“Green” Production of Power Semiconductors

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While everyone is talking about lead-free (Pb-free) electronic devices for environmental protection, the pollution during production of the parts itself has been of less interest. In 1995, Diotec introduced its “Plasma EPOS Technology” which not only allows the omission of tons of aggressive acids but also improves the quality of the produced parts. Using dip-tinning for the lead finish is another step to avoid lots of chemicals which would be necessary for galvanic tinning. In the future both legislative as well as market pressures will force electronics' manufacturers not only to sell eco-friendly products, but also to produce them according to stringent environmental regulations.

Several environmental laws have come into force within the EU, including the Reduction of Hazardous Substances (RoHS), Waste Electrical and Electronic Equipment (WEEE) and End of Life Vehicles (ELV) directives, all of which require electronic device manufacturers to reduce or avoid use of hazardous substances like heavy metals. The best examples for such substances are the lead-based tin alloys for plating the contact leads of electronic components. The European Directives were created to cope with the rapidly-growing waste stream of electrical and electronic equipment that’s been identified as one of the largest source of heavy metals and organic pollutants in municipal waste. Similar are actions are underway in Japan, and should eventually be in force in the US as well.

There is also a less well-known EU regulation (currently in the draft proposal phase) that deals with the impact of Electrical and Electronic Equipment on the Environment (EEE). This directive’s goal is to avoid waste even before a device has finished its life cycle. In addition to addressing issues concerning the disposal of equipment, it also contains measures that require minimization of pollution during production and usage.

There is also a growing market pressure which may drive manufactures nearly as heavily as any legislative requirements. While not required by law many companies are finding that their customers want them to comply with environmental certification processes such as ISO14000 and EMAS. This produces a “trickle-down” effect as major manufacturers in the telecom, networking, and other industry sectors begin to ask their suppliers to help them “clean up” their supply chain by employing environmentally-friendly production processes.

These factors, plus a strong corporate commitment to environmental responsibility, caused Diotec to replace its conventional processes for the production of its diodes and rectifiers with innovative, eco-friendly technologies. Adoption of these processes has resulted in a drastic reduction of chemical waste with no increase in production costs. As we will see, the other important benefit of using these “clean” processes is an improvement in the quality of the products we make.

Fig. 1: Semiconductors made with Plasma EPOS technology drastically reduce chemical waste and improve quality

The Standard Technology

Normally, a silicon wafer is cut into many separate chips after the diffusion process, using a mechanical saw. This results in the crystal lattice being destroyed in the area of the saw cut, as well as creating a problem with "dust" (particles from the metallization, particles from the silicon wafer etc.) that remains at the edges. The destroyed portion of the structure is usually cleared off the diode using a chemical etching process when the completely-assembled diodes are put in an etching fluid. Once the etch process is complete they have to be rinsed in ultra-pure water. The p-n junction is then coated with a protective layer.

This process has several disadvantages. For one thing, electrical tests on the chips are only possible when all these production stages have been completed. Then too, the toxic and corrosive liquid etching fluids have to be disposed of in an environmentally-responsible, and often costly, manner. There is also the cost and environmental impact in producing and re-filtering the many liters of clear water used for rinsing the die. There are also quality and yield impacts since ionic contamination of the p-n junction can create unwanted leakage currents in a significant fraction of the diodes being produced.

The Plasma EPOS Technology

In 1991, Diotec replaced the conventional chemical etch technology with the EPOS-technology (**E**tched and **P**rotected **O**n **S**lice).

This has allowed us to check the quality of the chips before assembly, with a resulting savings in manufacturing costs. It is also possible to pre-select matched components for multi-chip parts like bridge rectifiers, or “bin” them for specific applications. The result is better yield, less waste and improved quality.

In 1995 Diotec further optimized the EPOS-process by developing the Plasma-Processes. Both elements of the manufacturing process are ecologically beneficial with a minimum of chemical pollution.

