

# SUPRA™ Series

## Heating Stage Applications

### Introduction

The Semiconductor Industry and other industries with an interest in Materials Science often find the need to expose various samples to a range of elevated temperatures. This can be accomplished in many ways.

The Scanning Electron Microscope (SEM) is a useful tool for observing the changes induced through heating due to the many detection options available to the SEM user (eg. EDS, BSD, SE). The user may see many different sample reactions and should be working with a system designed to handle the potential sample changes.

### Instrumentation

The SEM provides an excellent platform for such experiments for several reasons. It allows the user to collect images of the sample of interest at various magnifications. These magnifications allow for a wide range of samples to be imaged. The SEM can also provide images with a depth of field (DOF) much greater than a conventional light microscope. The increase in DOF allows for more detailed images to be collected. The SEM also allows the investigator to collect analytical data from the sample through the use of EDS (Energy Dispersive Spectroscopy). The samples can also be imaged using secondary and backscattered electrons.

The system used in this application note is a Zeiss SUPRA™ 55VP Field Emission SEM (Fig. 1). This SUPRA™ 55VP is equipped with a cryo anticontaminator to deal with any excessive out gassing, and a variable pressure pumping system to deal with any rapid changes in chamber pressure. The heating stage was provided by Ernest F. Fullam Inc. (<http://www.fullam.com/>). The stage is designed for temperatures up to 1200°C. It has a water-cooled heat sink for continuous operation. The heated area is 7.6mm diameter. (Fig. 2) The SEM utilises a Windows based graphical user interface (GUI). This GUI has the ability to capture AVI movies, which is a licensed



Fig. 1: SUPRA™ 55VP

feature of the SmartSEM™ software. The samples were imaged using SmartSEM™'s standard signal mixing feature, a 120 µm aperture for increased signal to noise ratio, and high current mode. The AVI software setup included capturing an image at the end of the frame. The SEM cycle time (how long to acquire an image) was 90 ms. The movies were acquired at either 1024 x 768 or 512 x 384 pixels, and varied in size between 600 MB and 1 GB. The original clips were between 10 and 20 minutes long.

### Sample Heating and Cooling

The samples imaged were a Si based semiconductor device with small solder balls on the reverse side for device mounting (Ball Grid Array or BGA). They were placed onto the heating stage at ambient temperature, while the microscope was at air. The system was pumped down, and the anticontaminator was cooled down with liquid nitrogen. After reaching vacuum ready, the beam was turned on, the BGA was located, and the secondary and backscattered signal mixed image was obtained. There were two types of solder imaged, PbSn, and CuSn. The different

solders have different melting points, both melted below 600°C. The different solders were imaged with and without flux. The use of the field emission emitter and high current settings allowed for excellent image quality, even at very fast scan speeds (90 ms per frame). The BGA's were then gradually heated until they reached the desired flow temperature for the solder being imaged. Upon reaching flow temperature the heating stage temperature was held stable to see if there were any changes exhibited by the solder balls when exposed to prolonged heating. After a fixed amount of time the stage was then cooled back to ambient to watch the response of the solder as it cooled. (Fig. 3,4,5)



Fig. 2: Heating Stage by Ernst F. Fullam Inc. Centre is the heating element; black tubing is for water-cooling of the heat sink. The heating stage is fitted with a standard dovetail to fit Carl Zeiss SMT SEM stages.

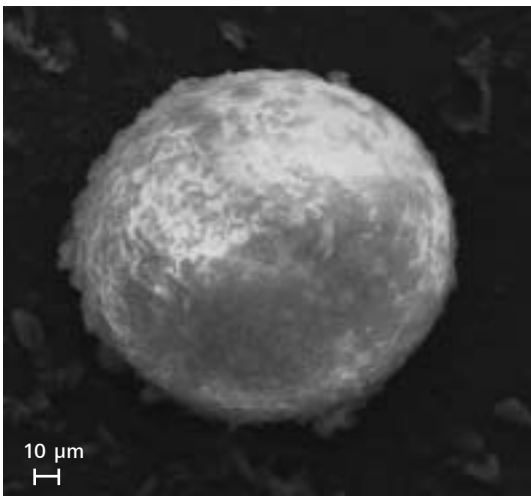


Fig. 3a: CuSn Solder with Flux.

