the outputs from their analog transducers.

The deflected beam is focused onto the work area by a flat-field, F-theta lens. This lens system not only maintains an accurate focus over the entire field, but also has some degree of telecentricity to convert constant rotational velocities to constant linear velocities during trimming. The beam is deflected through 90 degrees by adichroic reflector to allow closed circuit camera viewing of the process.

Figure 8 shows additional details of such a deflection system. The beam is upcollimated to a suitable size before hitting the deflection mirrors. In high-speed systems, beam size is kept to a minimum to allow use of very small deflection mirrors with low moments of inertia. The moment of inertia can increase dramatically as mirror size increases. This is because the thickness of the glass substrate must increase in proportion to mirror diameter to maintain the required flatness specification. The minimum beam size is governed by the final focused spot size requirements.

The optics in this example also have the facility of a built-in power detector and a through-the-optics camera viewing system. This second viewing system enables a much closer alignment of the laser beam to the resistor material than can be achieved with the overview system.

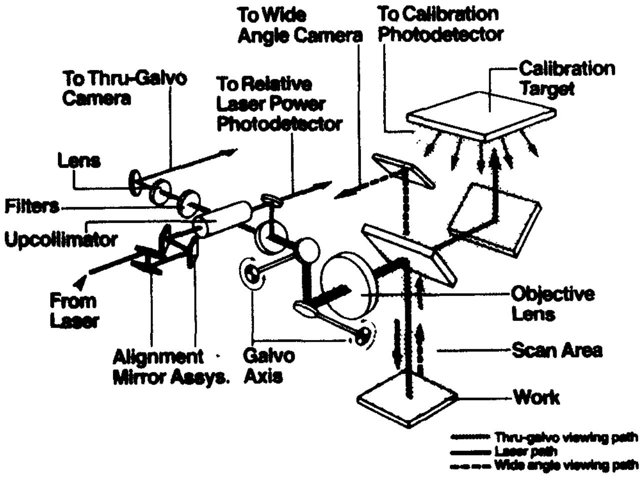

Figure 8. Beam deflection system.

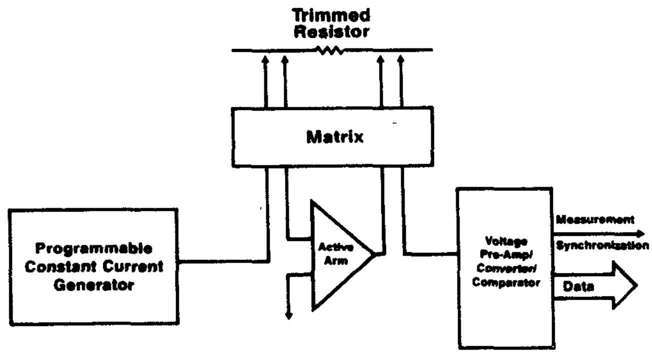

Figure 9. Block diagram of typical measurement system.

Accuracy errors in the field can be caused by lens distortions as well as the nonlinearities inherent in any two-mirror deflection system. Because of this, a calibration plate has been included that enables the field to be periodically measured. Such measurements can be made by allowing a small percent of the beam to pass through the 45-degree dichroic onto a detection area. There, the beam's position can be accurately determined, either manually or automatically. Computer corrections can then be made that will help eliminate the accuracy errors.

A typical beam positioner and optics package can provide random point-to-point move times over a 105mm square trim field in better than 6ms with a positional repeatability of 12 microns. This can all be accomplished while maintaining an operational laser spot size variation of less than 2 percent over the entire field.

The measurement system

During trimming, the resistor value is monitored by a high-speed measurement system that is sequentially connected to each resistor processed through a relay matrix. Although most measurement systems are custom designed, they typically employ some type of force current/ measure voltage technique.

For example, in the measurement system shown in Figure 9, a programmable constant current generator forces the current through the resistor. An active arm allows the use of 4-terminal measurement techniques which greatly reduces the effects of series resistance in the matrix and connection system. The voltage across the resistor is then measured. It is proportional to its resistance value and can be converted to digital value that the computer can then process.

