

# Chapter 54

## Materials Characterization Techniques for Solar Cell Devices: Imaging, Compositional and Structural Analysis

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### ABSTRACT

*Characterization of an issue provides the required information to determine the root cause of a problem and direct the researcher towards the appropriate solution. Through the explosion of nanotechnology in the past few years, the use of sophisticated analytical equipment has become mandatory. There is no one analytical technique that can provide all the answers a researcher is looking for. Therefore, a large number of very different instruments exist, and knowing which one is best to employ for a specific problem is key to success.*

### INTRODUCTION

A large number of analytical techniques have been developed to determine the properties of a specimen. The reason behind this variety is that each method will provide a very specific type of data. Therefore, in order to fully characterize a specimen, a variety of such methods need to be implemented. Most of these techniques rely on the same principle: an incident beam of photons

or charged particles interacts with the specimen generating various types of signals. Part of these signals is collected by an appropriate detection system and the data is analyzed to provide information on the properties in question (Brandon and Kaplan 1999).

The purpose of this chapter is to give a short description of the most widely used analytical techniques along with their advantages and disadvantages. The end goal is that the reader will be able to determine which technique is most suitable for a given situation.

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## **BACKGROUND**

Analytical instruments and analysts can be seen as “problem solvers.” In almost any environment the solution requires the knowledge of all processing steps underwent by the specimen. The more information available the more likely it is an answer will be found. Often enough analytical results can be interpreted in more than one way due to various issues, such as overlaps, detection limits and resolution. A separate piece of information, obtained by other means, can rule out one scenario and support another. Furthermore, an absolute answer may sometimes not be obtainable due to various limitations. In such cases a comparative analysis is performed between a “good” and a “bad” sample. A “good” sample is a reference, a structure that “works,” or a thin film that does not show the problem. Differences in the collected signals can point to the correct direction without necessarily knowing the absolute values of the measured quantity. This approach is known as qualitative analysis. When a traceable standard is used, for example a structure with known dimensions or a film with a known composition, then the instrument can be calibrated based on this standard and quantitative results are obtained.

## **IMAGING**

Everyone has heard of the expression “a picture is worth a thousand words.” When we are presented with a sample that does not “work,” our first reaction is to examine it and see if there is something obviously wrong with it. The following section will cover the most commonly used techniques that are used to examine a specimen.

### **Optical Microscopy**

Optical microscopy is the first line of defense. It is often the first technique used to assess the condition of a sample and such instruments are found

in almost every laboratory. Optical microscopy is used to examine surfaces for imperfections, contaminants, micro-cracks or to make ourselves familiar with the sample and make markings that can be used later in a different technique to more easily navigate to the region of interest. Variations of brightfield microscopy are also used to extract information that may not be otherwise visible (e.g. darkfield, uv fluorescence and polarized light microscopy).

Little or no sample preparation is required and optical inspection of interior features is possible through optically transparent layers. Using calibrated magnification standards, feature sizes down to a few micrometers can be seen and measured (the magnification limit is of the order of 2000x in air).

### **Scanning Electron Microscopy**

Scanning Electron Microscopes (SEM) use a finely focused beam of electrons that is scanned over the surface of the specimen. The incident electrons undergo a series of elastic and inelastic collisions creating various signals, including secondary and backscattered electrons. These signals are used to form an image of the specimen on the viewing monitor (Goldstein 1992).

The basic components of an SEM are the electron gun, the lens system, the electron detector, the vacuum system and the viewing monitor. An electron source is incorporated in the gun assembly and provides electrons by thermionic or more typically these days field emission. The emitted electrons are accelerated to energies, usually, up to 40keV and are focused by the lens system to a spot of the order of 1nm. A deflection system scans the electron beam along a line which is then displaced for the next scan until a rectangular raster is generated that covers the inspected area on the specimen. There is a point-to-point correlation between the location on the sample where the electron beam strikes and the location on the viewing monitor where the image is formed. The

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