

## Smart Phase Mapping

### Introduction

Traditionally, X-ray mapping involved the creation of multiple elemental maps. One of the primary goals was the interpretation of phases from the individual maps. This interpretation was done after the maps were collected and was strongly dependent on the skill and experience of the operator. Different operators would likely make different interpretations. With the TEAM™ EDS Analysis System, EDAX's revolutionary Smart Phase Mapping allows the user to see phase information while the maps are being collected. The skill and experience of the operator are no longer requirements for accurate phase determination.

### What is a Phase?

The word "phase" is used in a variety of ways in microanalysis and is used most generally to refer to an area or volume of a sample that has some characteristics which make it distinct from an adjacent area or volume. In some instances reference can be made to a gray-level phase in a BSE image (Figure 1a) even though gray-level phases are often not unique

and are really just a relative term (e.g. "dark phase") that will have no meaning when a new area or a new sample is examined.

A phase may also be described by using the chemical composition. When using phase in a chemical context it is possible to provide a composition, a formula, a phase name or a mineral name. This provides a more absolute basis of classification, because the phase that has been defined will have meaning when examining another area of the sample or of a different sample altogether. Using chemical composition to define a phase is typically far more meaningful than just the gray-level phase of the BSE image. In some instances additional information may be necessary that will require the analyst to know the crystallography and perhaps the orientation of the area of interest. However, this discussion of phase mapping will refer to a chemical phase as defined by X-ray mapping using an EDS detector.

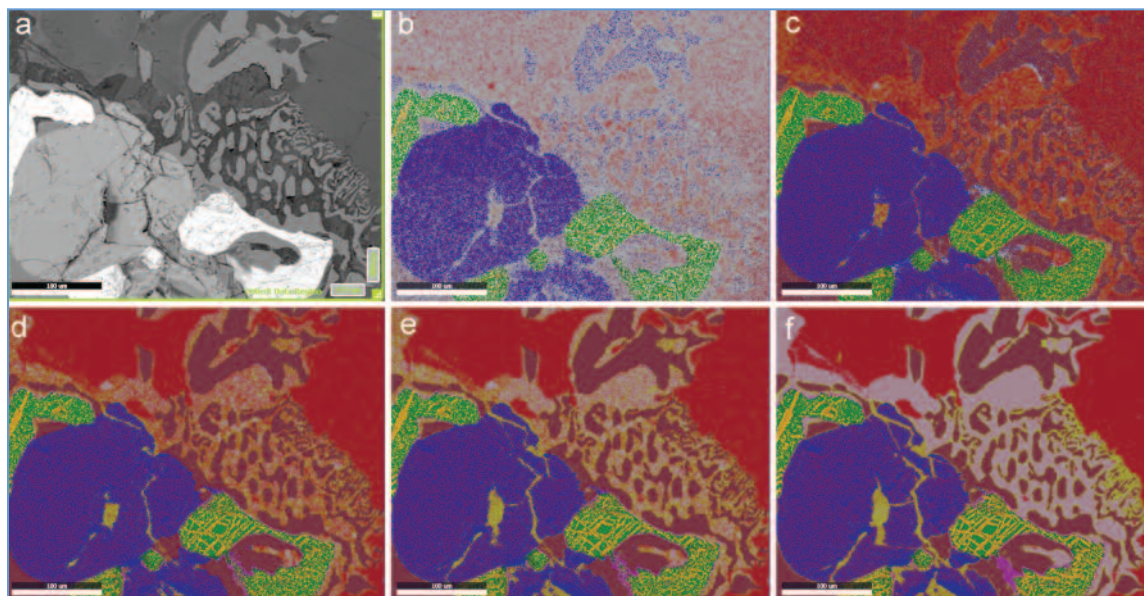


Figure 1. The sequence of collecting a live phase map is shown. First, an image is collected (a) and then the map starts. The phase map shown in (b) is after only a few frames and the maps which follow are in sequence. Note that the images become less noisy over time and some areas change from one phase to another - the blue mottled area in the upper part of (b) gradually changes to a reddish brown phase. Each phase is named or defined by the dominant elements present.