The measurement system must be able to sample the resistance between laser pulses to decide whether additional pulses are required to bring the resistor to value. At laser repetition rates of 30Khz, the decision must be made in under 30 microseconds. Extremely high speed measurement systems that employ hardware event lines have been designed to meet this requirement.

In such systems, a high-speed hardware event line connects the measurement system to the laser to allow trimming to be terminated without involving any software interrupt overhead. When the measurement system determines that the resistor has been brought to value, the laser is turned off immediately even though the beam positioner may remain in motion until the controller can be commanded to move to the next resistor in sequence.

Summary

Thick-film resistor technology will continue to advance and dominate the hybrid circuit market bringing with it new challenges to provide higher performance laser trimming systems. As in today's systems, care in design of the laser and optics will provide one of the main keys to system success, but attention must also be paid to positioning and measurement technologies. A balanced combination of these subsystems put together in a suitable architecture will optimize high-speed laser trim systems for the thick-film resistors of the future.

Functional laser trimming: an overview

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Abstract

Laser trimming of hybrid circuits, and more recently, monolithic IC's is often used to improve yields and/or device performance. As device technology advances, trim technology continues to evolve and now offers spot sizes under 4um, positioning accuracy to 1um, positioning speed of a few ms, and field coverage of up to 8 inches; addressing such diverse applications as VLSI memory repair, and complete PC board assembly trimming. Increased automation in the form of fully automatic device loading, alignment and beam focus are resulting in vastly improved thruput and lowered manufacturing costs. New, faster, and more accurate instrumentation is being introduced to trim the new mixed digital/linear parts beyond the traditional restriction to simple passive resistance and functional DC trimming. Furthermore, trimmable device design has emerged from the "black art" catagory and predictable results can now be achieved. However, gaining familiarity with all aspects of functional trimming is a formidable task and this is a major reason more manufacturers haven't added laser trimming to their bag of tricks.

Introduction

To get the most out of functional laser trimming, a manufacturer must be familiar with device processing and how it affects trimmability; circuit design and how the trims affect device parameters; test methods and how influenced by laser light and trim dynamics; and the mechanics of device handling for proper beam alignment and focus. This review attempts to give an overall perspective of current capabilities of functional trimming, while identifying avoidable problem areas.

Laser trim fundamentals

Nd:YAG lasers have been used for resistor trimming to improve accuracy since the late 1960's. The basic principle is to cut away a small portion of the resistor by vaporizing with intense pulses of laser energy until the desired resistance value is reached as read by a resistance bridge. Accuracy gains of several orders of magnitude are possible making the use of inexpensive bulk processed thick and thin film resistor networks practical for precision circuit applications.

By far, most circuit trimming using lasers involves resistors, but some manufacturers trim crystals, capacitors, and even printed inductors as well. The trim mechanism is always the same, however; material cutting by vaporization. Other trim mechanisms such as selective diffusion and annealing have been demonstrated (1), but none of these have yet been used in production applications.

Depending on the component and laser cut geometries, the change in measured parameter can be made in large steps by cutting links or essentially continuously by using a series of overlapping pulses creating a variable length cut. The continuous approach shown in figure 1A has the advantage that the trim resolution and hence potential trim accuracy is limited only by the incremental cut length or physical spacing between laser pulses. On the other hand, link cutting shown in figure 1B results in relatively poor trim resolution but is capable of superior post trim stability.

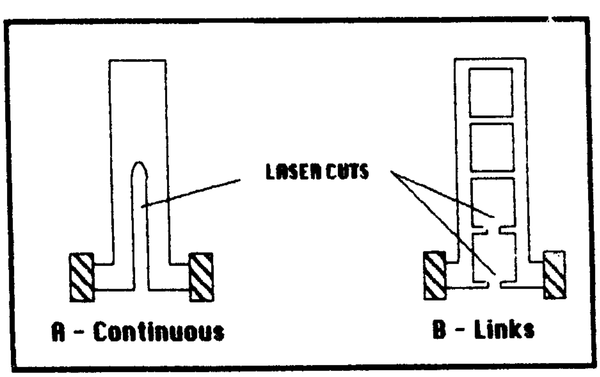

Figure 1 - High Resolution Vs Discrete Step Trim Geometries.

