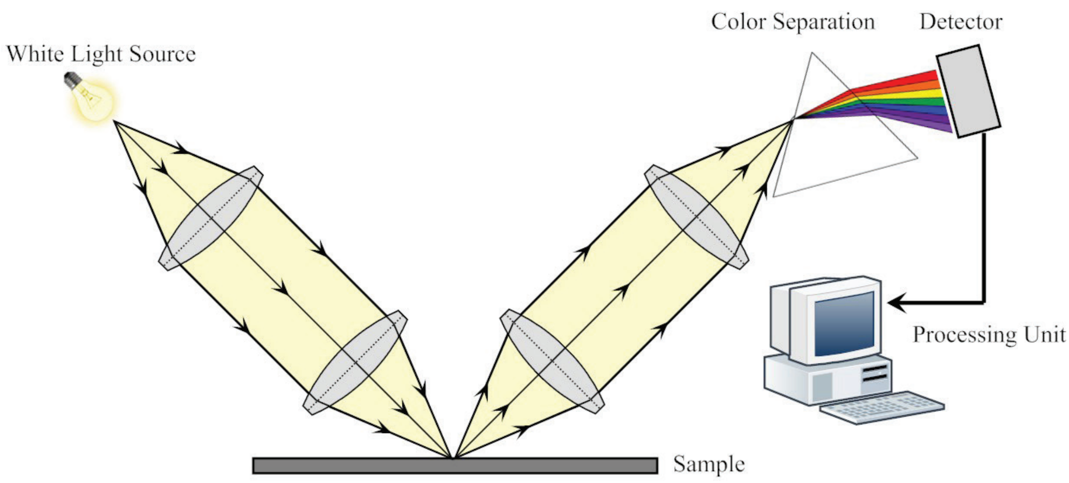
Spectral Reflectometry

What is Spectral Reflectometry?

Spectral reflectometry (SR) is a method of characterizing unknown properties of a sample by measuring the reflection of electromagnetic radiation, or more specifically, light, from an object.

In this method, light is shined upon the sample, and due to an interaction with the sample, some light is scattered back - or reflected (hence the name "reflectometry"). By placing detectors at the path of the reflected light one can measure how much light is reflected back. By using models that can predict the amount of light reflected from a given sample (characterized by its geometry and/or its material content), one can deduce, using highly sophisticated methods, what the sample is made of, and how its profile looks like.

To obtain additional information from the measurement, and subsequently a more accurate characterization of the sample, light is further separated into its wavelength components, and into its various polarization states. The figure below shows a schematic of a basic spectral reflectometry system:



A white light source is focused onto a sample. The light reflected off the sample is focused onto a device that is able to separate the color into its spectral components (represented schematically by a prism), and each component is then transformed into an electrical signal using a specialized detector. The spectral data, which is the signal level for each wavelength, is then delivered to a processing unit. Using the physics describing how matter interacts with light (Maxwell's equations), the processing unit evaluates the properties of the sample that best matches the measurement.

What are the main benefits of Spectral Reflectometry?

Spectral Reflectometry offers several benefits that make it the main method of choice for Optical CD characterization:

- **High measurement speed:** Measurement speed is usually very high with spectral reflectometry, due to the availability of strong light sources, and very sensitive photodetectors. This eventually yields fast measurement with a high signal-to-noise ratio.
- **No need for sample preparation:** Unlike other methods, Spectral Reflectometry does not require special sample preparation before it is measured. This makes SR easy to use for process monitoring and particularly for integrated metrology.
- **Non destructive:** Spectral reflectometry is a non-destructive type of measurement, and has no impact on the production line.
- **Accurate interpretation:** Since the interaction of light with the sample is well-known, the interpretation of the spectral reflectometry signal is much more accurate than with other metrology tools (such as with scanning electron microscopes, for which there is no complete knowledge as to the many interactions that an electron sample undergoes).

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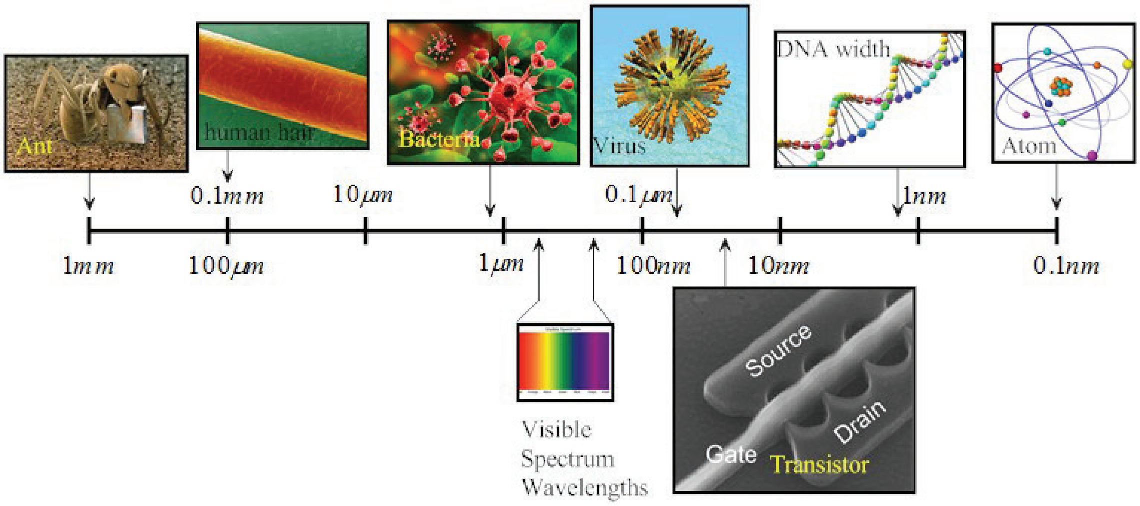
The patterns that are formed are of typical sizes ranging from 1 nm to 2000 nm. To appreciate these sizes, the following figure shows typical sizes of various organisms and devices, starting with a small ant, measuring about 1 mm, to an atom whose size is about one tenth of a millionth of an ant size.



The typical sizes SR tools target are those associated with state-of-the-art transistors. These are based on the most advanced industry design node of just over 10 nm The typical sizes SR tools target are those associated with state-of-the-art transistors. These are based on the most advanced industry design node of just over 10 nm.

Spectral Reflectometry Challenges

SR tools are required to deliver sample properties with a high degree of accuracy, and very fast. In addition, to eliminate the risk of contaminating the measurement with nearby structures that are not of interest, SR tools are required to focus the light onto a very small area. These three requirements, that are often considered contradictory, are reached by several approaches.

Since the size of the sample is usually extremely small, the signal is expected to be very weak. This problem is mitigated by duplicating the sample so that a single structure is produced as an array of nearby identical structures, closely and equally spaced, forming a periodic structure or grating.

Another method to provide accuracy is to fully exhaust the amount of information that can be extracted from a sample. Some of the ways to do this include using a broader wavelength range, using a high spectral resolution, using scatter properties for several polarization states and for different illumination directions.

To further improve accuracy, extra care should be taken to eliminate inclusion of signals that are not related to the sample under study. This requirement dictates a delicate optical design that minimizes the optical effects that are responsible for spot enlargement, and an appropriately educated measurement sequence that minimizes the amount of error that can leak into the signal.