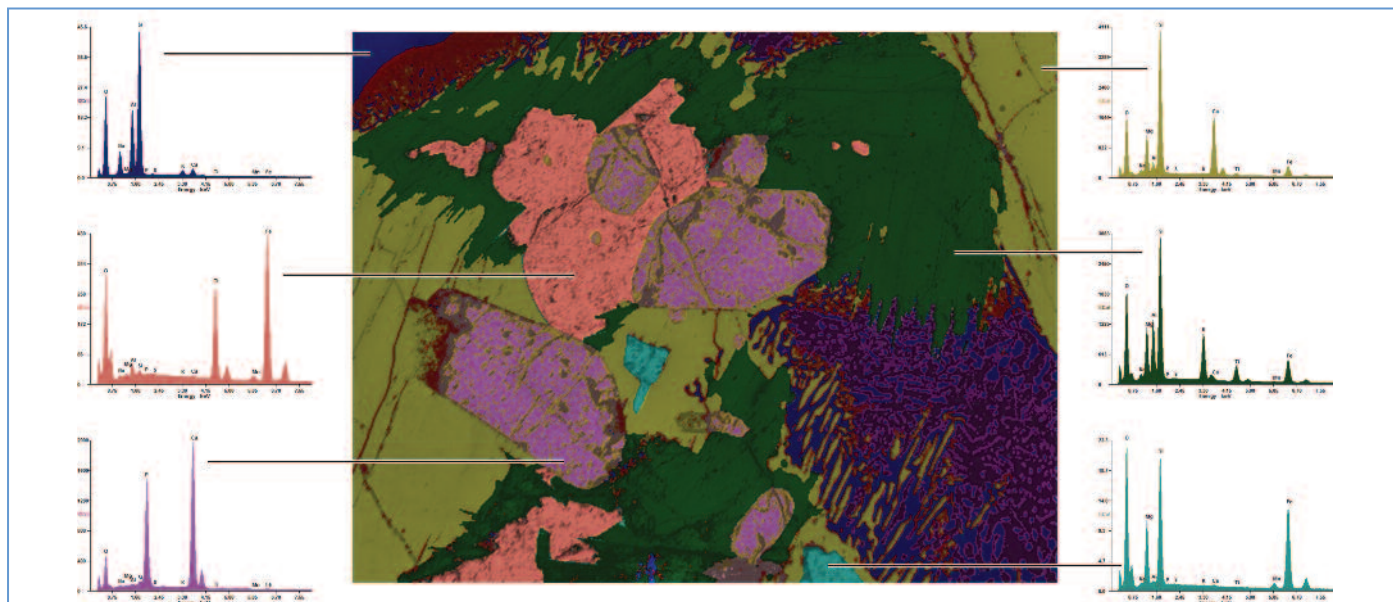


Figure 2. Phase map of a geological sample showing the composition of six of the phases present. The phases are named based on the dominant elements present and each phase represents a different mineral (e.g. feldspar, mica, pyroxene, apatite, etc.)

## Live Phase Mapping

Previously, the analyst would be forced to consider three steps for their analysis – data collection, phase analysis, and interpretation. With phase mapping in the TEAM<sup>™</sup> software it is now possible to combine all these tasks in a simultaneous analysis.

In TEAM<sup>™</sup> EDS live phase mapping, the phase determination occurs while the primary map data are collected and does not require a separate processing step after collection. No prior knowledge of the sample chemistry is required and no parameters need be defined. A comparison of the composition at each pixel begins in the very first ‘pass’ or frame of the analysis (Figure 1b). The quality of the phase definition improves with subsequent frames (Figures 1b-1f). Spectra of each phase are saved at the end of the analysis (Figure 2) and the phases are easily quantified.

## Element Mapping

In addition to a live phase map of samples, it is still possible to see the elemental maps for each element (Figure 3) as in the past. The number of elemental maps is not limited in the TEAM<sup>™</sup> software.

The color palette for each map is pre-defined but it is possible to change the palette for any map. A set of additional images called the Counts Per Second (CPS) Map is shown in Figure 3. Contrast in the CPS Map is based on the total count rate at each pixel. The areas that have the highest count rate are the brightest in this image. All images are easily exported to a standard file format that can be opened by other programs as needed.

