Electrodeposition of Indium Bumps and Under Bump Metallization for High Sensitivity Spectroscopic X-Ray Detectors

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The assembly of pixellated X-Ray detectors used in high-energy physics, (e.g. the PILATUS detectors at the Diamond Light Source) requires the direct interconnection of sensor and readout chips (both bare Si die) for which indium bump bonding has been successfully applied. In general, indium bump bonding is used as it does not interfere with the X-ray signal detection, offers ultra-fine pitch interconnections (<100 μm), is a low temperature process and can be carried out with a high yield (greater than 99%). The current state-of-the-art solution developed by the Paul Scherrer Institute (PSI) employs photolithography, sputtering and evaporation to produce the indium bumps with a Ti/Ni/Au under bump metallization (UBM) [1]. However, the process requires many steps which make it expensive for relatively large production volumes.

The aim of this project is to investigate alternative manufacturing methods for the deposition of the indium and UBM based on the use of electroplating rather than sputtering and evaporation (Figure 1). Electroplating offers the potential for lower cost and higher productivity. However, for this to be successful, it is necessary to generate the indium bumps at fine pitch with a variation of bump height across the wafer of less than 5%. Therefore, a key challenge for the electroplating method is to control the current density and distribution across the wafer surface to ensure the bump uniformity. Due to the application of the electrical contact at the boundary of the wafer and the appreciable resistance of the thin seed layer, the current density will vary across the wafer (known as the terminal effect) leading to bumps of different heights. On the other hand, the mass transport can play a significant role in determining the bump morphology and uniformity within different dimension scales.

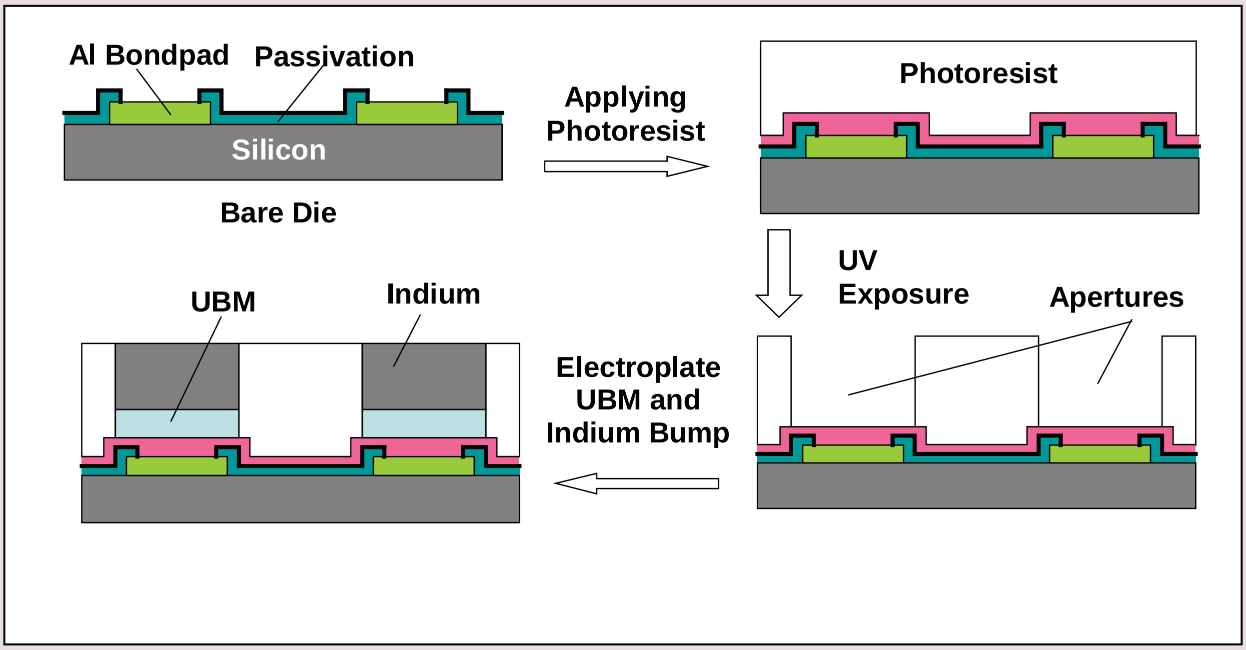

Figure 1 Schematic diagram of the electroplating process applied to indium bump bonding.