So far we have been discussing passive trimming ie, the circuit is not operating, only the portion of the circuit being trimmed is connected to the measurement instrument. Functional trimming, the subject of this review, is where the entire circuit is powered up and operating normally while some internal component is trimmed. In this case the instrumentation is monitoring some device parameter rather than the component itself. The chief advantage is that all contributors to the error in the device parameter are accounted for in the trim process resulting in higher overall trim accuracy. Depending on the choice of instrumentation, literally any parameter can be trimmed.

Circuits currently being functionally trimmed in high volume production include those made from discrete components, thick and thin film hybrids and monolithic IC's. Recently wide field lasers have become available to allow trimming of complete printed circuit assemblies or complex hybrid functional blocks up to 8 inches square.

Any functional trim system consists of four fundamental parts ie, the laser source which generates high intensity light pulses, the optics for focusing and deflecting the beam, the instrumentation system for device stimulus and measurement and the device handler for contacting the device and positioning it under the beam in proper alignment.

Laser source characteristics

Nd:YAG lasers are now used almost universally for circuit trimming applications due to their reliability, stability and high peak power output, all vital for functional trimming. General purpose lasers from several manufacturers were successfully used in passive and some functional trim applications up to about 5 years ago but as the applications got more sophisticated, these lasers were found lacking. Laser rails specifically designed for functional circuit trimming are now available. Let's look at the important features required for functional trimming.

Typical laser sources are notorious for generating radio frequency interference (RFI) which if uncontrolled, interferes with measurements, particularly on functioning devices operating at low levels or wide bandwidths. For example, a typical laser rail may contain a 3000 watt arc lamp which is a very effective broad band noise source. Also, a 10-50 watt 50 mHz generator is used to gate the beam on and off thru a Q-switch; another effective RFI source. The associated power supplies need suppression of switching spikes as well. Fortunately, some trim system suppliers have recognized this problem and taken steps to reduce RFI to tolerable levels. Conventional laser sources intended for passive trimming or general cutting applications can rarely be used successfully in a functional trim application.

Another important characteristic is the peak power stability of the source. Insufficient power can cause unstable trims while excessive power causes substrate damage or microcracking. The process window of thin film on silicon is particularly narrow. Pulse-to-pulse stabilities of <4% are available to satisfy these applications.

A problem peculiar to silicon wafer trimming is power control. Considerable variation occurs in the optical characteristics across a typical wafer and the acceptable process window is quite narrow. To maintain cut quality, the laser power must be varied to match the absorptivity of the device. This is usually done by periodically interrupting the run, examining cut quality, and making any required laser power adjustments manually. Many bad trims still get thru, however. What is needed is a method to continuously monitor cut quality and make adjustments on the fly.

Programmable laser power is provided by most systems but the method varies. The most common technique is to adjust the pump lamp current. But this is slow, tends to shorten lamp life, and results in less pulse to pulse stability. Another method is to use solenoid operated attenuator mirrors in conjunction with motorized cross polarizers for coarse and fine power adjustment. This is also somewhat slow but allows the laser to run at its most stable operating point at all times. A recent development is the extra-cavity linear Q-switch which can modulate laser power over a wide range in microseconds while maintaining pulse stability. But determining optimum laser power on line requires a means to monitor cut quality as well.

One technique is to sever a resistor with the laser and measure the electrical leakage current across the cut. If the leakage is too high, indicative of material remaining in the cut, the power is raised. However, this gives no indication of substrate damage from excessive power. Another recent development allows the laser to measure the amount of reflected light from the device during trimming which can detect this damage. Thus all the elements for automatically controlling cut quality are now available for the first time but to my knowledge have not yet been exploited by manufacturers.