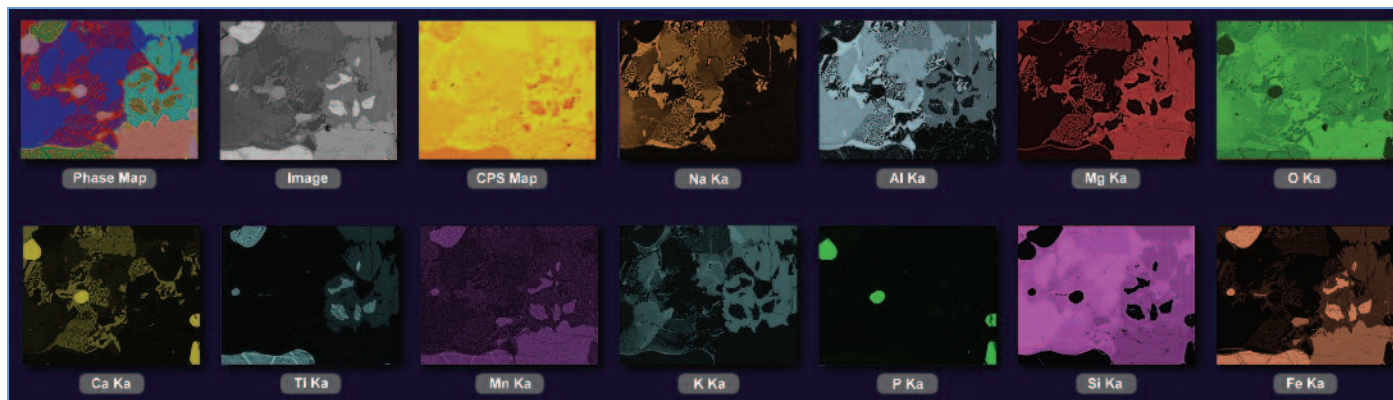


Figure 3. Phase map, image, CPS Map, and elemental maps.



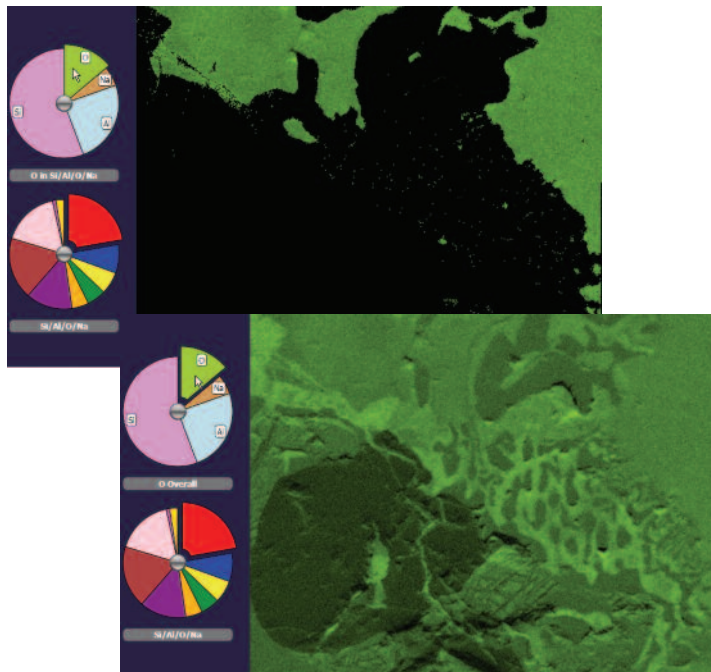


Figure 4: The elements present in a phase can be shown by clicking on the phase in the pie chart. In this case the red phase has been selected (a phase rich in Si, Al, O, and Na). By clicking the mouse on the O in the phase pie chart it is possible to see the distribution of O within that phase and clicking a second time will show the distribution of O throughout the map area.

## What are Smart Features?

The basic goal of any Smart Feature is to allow any user, regardless of their level of experience, to collect data comparable in quality to the data that would be collected by a skilled, knowledgeable user.

Smart Features permit a user to:

- Collect data with minimal setup
- Predict or calculate optimal parameters that cannot logically be made default
- Receive guidance and suggestions on how to optimize microscope parameters
- Be warned if it is possible to collect incorrect or misleading data
- Have parameters dynamically adjusted during an analysis when it makes sense to do so
- Collect quality data in a very efficient manner

## Interactive Phase Mapping

Interactive phase mapping allows the user to interact with the dataset during collection. With TEAM™ EDS Smart Phase Mapping, the task of determining which phases are present can start during the initial analysis. Interpreting the spatial relationship of phases is often very helpful to understand the mode of origin of the sample or feature.