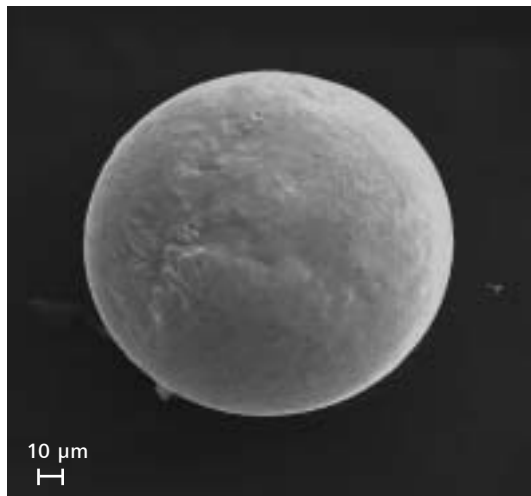


Fig. 3b: CuSn Solder Heated, please note the absence of the flux.

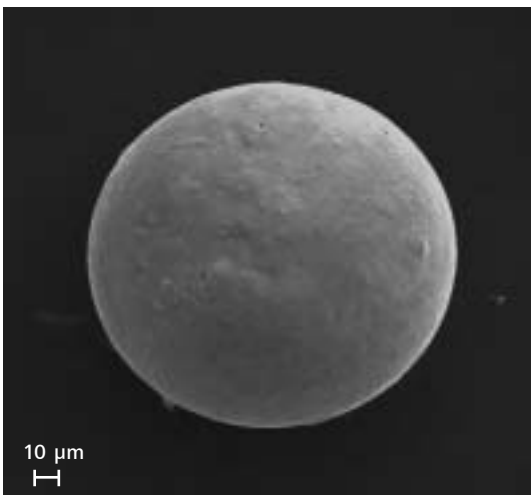


Fig. 3c: CuSn Flux Heated, note hole in solder ball lower left.

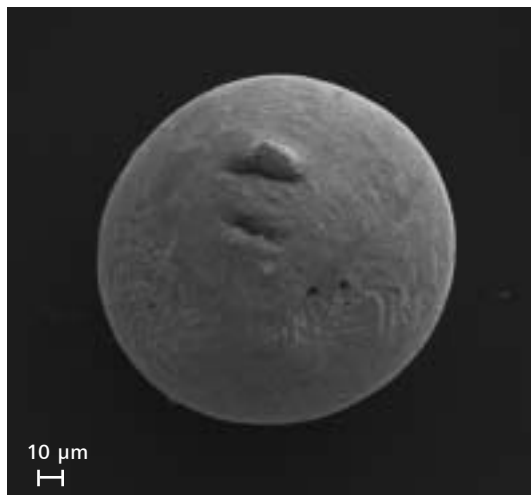


Fig. 3d: CuSn Solder heated, note slag defect in center solder ball.

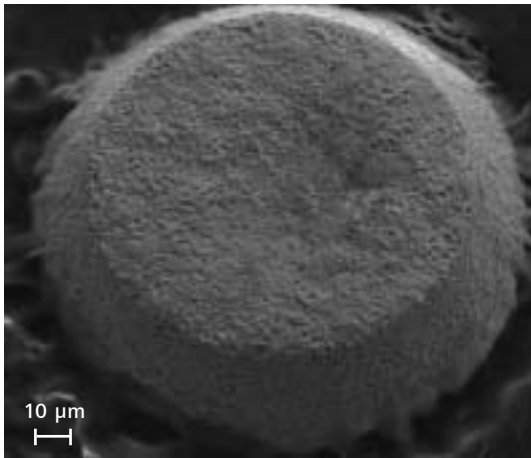


Fig. 4a: PbSn Solder ball in a BGA. Un-heated state. There is a dimple in the centre. (The image was captured from AVI file.)

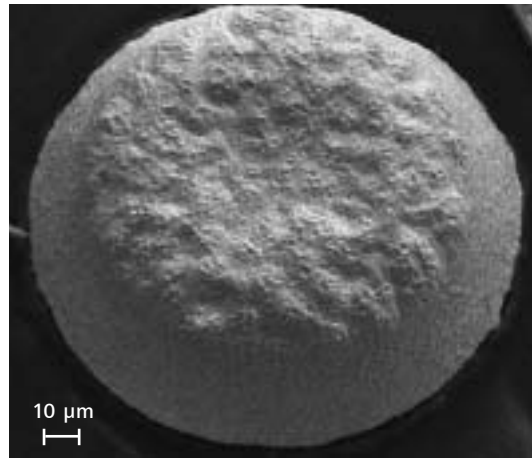


Fig. 5a: PbSn Solder ball in a BGA with flux. Un-heated state. The flux can be seen as the crystals around the base. Please note the small dimple in the centre. (Image captured from AVI file.)