An inherent characteristic of Nd:YAG lasers is the emission of a particularly energetic "first pulse" just after being gated on. This pulse must be suppressed for maintaining uniform cut quality. Three methods are being used. One is to keep the pulse repetition rate below 1kHz where all pulses tend to be "first pulses" of similar size. However, this restricts trim speed in some cases. Another technique is to use a mechanical shutter to block the beam for a short time. This is also slow, requiring 20-50ms each time the beam is gated on or off and tends to drift out of adjustment as the shutter blade itself is trimmed. It also produces gaps in multi-cut trims such as L-cuts or coarse/fine algorithms. The best technique is to downward modulate the lamp power for a few mS to dump excess power. This method is trouble free, needs no adjustments, and is very fast, but is only available from one laser vendor.

Experiments (2) have shown that trim stability can be improved by reducing the pulse duration from the typical 150-300ns of standard rails to the 30-70 ns region. In addition, short pulses induce less photocurrent and thermal heating effects detramental to functional trimming. Pulse slicers can be used for this but are not recommended due to reliability and RFI problems. Laser rails designed to deliver short pulses are the best way to go but are not suitable for all applications since short pulses tend to do more damage to some passivation layers.

Table 1 summarizes the major laser source attributes which are important for functional trim applications.

Table 1 - Typical Laser Source Attributes vs Application

Laser Source Parameter	Thick Film on Ceramic	Thin Film on Ceramic	Thin Film on Silicon
Pulse Width	70-300 nS	30-150 nS	30-200 nS
Mode	Tem 00	Tem 00	Tem 00
Rep Rate	1-5 kHz	1-4 kHz	0.25-3 kHz
Average Power	1-10 Watts	0.1-0.5 Watt	0.02-0.1 Watts
Wavelength	1.064 nm	1.064 nm	0.532 or 1.064 nm

Beam positioning and optics

For stable trims, the cutting beam must be the correct size, properly focused, and with a gaussian power density. Thick film resistors require spot sizes from 25 to 50 microns to achieve fast cutting and to prevent redeposition of vaporized material in the cut. On the other hand, thin film trimming spot size is limited primarily by the size of the resistors being trimmed. Trimming large resistors with a very small spot size will be slow while trimming small resistors with a large spot will be less stable. Spot sizes of 10 to 25 microns are suitable for thin film on ceramic substrates while spots from 4 to 12 microns are used for most silicon wafer trimming.

The beam emerging from the laser rail must be apertured to produce the fundimental Tem00 mode which gives a gaussian power density. An aperature too large may allow multi-modeing which increases the stray power outside the kerf causing less stable trims while an aperture too small reduces laser power efficiency.

Movable mirrors are used to position the beam under program control. Two methods are in general use ie, galvo and linear. The galvo method uses a pair of galvanometers to rotate X and Y axis mirrors in the collimated beam path ahead of the objective lens. This method is considerably faster than the linear type but requires periodic calibration to achieve accurate positioning due to its inherent nonlinearaties and distortions. The linear type consists of a linear translation mechanism driven by linear motors. Position encoders used on each axis provide closed loop control assuring accurate results without calibration. However, the mass of the mechanism is much greater than the galvo type, consequently, its speed is reduced during point to point moves. Trim speed is not sacrificed though since trim velocity is limited by cut quality and measurement constraints.

Positioning accuracy, resolution and repeatability are often confused with each other but they all have separate meanings. Accuracy describes the precision to which a point anywhere in the field can be programmed. Its chief importance is in the interchangeability among different machines and in accommodating device positions anywhere in the deflection field. Production applications demand the scheduling flexibility of being able to run any program on any machine. Sufficient accuracy permits entering trim coordinates directly from the layout drawing or CAD file, rather than experimentally "walking them in" using a joystick. This results in closer trim placement and more predictable trim sensitivity.

Repeatability means how well a certain point can be reached from different directions at different times. The point reached may not be that programmed or may have been "walked in" using a joystick with its absolute position otherwise undefined. You cant have accuracy without repeatability but you can have repeatability without accuracy.