Comparisons can be made between the phase map and the element maps (Figure 4) and the phase spectra can be examined while mapping (Figure 5). Elemental maps can be shown within the phase of interest or in the element map for the entire map area (Figure 4). It is possible to evaluate the phase composition with the usage of the pie chart. The phase map itself is interactive in that the user can click on an area of the map to see which phase in the pie chart is represented by that area and the summary phase spectrum can be created from the pie chart. The phase map can even be compared to the map of total X-ray intensity to see if an anomaly coincides with topographic features such as a crack, pit or a depression.

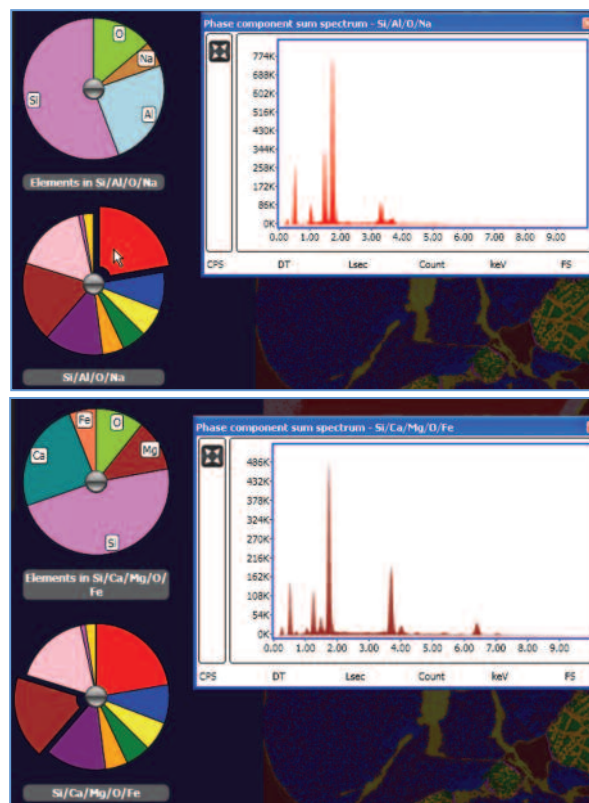


Figure 5. Phase spectra can be viewed during map collection by pressing the right mouse button on the colored phase of the pie chart. A left mouse click on the same area will show a pie chart of the significant elements present in the phase. The dominant elements in the red phase (upper image) are Si, Al, O, and Na. The dominant elements in the reddish brown phase (lower image) are Si, Ca, Mg, O, and Fe.

