Cleaning

STENCIL PRINTED WAFER BUMPING

KYZEN
CORPORATION

Stencil or screen printing of solder pastes is a well-known and well-proven process technology for surface mounted components. Application of this technology to the deposition of solder bumps is a natural progression for bump sizes and pitches commonly found in surface mount technology. Stencil printing offers a very quick in-line method of solder deposition but may have difficulty delivering precise solder volumes at ultra fine pitches (<150µm). For moderate pitches in the range of 200 µm, the bumping yield is sufficient. Stencil printing is a fast and cost effective method for wafer bumping.

Stencil printing is widely used in surface mount assembly. The conventional printing methods and materials are not suitable for applications with ultra fine pitch structures. To achieve reproducible and homogeneous solder deposits, the process techniques for fine pitch printing require an improvement of the physical properties of solder paste, of the stencil materials and of the stencil processing technologies as well as the printing equipment. Using solder printing for ultra fine pitch applications, solder pastes with very small particle sizes require a nitrogen atmosphere and a well controlled temperature profile of the reflow furnace.

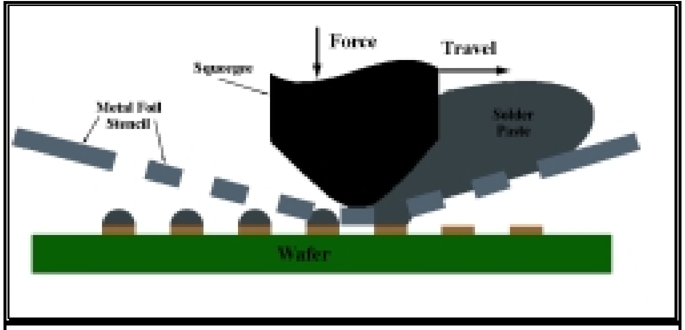

Figure 1: Stencil Printing Using a Squeegee

In order for the paste to release from the stencil and remain on the pad, the wetted area of the stencil must be minimized. Therefore, the stencil thickness should be less than the aperture diameter, setting a lower practical limit on bump diameter. Stencils less than 50µm thick are fragile and dimensionally unstable as the squeegee drags the paste over them. In addition, alignment must be performed optically for fine features and this requires finding wafer fiducials through small holes in the stencil.

The stencil printing process has many variables. The following factors have to be taken into account to achieve high quality and reproducible precision of ultra fine pitch printing.

- Printing Equipment: printer (pressure head or squeegee), wafer holder
- Stencil: aperture quality, wall smoothness, thickness, size, geometry
- Machine Setup: print speed, pressure, snap-off, separation speed, alignment
- Squeegee: squeegee material, hardness, angle
- Solder Paste: particle size, distribution, viscosity, thixotropy, flux vehicle, slump characteristic, metal content
- Environment: temperature, humidity, dust
- Operators: training, awareness

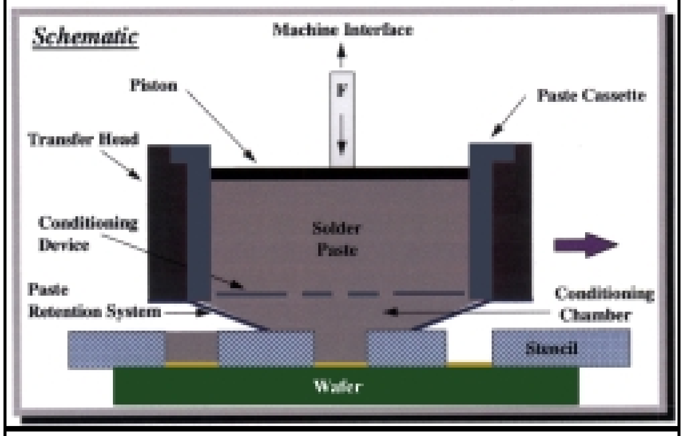

Figure 2: Stencil Printing Using Pressurized Head

For flip chip applications the particle size of the solder is an important factor. Solder pastes with homogenous distributions of particles and sizes smaller than 25µm is required. Volume and height of the deposited solder depend on the thickness and the size of the opening of the applied stencil and the squeegee material.

