# Silicon Band Edge Measurements Under Water Interface

k-Space Associates, Inc.

## Introduction and Motivation

It is possible to measure the band edge temperature (BET) of a semiconductor wafer under a transparent liquid surface. The key is in collecting a proper reference, whether through reflection or transmission. In this application note we use a kSA BandiT temperature measurement system to show proper measurement of Si wafer temperature while submerged under water.

## Band Edge Thermometry in Reflection

To demonstrate, a 3" diameter silicon wafer (SSP, (100), p-type, 380 µm thick, ~5 Ω-cm) was placed into a plastic petri dish and enough water was added to cover the wafer by ~2-3 mm. As the Si band edge is not very sharp (indirect gap semiconductor), it is helpful to have a proper reference to be able to ratio out the optical structure due to the lamp and spectrometer sensitivity. In addition, the water itself has some influence on the spectrum in the near IR.

In this instance, a white alumina ceramic square was used as a reference. Figure 1 displays the reference spectrum of the ceramic taken while dry. A 2nd reference spectrum was collected after the water was added. This is displayed in Figure 2.

After dividing out the reflection from the dry alumina plate, the effect of the water absorption on the spectrum can be seen in Figure 3.

For the band edge measurement, the reference spectrum with water is the one to use. Hence, in reflection geometry we see the normalized spectrum for the silicon wafer in Figure 4 on the next page.

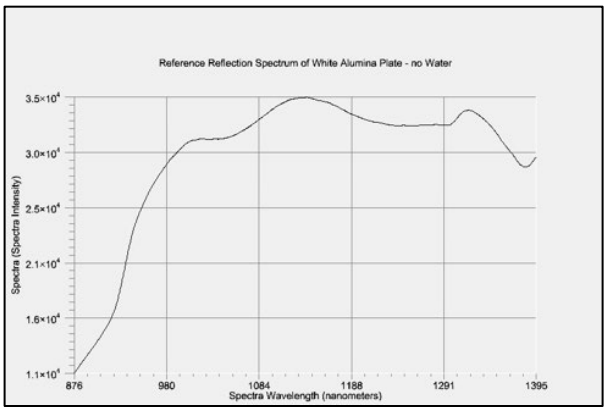


Figure 1: Reflection spectrum of dry white alumina plate

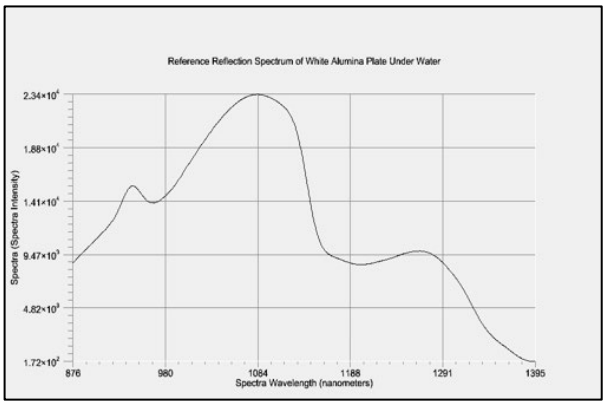


Figure 2: Reflection spectrum of alumina plate under water

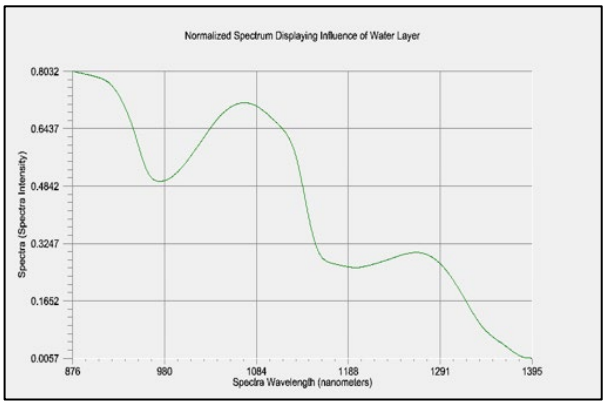


Figure 3: Normalized spectrum showing absorption due to water

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After adjusting the BandiT parameters to fit the band edge and adjusting the band edge wavelength to agree with the measured water temperature, we tested the BET measurement by using a heat gun to warm the solution. Figure 5 shows the temperature ramp up and down.

One source of noise in this measurement is the vibration of the surface of the water due to the heat gun air flow. This causes variations in the light intensity and results in small noise on the position of the band edge wavelength.