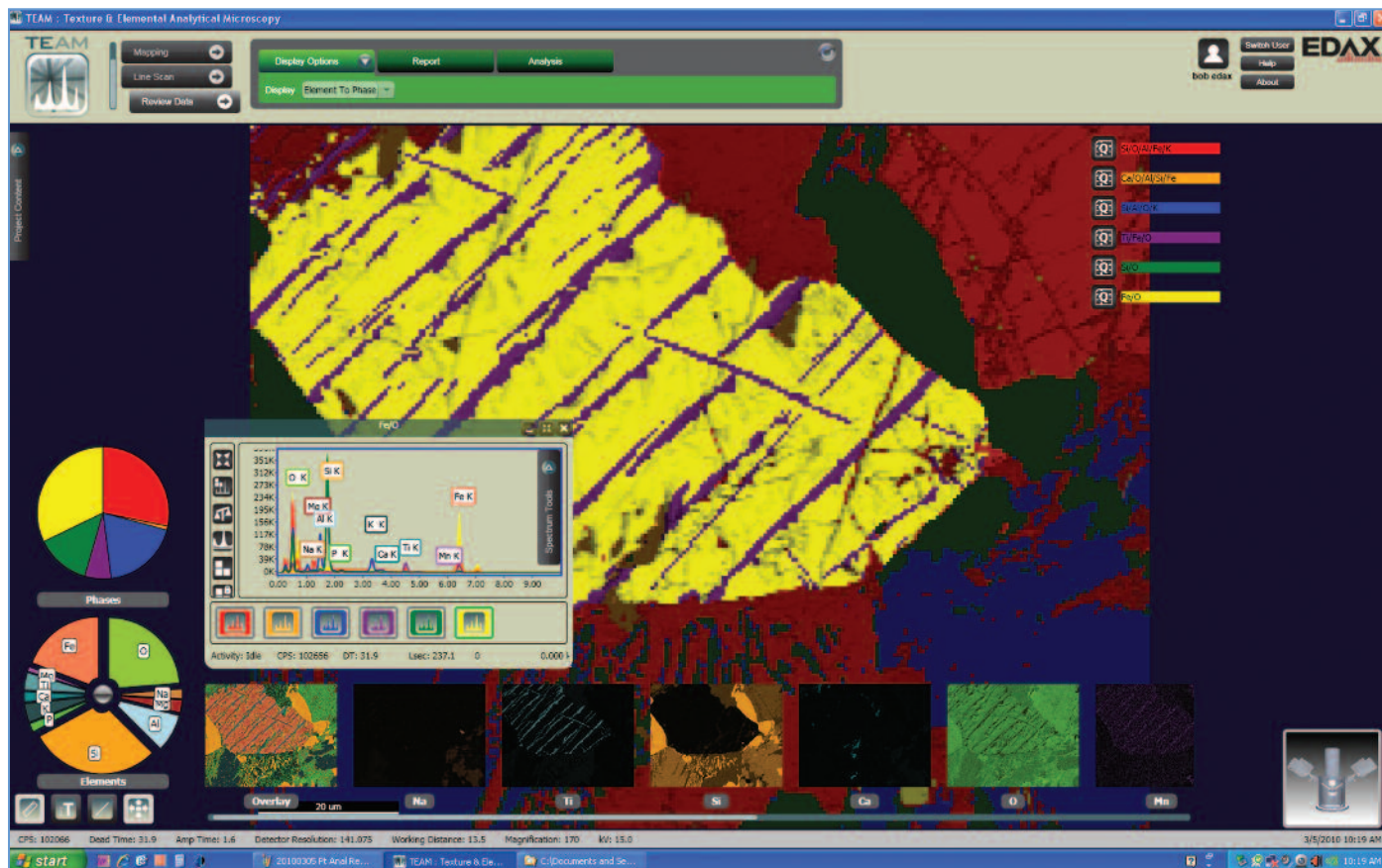


Figure 6. Phase map of a complex, multi-phase solder. The color key for each phase is shown to the right of the phase map. It is possible to quantify the summary spectrum of each phase by clicking on the 'Q' button.

## Conclusion

In the TEAM™ software phase maps (Figure 6) are automatically generated, without input from the user. No parameters need to be specified and no previous information about the sample is required. Because the phase maps are collected and displayed live during map collection, users save their valuable time for other critical tasks. With the Smart Phase Mapping feature, even a relatively inexperienced user can create a variety of phase maps quickly and easily and can feel confident in presenting their results.

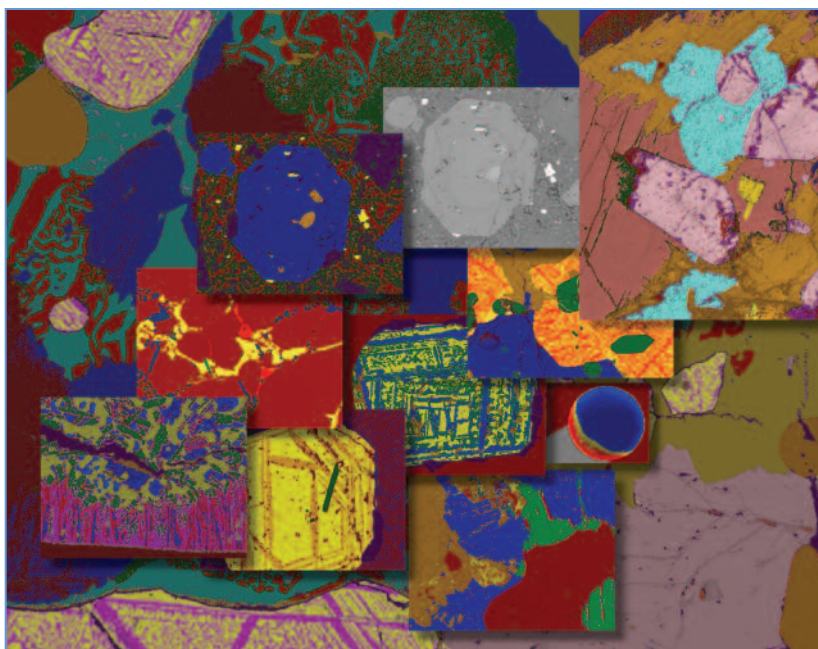


Figure 7. A variety of phase maps are overlain and shown as a collage.