Under Bump Metallurgy:

The purpose of the under bump metallurgy is to provide a solder wettable surface for the bump, where the bump can form strong intermetallic bonds. The UBM prevents solder balls from diffusing through the material, thereby dewetting from aluminum chip pad. The under bump metallization can be deposited by either sputtering or electroless plating.

Process Flow for UBM Sputtering:

Three metals make up the under bump metallurgy. The first layer is sputtered aluminum, followed by sputtered layers of nickel and copper. The aluminum forms a strong adhesion to the wafer passivation, nickel provides a diffusion barrier layer, and copper prevents oxidation to the nickel layer. Positive photoresist is applied, developed and patterned to protect the UBM. The Al/Ni/Cu layer is etched away except over the bond pad. The resist is removed, solder paste printed, reflowed and cleaned.

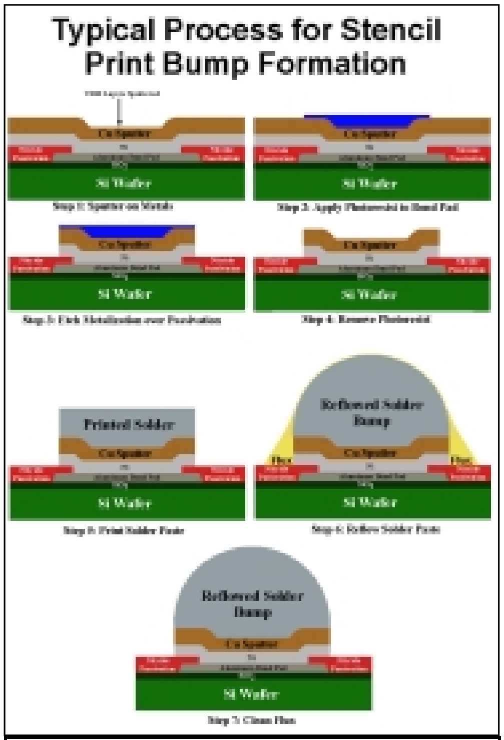

Figure 3: UBM Sputtering Process Flow

Process for Electroless Nickel UBM:

Electroless Ni/Au requires selective chemical plating technology. This technique allows parallel processing of multiple wafers, leading to a high throughput. When applying this technology to functional wafers with complex inner electrical structures, different metallization and different passivations, the process requires specific proprietary chemical compositions and know how for a reproducible and reliable result.

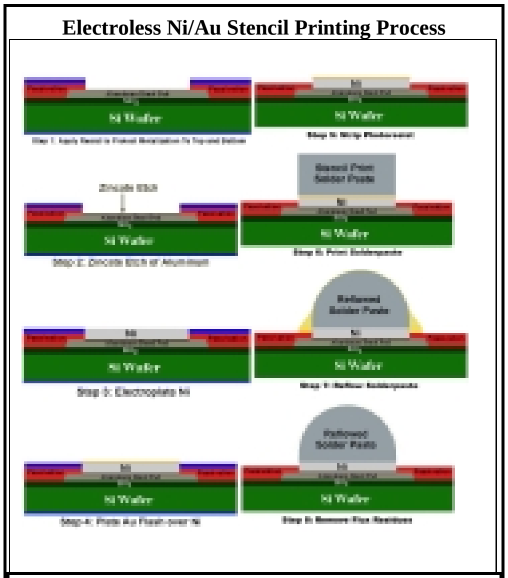

Figure 4: Electroless Ni/Au UBM followed by Stencil Printing Process

Electroless nickel is an under bump metallurgy that can be used as a foundation for a solder bump, or as a stand alone minibump that can be used in conjunction with conductive adhesives. The wafer must be compatible with the process. Except for the Al bond pads, all exposed metal must be passivated. The wafer backside has to be covered by a stable resist to prevent attack during processing. The next step is a treatment of the pads in an alkaline zincate solution that is designed to etch the aluminum bond pads. Nickel is plated onto the aluminum bond pads at a rate of 20µm per hour. A final Au coating on the Ni is necessary to prevent oxidation and enables long-term solderability.

Electroless Ni/Au provides a suitable UBM for stencil printing processes. The wafer is printed with solder paste that typically uses water-soluble or rosin flux bases. The wafers are cleaned using aqueous, semi-aqueous or solvent based cleaning formulations.

