Heat Cell Applications

by James Hilfiker

The term "optical constants" is often considered a misnomer. It is well known that the optical constants of any material vary with wavelength. In fact, about 50% of our short course is devoted to the better known descriptions of spectral variation (dispersion modeling). However, the optical constants of a material also vary with temperature.

Studying the optical properties versus temperature can lead to a better understanding of material behavior. For example, in Newsletter Issue 1 we showed data for a semiconductor down to 4 Kelvin. At low temperatures, the electronic band structure affects are more pronounced in the optical spectra.

Beyond basic research, the temperature dependence is important any time the ambient or internal material temperature varies (e.g. heating with absorption of laser light). A few commercial applications include laser optics, telecommunication devices that employ optical and optoelectronic components, and data storage devices.

In Newsletter Issue 4, we introduced a heat stage option for temperature studies from room temperature up to 300° Celsius. Preliminary research with this stage included temperature dependent changes in organic materials and dielectric films. Another important application within this temperature range is the study of phase-change materials used in recordable CD and DVD media. These devices work by heating the recording film with a focused laser to promote a "phase-change". The optical constants are dramatically modified with this change, which is utilized to distinguish between the recorded '1's and '0's.

Data shown in Figure 1 come from such a recordable film. Notice the large shifts in psi and delta near 140° and 280° C. The data are shown for three wavelengths, but were actually collected from 0.8 eV to 6.0 eV. For engineering development of improved media, optical constants are needed at only a few temperatures. This information is then used when developing improved candidate materials for recording technologies, even as the read/write laser wavelength shifts blue for higher data storage densities.

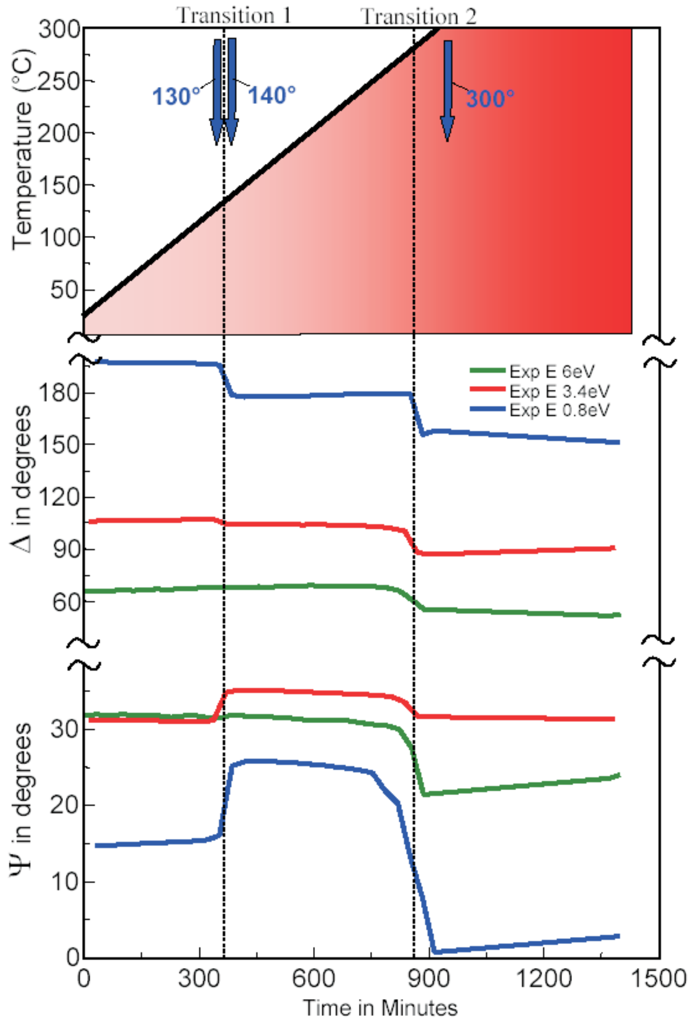

Figure 1. Ellipsometric data acquired on phase-shift media at elevated temperatures from room temperature to 300°C. Notice large changes in the ellipsometric data at 140° and 280° Celcius.

The optical constants determined from each of the marked temperatures of interest (130°, 140°, and 300° Celsius) are shown in Figure 2. For this type of material, the phase-change near 135° produces a shift in the optical constants for the layer. The material then goes from an opaque absorbing material to one which is absorbing in the UV but transparent in much of the visible and NIR at a higher temperature.

The phase-change media was measured on a VASE ellipsometer as shown in Figure 3. This has the advantage of an AutoRetarder for highly accurate measurements. The heating stage is also available for M-2000 and IR-VASE ellipsometers. The M-2000 can acquire spectroscopic data in less than a second, which allows real-time temperature dependent optical constant monitoring. The temperature ramp is programmable by the user. For example, a series of steps was used for the study in Figure 4. Notice the data from only 5 of the 500 collected wavelengths show subtle changes as the actual temperature of the stage follows the set point.

