Appendix: Thermoreflectance Imaging Fundamentals

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(Preserved from the source manual's Appendix A for internal engineering/support reference.)

Thermoreflectance thermal imaging relies on the linear change of a material's reflection coefficient with temperature. The effect was first noted in the 1960s; practical thermoreflectance imaging techniques are more recent. Because the reflection changes are imperceptible to the human eye, high-resolution, low-noise equipment and sophisticated averaging schemes are required. The NT220 provides two averaging modes:

- **Low Frequency Imaging** — a frequency-domain filtering technique. Advantages: works without pulsed illumination, and enables lower-frequency thermal images (down to 0.48 Hz) in "Transient" mode. It is possible to obtain low-frequency images without the BNC 6040/202H LED pulse generator, using CW (non-pulsed) illumination — useful for materials needing specific non-LED wavelengths (e.g., white light + bandpass filter). Disable the pulse generator (uncheck "use BNC 6040/202H" in Project Manager) when using CW illumination, to avoid unnecessary wear on the BNC and pulsed LED.
- **Transient Thermoreflectance Imaging** — captures thermal images at precise "snapshots" in the device's heating/cooling cycle via precise timing of illumination flash vs. device excitation. Has a lower noise floor (0.2 °C) than low-frequency imaging (0.5 °C), and is preferred when possible. A transient image series lets you visualize temperature change during the active heating cycle; the analyzer tools can display temperature at a

given point across different times.

Thermoreflectance Material Coefficient

The thermoreflectance coefficient is a material property, a function of temperature and illumination wavelength. Unlike infrared emissivity, it is not strongly sensitive to surface preparation or deposition method, so per-device calibration is generally not necessary — Microsanj's characterization of gold prepared by various thermal/E-beam evaporation techniques has been consistent over years. A significant change in visual material color from major microstructure/porosity changes can, however, meaningfully change the coefficient.

Microsanj provides thermoreflectance coefficients for basic IC materials at the LED colors supplied with the system. For a new material system, the coefficient can be extracted directly if there is an embedded temperature sensor near the ROI on the chip; otherwise a small chip sample (roughly 1×1 mm up to 1×1 cm) can be sent to Microsanj for in-house characterization.

For regions of interest covered in Aluminum, use the provided 780 nm LED — the thermoreflectance coefficient is too small at 530 nm (green) and 470 nm (blue) to produce usable thermal images.

Dielectric coatings: coatings change the surface reflectance coefficient and thus the thermoreflectance coefficient. If uncoated regions are present, use temperature continuity across the surface to calibrate the image; otherwise Microsanj can determine the coefficient for a coated sample given a small piece. Non-uniform dielectric film thickness can produce interference oscillations in reflected data (an inherent optical property); averaging measurements across different color LEDs can help detect the oscillation envelope and remove the optical artifact.

Microscope objective numerical aperture: the thermoreflectance coefficient can depend on the objective's numerical aperture (NA), due to the surface-perpendicular polarization component — non-negligible for NA > 0.5. Coefficients Microsanj provides specify the objective and illumination LED used. For precise high-NA temperature measurements, first measure with a low-NA lens over a larger area, then (without changing anything else on the device) switch lenses and scale the temperature data accordingly. Standard objectives are optimized for the visible (VIS) band but usable outside that range with reduced sensitivity; Microsanj offers NUV/NIR-optimized objectives (see the Optional Objectives tables referenced in Specifications — detailed NA/FOV/working-distance/resolution tables are figures in the source PDF and not reproduced here).

Measurements at different ambient temperatures: thermoreflectance's key advantage over IR emission is that it works over a wide temperature range, down to cryogenic temperatures. Microsanj has imaged gold contact layers with sub-micron spatial resolution from 10 K to 800 K. For measurements below 5–10 °C, use a cryostat with an optical window to avoid water condensation on the sample.

Referenced Publications (bibliography, as listed in the source manual)

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`[diagram/image in source — not reproduced here: Appendix B, Section 13.1 "NT220/NTIR220 CCD Camera" — heading present in source with no accompanying text, only a figure/image placeholder]`

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