Dry-Film Used as a Screen: This method is used for processes that have finer holes that require precise positioning. A layer of dry film resist is used as a screen to pattern the bump sites. Solder paste is pressed into the holes with a flexible wiper. The solder paste is reflowed. After reflow the dry film resist and flux residue are removed.

Dry film removal is not an easy process. Aggressive cleaning agents are required to dissolve the resist film as well as removal of the reflowed flux residues.

Stencil Printing Cleaning Requirements:

For most stencil printing processes, flux removal is the key cleaning requirement. The flux chemistries in the solder paste may consist of water soluble, low solids or rosin.

Water Soluble Flux Removal: Typically hot DI water is all that is required to remove water soluble flux residues. There are typically thousands of solder bumps on the wafer surface. The reflow profile must provide even thermal distribution to assure high yields. Water soluble flux chemistries have a tendency to form insoluble salts with the alloy. This increases the difficulty of cleaning these wafers with DI water only.

DI water with additives may be required to remove water soluble flux residues.

Recommended Cleaning Solvents:

Micronox MX2120: Concentrated surfactant blend that is diluted at a concentration range of 3-7% in the DI water wash process. The surfactant composition wets the residue allowing removal lead/tin salts, organic acids and solder balls in the aqueous cleaning process. Designed for use in aqueous batch or spray-in-air cleaning machines.

Non-linear alcohol based solvents also do a fine job of removing these residues. See description below.

Low Solids/Rosin Flux Removal: Low solids or rosin flux residues require chemical cleaning agent. Semi-aqueous cleaning solvents are typically selected to clean these residues. These cleaning agents solubilize the flux residue and are rinsed with DI water.

Non-linear alcohol**:** Non-linear alcohol compositions have a molecular weight of around 100, low vapor pressure, high flash point and low surface tension. Cleaning compositions formulated with this technology have been widely adopted as a leading alternative for a wide variety of flux residues. This cleaning composition does an effective job of solubilizing both rosin and resin structures as well as removal of ionic contaminants. The compositions have complete water solubility, which allows ease of rinsing with DI water.

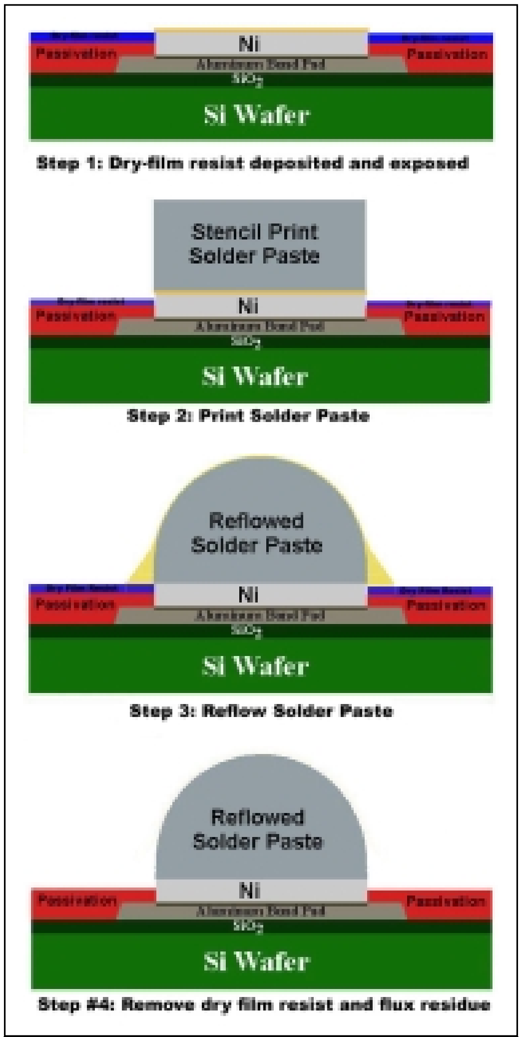

Figure 5: Dry Film Stencil Printing Process

Micronox MX2340 & 2350 cleaning solvents are based on Kyzen's non-linear alcohol. A simple organic compound, Kyzen alcohol is environmentally derived from natural organic material or biomass. It has a very low vapor pressure (approx. 0.6mm Hg at 70°F) and a flash point in excess of 160°F. These key flash point characteristics allow these formulations to be classified as non-flammable per DOT regulations. This alcohol-based formulation is highly effective on polar flux and ionic salts. These formulations are completely water-soluble and after cleaning, the substrates are typically rinsed with DI water.