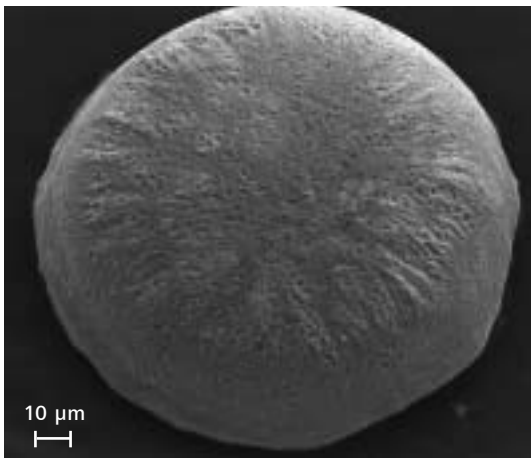


Fig. 4b: PbSn Solder ball in a BGA. Heated state, temperature is near 415°C. The dimple in the centre of the solder ball is gone once the solder has reached temperature.

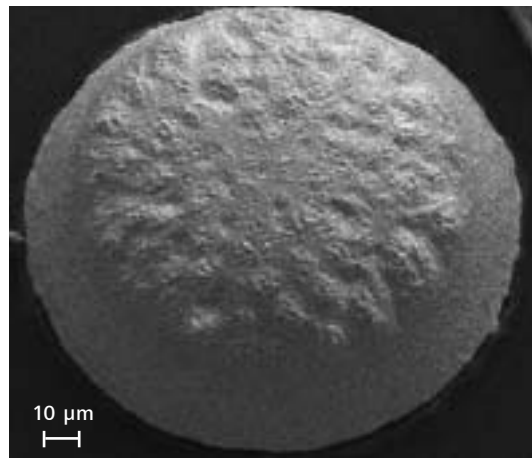


Fig. 5b: PbSn Solder ball in a BGA with flux. Heated state, temperature is near 415°C, the flux has evaporated and the ball has rounded out.

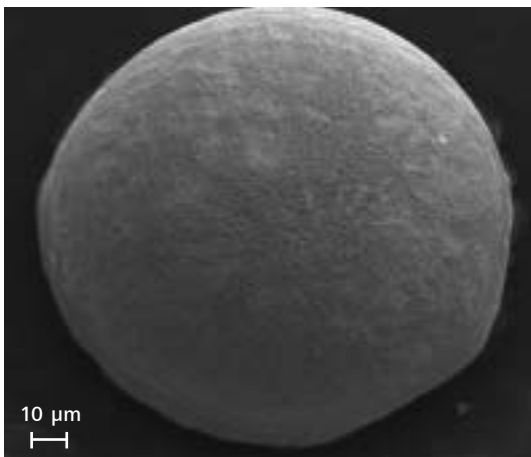


Fig. 4c: PbSn Solder ball in a BGA. Cooled state, temperature is near ambient. The original dimple has become deeper now the ball has cooled.

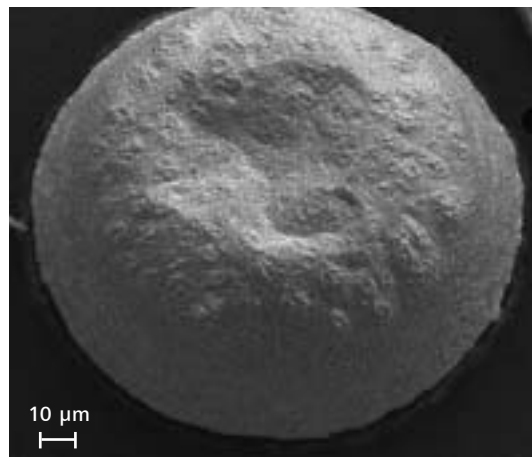


Fig. 5c: PbSn Solder ball in a BGA. Cooled state, temperature is near ambient. Notice the ball has not returned to its original shape. It has held the rounded shape caused by the heating.

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