To date, a number of methods to ensure the uniformity of deposition have been investigated including the design of plating cells that lead to a more even current distribution. Pulse plating has also been used to control the deposition rate and deposit properties through the application of various waveforms of current and voltage. Ultrasonic agitation (up to 1 MHz) has also been considered as a promising approach to pre-wet the ultra-fine pitch pattern and to enhance or modify the mass transfer distribution.

A plating plant has been designed and built capable of 8 inch wafer plating. The plant has a built-in circulation system to flow the electrolyte during the electroplating process and the temperature of the solution can be carefully controlled. The distance between the electrodes can be adjustable which allows the electrical field in the tank to be modified by introducing an electrical shield etc. The result of DC plating has shown the capability of the electroplating process to generate ultra-fine pitch indium bumps with high yield, as shown in Figure 2. Noticeable non-uniformity in the bump height across the whole wafer and uneven bump profile was observed. Pulse plating has shown improvements in the morphology and microstructure, however, a change in frequency and duty cycle did not have significant influences on the indium bump morphology (Figure 3).

The removal of the seed layer which is also part of the under bump metallization is an important issue for the process. A binary layer of Ti/Cu was utilized for the experiments and methods to remove the Cu layer were developed. The titanium layer was left in place to prevent the indium from wetting the wafer during reflow. Bumps were reflowed with the aid of a flux using a conventional reflow oven. Figure 4 shows 20 µm diameter bumps at 50 µm pitch after reflow. In initial investigations, the difference of the bump height within a 3 inch wafer could be reduced to 3.6 µm combining pulse plating and a thief ring design.

Megasonic agitation was also investigated using a copper plating bath to determine the influences of vigorous mass transport on the bumping process. The results for copper indicated that megasonic agitation is able to dramatically change the morphology of deposits and the deposition rate could be increased. The indium plating plant has now been equipped with a megasonic transducer and the investigation of megasonic agitation enhanced indium bumping is ongoing. Further studies will focus on optimisation of the processing parameters to achieve the best uniformity and yield. Also, electroplating of a thicker UBM will be carried out. A compatible seed layer removal and reflow process needs to be optimised as well. Finally, the process will be transferred to real detector chip assembly through the research collaboration of Loughborough University and Rutherford Appleton Laboratory.

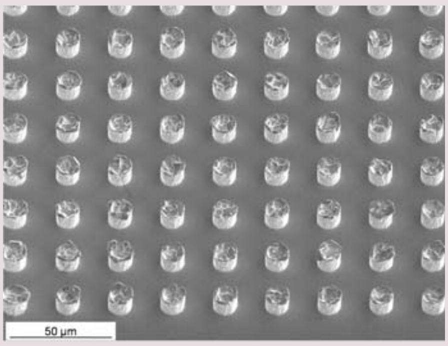

Figure 2 DC plated indium bumps at 20 µm diameter and 50 µm pitch

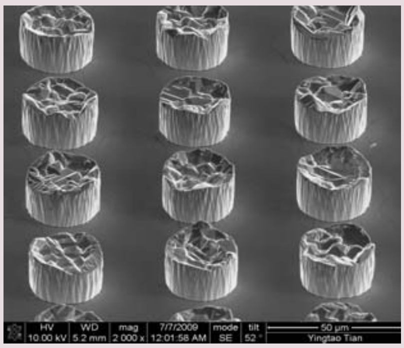

Figure 3 Indium bump plated through pulse plating: 100 Hz, 20% duty cycle.

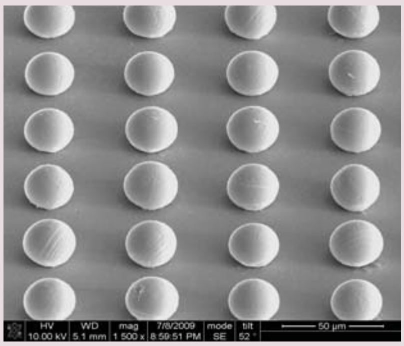

Figure 4 Reflowed indium bumps: 20 µm diameter, 50 µm pitch.