Dry Film/Rosin Flux Removal: This is a highly difficult cleaning task. The ideal approach is a cleaning agent that dissolves both the dry film and flux residue. The cleaning solvents are typically solvent or aqueous blends that contain highly aggressive activators.

Micronox MX2414 contains an aprotic solvent composition in combination with an inorganic base. The cleaning composition is inhibited from attack on non-ferrous alloys. This is an extremely aggressive cleaning formulation that will dissolve both dry film resist and flux residues that are caramelized. It is effective on residues that have undergone multiple reflow cycles.

Micronox MX2365 is an aqueous solvent composition that combines solvency with reactivity. This cleaning agent effectively removes both dry film and flux residue during the cleaning process.

Four key variables must be considered when cleaning high temperature flux residue around the base of the bumps:

1. **Solvency**: The flux residue consists of water-soluble, rosin or low solids no clean formulations. Aqueous or semi-aqueous solvent cleaning technologies are typically selected to remove these tenacious residues. It is important to match the solvent cleaning composition to the contaminant. "Like dissolve like" is a general rule worth consideration. Flux residues leave behind both ionic (flux activators, plating salt residue, salts from handling) and non-ionic (rosin, resin, oils) contaminants. The cleaning composition must have an affinity for both soil types. In addition, it is advantageous to have water solubility, low surface tension, low viscosity and high flash point.
2. **Impingement:** The greater the impingement energy sources the lower, to a degree, the other three variables of time, temperature, and solvency may be to achieve the same cleaning result. There is a limiting factor of impingement force based on the part being cleaned. Impingement sources for cleaning bumped wafers include spray under immersion, megasonic, centrifugal and spray in air agitation.
3. ***Temperature***: Flux residues dissolve into the semi-aqueous cleaning composition. Temperature of the cleaning bath is directly proportional to cleaning time and effectiveness. Flux residues have a rosin or resin structure. Rosin and/or synthetic resins have a melting point around 80°C. Semi-aqueous cleaning compositions heated at a range of 60-80°C rapidly soften the flux resin, allowing solubilization into the cleaning media. The viscosity and surface tension of the semi-aqueous cleaning composition typically go down when heated to the desired temperature range.

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4. ***Time:*** Time is the most elastic of the four variables. Increases in temperature, impingement, and solvency all allow a decrease in time. Likewise decreases in temperature, impingement, and solvency create a need for more time. Time can be impacted by outside parameters such as the flux formulation, reflow parameters, and alloy.

Benefits and Drawbacks of Solder Printed Bumps:

- Economics: The solder paste bumping process is less expensive than the evaporative wafer bumping processes and competitive with plated bumping costs.
- UBM: The sputtered Al layer provides excellent adhesion to the IC metallization and protects the underlying bond pad. The UBM also exhibits excellent adhesion to many passivation types including silicon nitride, silicon oxide and several types of polyimide. The Ni layer provides a solder diffusion barrier and is a solder wettable surface after the oxide prevention Cu or Au layer is consumed.
- Solder Bump Structure: The solder bump is extremely reliable and robust enough to withstand over 10 reflow cycles. The structure of the bump and the type of alloy used ensure a predictive amount of solder bump collapse. The deposited solder bump can experience a 10-30% collapse when reflowed providing a robust assembly process.
- Alternative Alloys: Solder paste deposition allows for alternative alloys such as lead free solder.
- Eutectic 63Sn/37Pb Solder: Lower reflow temperatures and compatibility with organic substrates.
- Environmental: Solder deposition processes are typically well controlled with little wasted material.

Conclusion:

Kyzen's innovative Micronox product line provides solutions for stencil printing wafer bumping specialized cleaning applications. Precision cleaning is about process. The four process parameters of time, energy, solvency and temperature must all come together in an integrated cleaning solution.

Kyzen's Cleaning Applications & Evaluation Center provides technical support for selecting the appropriate chemistry and process. The lab is designed for prospective customers to send their parts for cleaning process evaluation. The technical support staff will validate and recommend the cleaning process parameters to meet your requirement. Prospective customers are encouraged to take advantage of these resources. Technical personnel are available to discuss your critical cleaning application.

Figure 7: Kyzen's Cleaning Applications & Evaluation Center

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