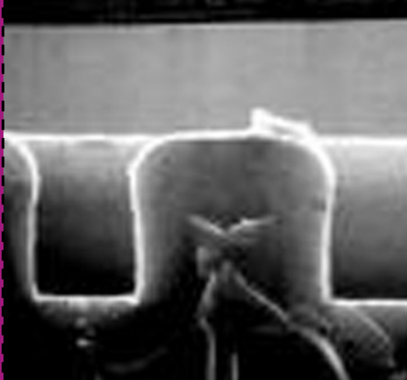
# Comprehensive BPSG Thin Film Analysis



## Continuous Dopant Verification Ensures Film Quality and Device Reliability

Balazs™ NanoAnalysis has analyzed phosphorus silicate glass (PSG) and borophosphosilicate glass borophosilicate glass commonly known as BPSG for the semiconductor industry since the business began in the early 1970's. Initially, accurate determination of P dopant concentration in these films was done using wet chemical methods such as UV/Vis spectroscopy or colorimetry. A new method was developed and implemented for determination of B dopant concentration in borosilicate glass (BSG) and BPSG films using inductively coupled plasma optical emission spectroscopy (ICP-OES). Today, BSG, PSG, and BPSG films are also characterized in our laboratory by glow discharge optical emission microscopy (GD-OES), Fourier transform infrared spectroscopy (FTIR), laser ablation ICP mass spectrometry (LA ICP-MS) and secondary ion mass spectrometry (SIMS).

### Verification of B and P Composition

The continuous verification of dopant composition and consequent adjustment of the deposition condition ensure film quality and ultimate device reliability. At Balazs™, BSG, PSG, BPSG, BTEOS, and PTEOS thin films are typically converted into aqueous solutions prior to their analysis. The resultant solutions are then analyzed for B and P against NIST solution standards. The dopant concentrations measured by Balazs™ are therefore independent of surface conditions and physical properties of the films (i.e. film thickness, density, and strength). Because our results are absolute, primary and traceable to NIST standards, they have been recognized as industrial standards and used to calibrate secondary analytical instruments such as XRF, EDX, SIMS, and FTIR for the past 33 years. The analytical accuracy and precision of Balazs's methods can be illustrated by the results shown below.

*Table 1. Certified and Balazs results from NIST reference standards*

| Reference Standard | NIST 93a Glass | NIST 1411 Glass |
|---|---|---|
| **Dopant** | B (% w/w) | B (% w/w) |
| **Certified Values** | 3.900% | 3.389% |
| **Balazs' Values** | 3.899% ± 0.051% | 3.389% ± 0.031% |

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*Table 2. Repeatability study with a BPSG film*

| Replicates | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | AVERAGE | S.D. | RSD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B (% w/w) | 3.36 | 3.34 | 3.30 | 3.31 | 3.29 | 3.34 | 3.33 | 3.40 | 3.33 | 3.32 | 3.33 | 0.032 | 0.95% |
| P (% w/w) | 5.06 | 4.97 | 5.01 | 5.03 | 4.96 | 4.91 | 4.98 | 4.95 | 4.93 | 5.01 | 4.98 | 0.047 | 0.93% |

## Specification of $P_2O_3$ and $P_2O_5$ within a Film

Using ICP-OES, total elemental P concentrations in the thin films can be obtained. Within the films, however, phosphorus exists in various oxide forms, either $P_2O_3$, $P_2O_5$, or a combination of both. Using UV/Vis spectroscopy or colorimetry, Balazs™ can identify P in different oxidation states and can separately measure the quantities of $P_2O_3$ and $P_2O_5$ in a film.

## Lateral Distribution of B and P in Films

Mapping at various points on a wafer is also available to determine dopant uniformity across the wafer. Wafer mapping verifies dopant distribution across the wafer, from top to bottom, and from left to right. Balazs™ provides 9 and 13 points mapping pattern in accordance with International SEMATECH 1300 I (see Figure 1). Alternate mapping patterns or number of points tested (5, 7, 9, 13, etc.) are also available depending on wafer size. The wafer mapping can be performed by UV/visible spectroscopy, ICP-OES or FTIR.

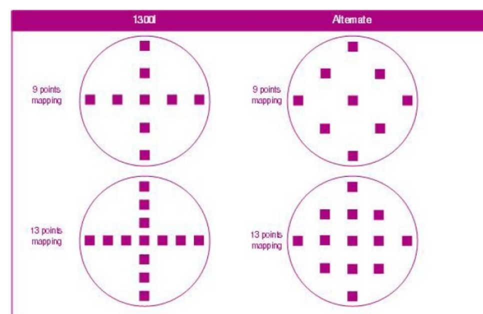


*Figure 1. Balazs wafer mapping patterns*

## Vertical Distributions of B and P Dopants in Films

Vertical distributions of B and P in dopants a film are also important and can be studied by depth profiling. At Balazs™, depth profiling is done by GD-OES and SIMS. Both techniques have adequate sensitivity and depth resolution for profiling BSG, PSG and BPSG films. A typical GD-OES depth profile is shown in Figure 2.

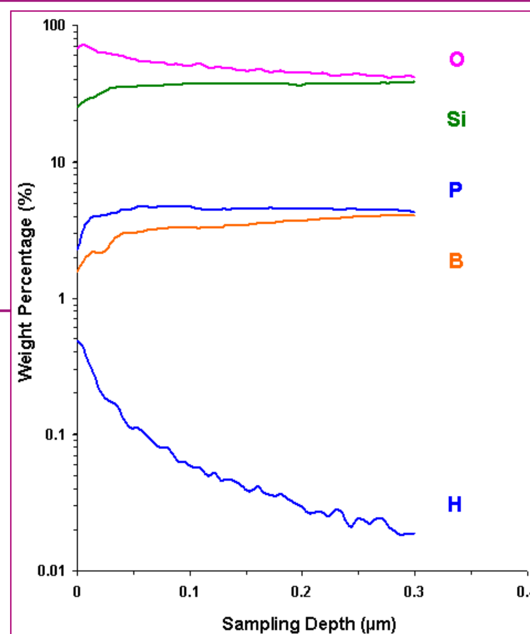


*Figure 2. Simultaneous multi-element depth profile of a BPSG film by GD-OES*

## Determination of Trace In-Film Impurities

Contamination of thin film layers may occur from CVD, ion implanters, and other reactors or equipment. Trace impurities in the dielectric thin films can be detrimental to device performance. In particular, those mobile ionic contaminants such as $K^+$ and $Na^+$ can migrate to the wafer surface posing a serious reliability risk that needs immediate attention.

At Balazs™, the trace in-film impurities can be analyzed both qualitatively and quantitatively using LA ICP-MS or drop scan etch ICP-MS (DSE ICP-MS).

## Sample Size Requirement and Turn Around Time

Balazs™ analyzes thin films for all wafer sizes. There is no specific wafer size requirement. Balazs™ provides accurate and precise UV/Vis and ICP-OES results within 24 hours (4 hours priority). GD-OES, LA ICP-MS SIMS results can be obtained within 5 working days after sample receipt (3 days priority).



Balazs™ NanoAnalysis operates ISO 17025 certified laboratories that identify, analyze and resolve contamination issues for high-tech industries around the world. The Microcontamination Experts™ at Balazs provide rapid and accurate analyses and expertise for water, air, chemicals, process gases, components, wafers, consumables and any other contamination sources.

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