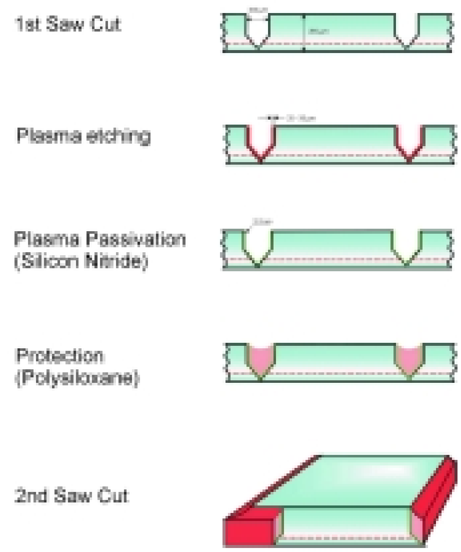

Fig. 2: Schematic Representation of the Plasma–EPOS Technology

Instead of using toxic chemicals, the etching and first passivation are done using plasma under near-vacuum conditions. The separation of the chips takes place in two stages (see Fig. 2). First, V-shaped cutting blades create a bevel groove that electrically isolates the chips from one another without completely cutting through the wafer. Plasma-etching is then used to clean the p-n junction. The gas flow removes the particles, preventing them from settling on the wafer again. Immediately afterwards, the remaining clean lattice is passivated using a plasma stream containing Silicon Nitride Si_3N_4. The furrows on the wafer are filled with Polysiloxane and, after the curing process, completely cut through. This second cut through the Polysiloxane is made with a very thin saw blade which does not disturb the crystal lattice near the diode’s junction.

Double Passivation

a) Silicon Nitride thin films are used for insulation because they are dense, stable against oxidation and show very good barrier characteristics against moisture penetration. They feature many of the same characteristics of glass passivations, made by silicon-oxide (SiO_2). By using the plasma technology it becomes possible to deposit Si_3N_4 at a temperature lower than the melting point of the Ni/Au-metallization.

b) Polysiloxane has optimal characteristics and is used in the semiconductor industry mainly for the passivation of ICs, eg RAM-chips, where very low longterm defect rates are required. Polysiloxane is temperature-proof, so that the chips in the following process can be soldered as normal and be moulded into epoxy. Since this material is flexible it also provides protection against mechanical stress to the edges of the silicon chip, eg during temperature cycling.

Tinning the Leads

After moulding the parts, the contact leads are finished with a tin coating. This is usually accomplished using either galvanic plating or dip-tinning processes. The plating process results in smooth, good-looking surfaces but there are several disadvantages, including the need for toxic fluids, like hydrogen cyanide, that have high disposal costs. Equally important, the adhesion of plated tin is not always prefect, resulting in separation from the contact and a loss of solderability. As its name implies, the dip-tinning process plates component leads by dipping them into a molten-tin alloy. The advantages of dip-tinning include excellent adhesion to the contact material and stable solderability -- even when the parts have been stored for some time. The only drawback here is that the thickness of the tin coating varies slightly, causing the surface to look worse than with galvanic tinning.

Since May 2004 Diotec has used lead-free (Pb-free) tin alloys and dip-tinning processes for plating all its component leads in full compliance with EU directives like RoHS, WEEE and ELV.

Conclusions

Sooner or later global eco-legislation will force electronic component and equipment manufacturers to institute environmentally-responsible manufacturing and design practices. This will include considerations for both the design to minimize products' impact when they are manufactured, as well as at the time of their disposal. What's more, customer demand may force some manufacturers to institute these practices ahead of legislative requirements. But even though these changes in business practices take significant effort and expenditure, Diotec's experience shows that most manufacturers will benefit as much as the environment in the form of lowered costs and improved quality.

References

For more information about European environmental laws, visit the EU Law web site
http://europa.eu.int/eur-lex/en/index.html

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