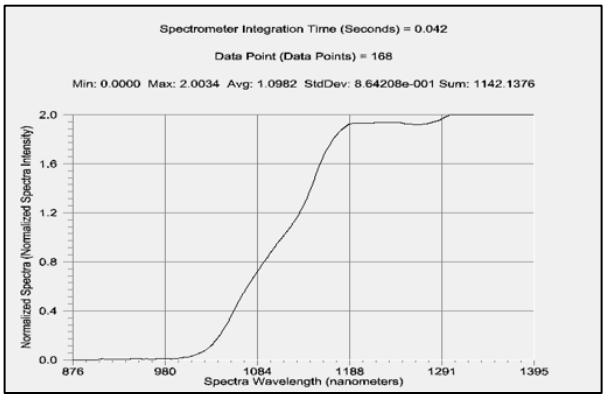


Figure 4: Normalized spectrum for the silicon wafer in water

## Band Edge Thermometry in Transmission

Similarly, in transmission a reference is taken through the water-filled petri dish without the silicon wafer. The normalized spectrum in Figure 6 looks much cleaner than the one in reflection, which is generally the case.

Again, using a heat gun to warm the wafer and water, the measured temperature looks less noisy (Figure 7, following page). Transmission is not as sensitive to variations in the light reflected from the liquid surface due to the air movement.

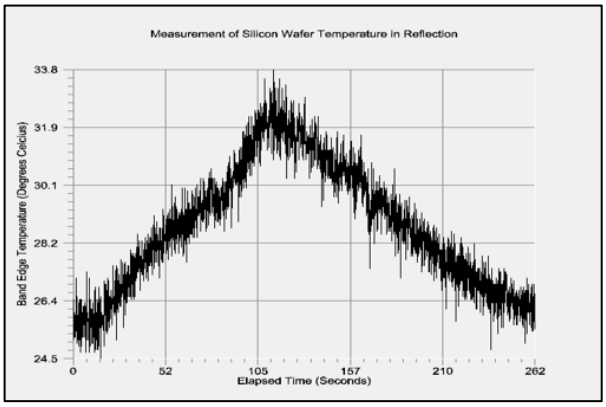


Figure 5: Reflected light BandiT temperature measurement of silicon wafer in water during heating and cooling

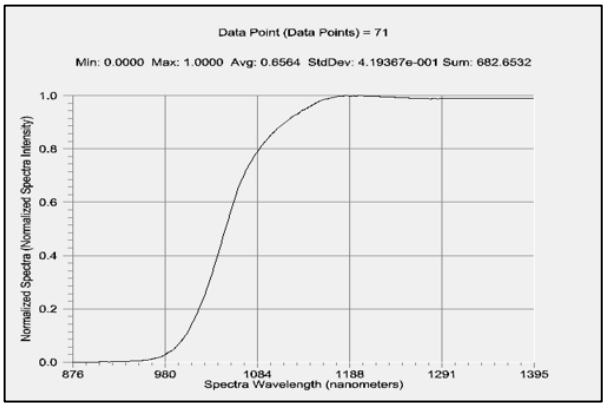


Figure 6: Normalized silicon band edge through water in transmission

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# Silicon Band Edge Measurements Under Water Interface: Summary

- BandiT temperature measurements of a silicon wafer under a transparent liquid, like water, can be made in either reflection or transmission after obtaining a proper normalization reference spectrum.
- Measurement in transmission appears to be less noisy than in reflection. This noise appears to be due to signal intensity variation from vibrations of the water surface in reflection mode (due to the heat gun blowing on the water surface). Bubbles and other thickness/density fluctuations in the liquid could add noise as well. If a measurement in reflection is necessary, one way to eliminate this noise would be to add a transparent window cover so that the solution completely fills the gap between silicon wafer and window, resulting in no liquid meniscus to reflect light.
- The positive results of this report suggest that the kSA BandiT system can easily be used to monitor Si wafer temperature while undergoing an acid etch or other chemical treatment via wafer submersion in a diluted acid or other water-based liquid.

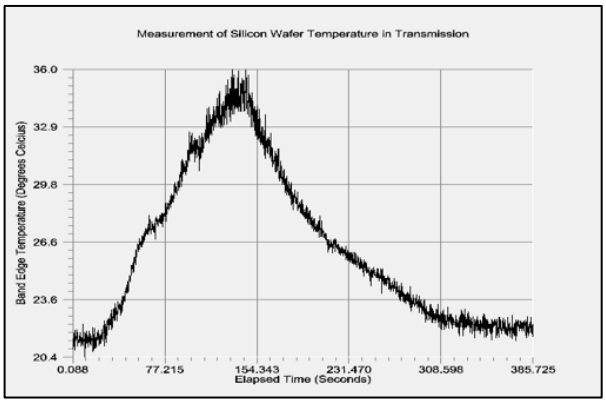


Figure 7: BandiT temperature measurement of silicon wafer in water in transmission geometry

**About k-Space Associates, Inc.**

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k-Space Associates, Inc., is a leading supplier to the semiconductor, surface science, and thin-film technology industries. Since 1992, we've delivered the most advanced thin-film characterization tools and software, thanks to close collaboration with our worldwide customer base. We realize the best products are developed with our customers' input, so we're good listeners. For your real-time surface analysis, curvature/stress, temperature, deposition rate, or custom project, we look forward to helping you with your thin-film characterization needs.

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