For more information about heat stage applications, please contact the JAWCo applications engineers at measurements@jawoollam.com

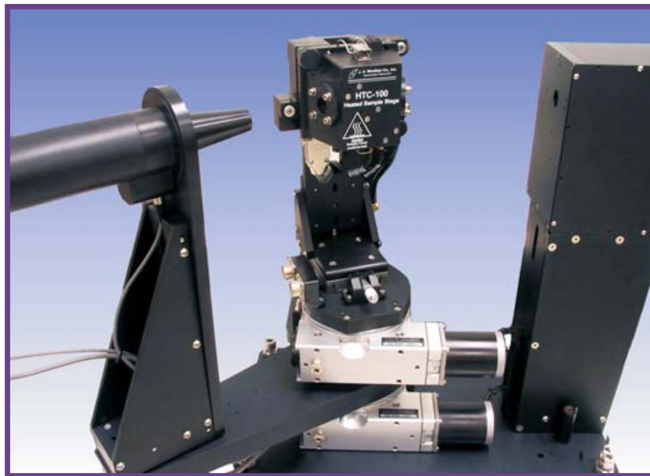

Figure 3. VASE ellipsometer with heating cell option attached.

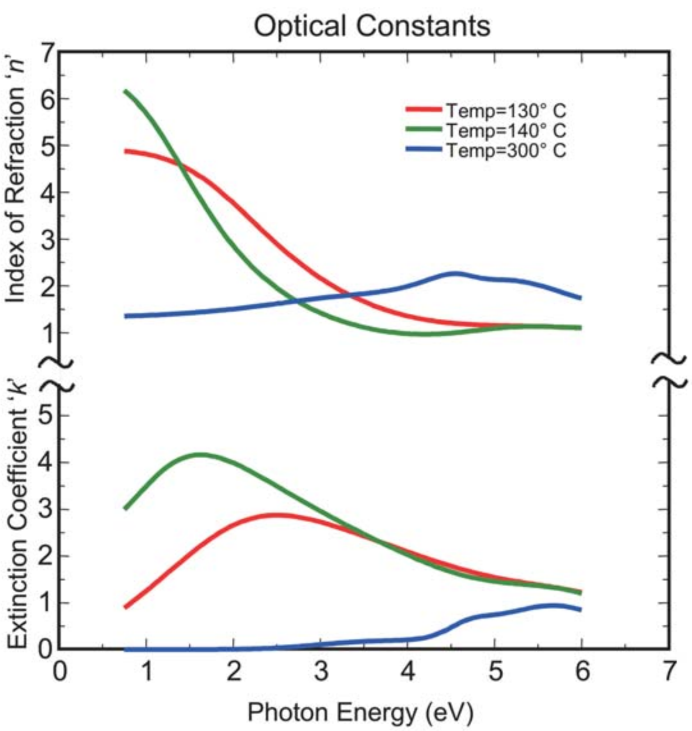

Figure 2. "Phase change" material optical constants at three different temperatures (130°, 140°, and 300° Celcius).

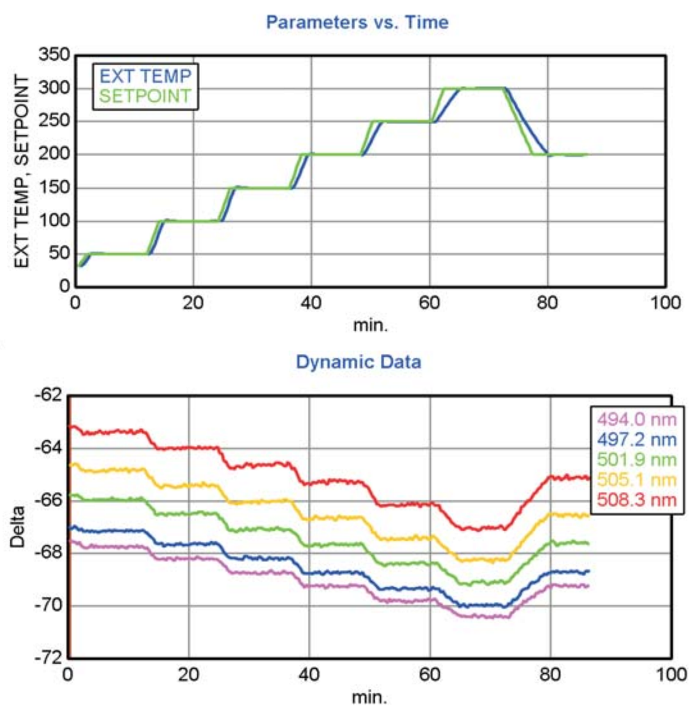

Figure 4a-b. a) A user-defined temperature profile is shown as the set-point changes with time. The actual temperature follows the set-point, as shown in the EXT Temp graph. In (b) the ellipsometric data showing changes at each set point temperature.