Resolution generally means the smallest step size or beam increment possible. In galvo systems, this is also the trim resolution or byte size. Linear systems, however have higher trim resolution than positioning resolution since the beam moves at a programmed velocity during trimming. The trim resolution becomes the velocity divided by the pulse rate.

Table 2 lists typical beam positioning parameters used for thick film, thin film on ceramic and monolithic IC trim applications.

Table 2 - Typical Beam Properties vs Application

Beam Parameter	Thick Film on Ceramic	Thin Film on Ceramic	Thin Film on Silicon
Focused Spot	25-50 um	10-25 um	4-12 um
Positioning Resolution	2.5-10um	2.5 um	1-2.5 um
Positioning Accuracy	2.5-10 um	2.5-5 um	0.5-2.5 um
Depth of Focus	250 um	100 um	12-25 um

Beam to device alignment

All of the above terms apply to the beam deflection field, not the actual beam position on the device being trimmed. This is an important distinction since the former is specified but the latter is what is important. Some provision is needed to align the beam to the device or vice versa, in X, Y, and angle. Mechanical alignment of the device to the beam, described later in the handler section, is often combined with some form of alignment of the beam to the device, either manually or automatically.

Manual beam-to-work alignment is done by directing the beam as indicated by a cross hair or spotting beam to a designated alignment mark or feature of the device using a joystick. The offset between the actual mark position and its programmed position is then used to offset all trim positions. Some systems provide software for doing a two point alignment and correcting device angle as well. In this case the trims are made diagonally to coincide with the device angle. Accuracy of the manual method depends on the care the operator takes in making the adjustments, the viewing resolution, and the alignment accuracy between the cutting beam and the cross hair or sighting beam. The chief disadvantage of the manual method is that it typically takes from 2 to 10 seconds per joystick operation.

The above operations can be performed automatically and much faster using the laser in an edge sensing routine, provided suitable resistors are available in the device layout. Basically the beam is positioned well off the resistor and a trim is begun with the beam moving toward an edge of the resistor. A marked change in resistance occurs when the resistor edge is reached. (See figure 2A.) At this point the trim is stopped and the position read back. Repeating the routine in the other axis allows X and Y position corrections to be made. Accuracy depends primarily on the trim and measurement resolutions and the resistor geometry. Special narrow resistors are sometimes provided to enhance the edge finding resolution. An edge finding trim can be performed in 5-50 ms, depending on the resolution and correction range requirements.

Recently, laser systems have become available with the ability to see features on the device by sensing reflected laser light. By attenuating laser power during a scan, device features can be located non-destructively, requiring no special resistors or measurement access. (See figure 2B.) It is also possible to sense relative focus of the laser beam allowing completely automatic alignment of X, Y, angle, and device height. Variations on the routines can be used for making wafer alignments automatically as well.

Edge finding speed is similar to the active trim method ie, 5 to 50ms and complete wafer alignments can be made in 10 to 45 seconds. Accuracy depends primarily on the optical properties of the device. Rough surface texture of the device features and background can make it hard to distinguish an edge. Furthermore, certain features may be invisible to the laser wavelength even though readily apparent to the eye. These problems can usually be circumvented by proper selection of feature used for alignment.

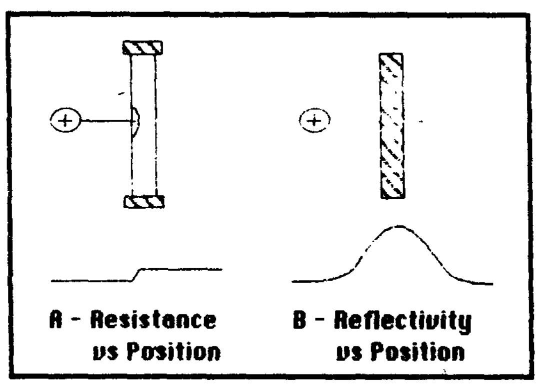

Figure 2 - Automatic Edge Finding Schemes