Introduction

Electron backscattered diffraction (EBSD) is an established technique in micro-structural materials characterisation. It is applied in determining grain size, grain orientation, in characterising grain boundaries and in determining texture. It offers useful insight for many different materials and industries, including microelectronics. This application note describes the use of AZtechHKL with a Nordlys EBSD detector in the characterisation of Through-Silicon Vias, or TSV.

Through-Silicon Vias

TSVs are becoming increasingly important in the microelectronics industry, as there is a continuous demand for faster, cheaper and smaller devices. Typical applications include demanding high power devices and the integration of many devices on the same package.

One approach is 3D integration, which relies on stacking or flip chip configurations and this has led to the development of Through Silicon Vias. The TSV are used to establish an electrical connection so that the stacked chips function as an integrated circuit.

Performance and Lifetime

This new technology requires a thorough understanding of materials, processes and reliability at the nano-scale. The TSVs are generally formed by etching the silicon, the manufacture must be controlled during fast etching so that the TSVs retain a good via profile. The etched via is typically lined with an insulating layer of oxide or a dielectric, and this insulator must maintain its integrity and function throughout the device lifetime. Typical failure analysis at this scale requires FIB lift-out followed by analytical and structural characterisation in TEM. EBSD offers an SEM based characterisation method that is immediate and effective.

Electron Back-Scattered Diffraction

Key components which influence TSV performance include the structure of the metallic infill and the nature of the metal-oxide interface. Characteristics of interest include grain size, grain orientation and grain boundary types. EBSD provides a full characterization of these properties, which is comparable to TEM-based methods. In addition, EBSD delivers a quantitative description of phases, grain orientation and texture.

Experimental Work

In this investigation a TSV sample, taken after the filling stage of production, was examined. A section of the sample containing a series of TSV’s was extracted using a Focused Ion Beam (FIB).

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This section is illustrated in the low magnification images in Figures 2a and 2b: the light contrasting vertical features are the TSV’s.

This section was polished using an ion mill and examined in a FEG SEM using both EBSD and Energy Dispersive Spectrometry (EDS) techniques. The detectors used were a NordlysMax² and an X-Max 80 respectively. The EBSD & EDS data was acquired at an SEM acceleration voltage of 20 kV and a probe current of 6.7 nA.

Results

Figures 3a and 3b show higher magnification images of the TSV after ion milling. The main body of the TSV has a coarse grain structure (Figure 3a). The interface between the silicon substrate is scalloped (Figure 3b), possibly a result of the etching process. This structure of the scalloped region differs from the bulk, it comprises much finer grains, and is porous.
Simultaneously acquired EBSD and EDS maps are shown in Figures 4 a-f. EBSD pattern quality and phase maps are shown in Figure 4a and 4b respectively. The pattern quality map gives an overview of crystal structure and the phase map illustrates the spatial distribution of phases identified. The TSV is filled with copper, shown in red, the silicon substrate is blue and there is a region between the copper and the silicon that is un-indexed.

X-ray maps confirm the elements of the substrate and infill. The un-indexed region is rich in oxygen and silicon. This oxidised layer produces no EBSD patterns and is amorphous silica. The X-ray map in Figure 4f illustrates a narrow layer of titanium between the oxygen rich region and the copper TSV, but no EBSD patterns were observed from this titanium layer.
Higher resolution EBSD phase and IPF maps from the TSV/substrate interface are displayed in Figure 5. The coarse grains within the TSV bulk and the finer grains at the interface are clearly seen. A set of pole figures from the surface copper layer, labelled as region A are shown in Figure 6. The pole figures illustrate the surface copper layer has a very strong <111> fibre texture.

The TSV/substrate interface is displayed at higher magnification in Figure 7. The fine grain structure at the scalloped interface region is clear. These grains also show a strong fibre texture (Figure 7b) but with fibre axis <111> rotated about 20 degrees, into the bottom left quadrant of the pole figure.

**Summary**

Microstructural characterisation using EBSD and EDS gives insight into the production process of the TSV.

The TSV had been etched and oxidised to produce an insulating amorphous silica layer, which was then coated with a very thin seed layer of titanium followed by the electro-deposition of copper. The bulk of the TSV has a coarse grain structure, but very fine grains are identified at the interface with the seed layer. As TSV performance and lifetime is related to grain size, grain boundary type and grain orientation, characterising these parameters during production and in service can provide better understanding for control during production and component lifetime. Microanalysis using EBSD and EDS provides a valuable insight into these key components.

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