



THoT Technologies, Inc.

TEST PROTOCOL

Summary:

This document lays out the test protocol to demonstrate the capabilities of the THoT tool. The purpose and a recommended protocol is outlined. A description of the standard tests that are used to demonstrate the tool capabilities is provided. An explanation of the tool test capabilities is given. A list of suggested tests is provided for various disk manufacturing process stages.

Purpose:

The following is the recommended test procedure to demonstrate the capabilities of the THoT Model 42000 Optical Process Certification and Optical Defect Scanner tools. Due to the fact that the tools are non-destructive, non-contact, high resolution and extreme range, they can be applied at many stages in the disk manufacturing process.

As the disk is processed through substrate grinding or turning, polishing, cleaning, texturing and sputtering, there are different issues that need to be considered. For example, a first stage polish is intended to provide very low flatness and waviness characteristics. The second stage polish is intended to provide the necessary micro-waviness and roughness characteristics. Post wash inspection is normally an examination of the ability of the wash process to remove particles or detection of contaminates.

Protocol:

The following protocol for testing samples should be used wherever possible:

- 1.) Tests should be conducted on a minimum of three samples, a maximum of six samples to provide a sufficient sample size to demonstrate measurement capability.
- 2.) Full surface tests of one sample should be performed six times to demonstrate tool repeatability and lack of “drift”.
- 3.) Two sets of samples with different characteristics should be tested for comparison.
- 4.) The tests performed will vary with the process step to be evaluated. The only exception to this is an evaluation of the disk at pre-sputter and final test which should be treated as a first article inspection with a complete spectrum of tests.

When specialized requests are made, for example, to locate or identify a specific problem or condition, the samples will be provided with:

- 1.) A clear statement of the specific problem or condition.
- 2.) A sample of the problem or condition. This sample shall be clean and the problem area will be identified with an indexing mark on the OD of the disk and the approximate radius shall be defined.
- 3.) Documentation of the specific problem or condition from existing instrumentation or a detailed explanation of how the problem was identified. Lack of documentation shall be considered to be a lack of specific knowledge of the problem or condition.
- 4.) A technical contact at the site who is familiar with the problem or condition.

Note: Specialized tests and testing for specific problems or conditions constitute troubleshooting and are not considered demonstrations of tool capabilities, gauge studies, resolution and repeatability. Such testing may require either a conditional Purchase Order for equipment or a service charge for the testing. If a service charge is required, it will apply to the purchase of the equipment by the following schedule: 100% if an equipment order is placed within 30 days of the testing invoice date, 66% within 45 days, 33% within 60 days.

Standard Tests Performed:

All samples should be clean and provided in sealed containers. Samples unfit for testing (i.e. dirty samples provided for defect testing) will be rejected as unsuitable for evaluation. The following tests will be performed on suitable samples that are submitted:

Flatness: Full surface test with best plane fit polar plot. Tests are performed using a 10 revolution average to remove flutter or resonance. All plots will be set to the same scale. Production data is also provided and consists of the maximum runout and acceleration values for each surface.

Filtered Waviness: Full surface tests for macro-waviness, waviness, micro-waviness, nano-waviness, macro-roughness, roughness, micro-roughness and nano-roughness. Three sets of plots are provided, a polar plot and a defect plot. These plots are from the standard tool displays and will all be set to the same scale for comparison. The third plot is from the production files of the RMS analysis and will display all similar samples on a single graph.

Power Spectral Density (PSD): Four track PSD tests will be run on all surfaces, ID, MD, OD and Extreme OD. PSD plots will be provided for each surface, all on the same scale for comparison. Production information is provided in a text file.

Thickness Variation: All samples will be tested for thickness variation and polar plots of thickness variation will be provided. Tests are performed using a 10 revolution to average to remove disk flutter or resonance. Production data, maximum thickness variation, is also provided. Thickness variation is only performed on dual beam systems and only on special request.

Resonance: Resonance testing is performed at the outer diameter but well inside of the chamfer edge. Testing is designed to cover the speed range from 3,000 to 15,000 rpm in 20 rpm increments. Data is displayed in a rectangular plot showing 360 degrees of rotation on the horizontal scale and the various test rpm on the vertical scale. The colors show the severity of the resonance. Resonance testing is only performed on a single material sample. If different materials are provided for testing, multiple samples will be tested. Resonance testing is only performed when specifically requested.

Asperities (Optical Glide): Full surface tests with defect polar plots to show the higher asperities sorted into sixteen defect levels. All samples will be plotted with the same defect levels. Two sets of avalanche plots will be generated from the production data, one showing the complete surface distribution and a second showing the higher defects.

Pits and Scratches (Optical Certification): Full surface tests with defect polar plots to show the deeper pits and scratches sorted into sixteen defect levels. All samples will be plotted with the same defect levels. Two sets of avalanche plots will be generated from the production data, one showing the complete surface distribution and a second showing the deeper defects.

Nano-Scan (Asperities): Full surface tests with defect polar plots to show the defects by spatial size, nano-asperities (0.1 to 0.6um), micro-asperities (0.6 to 2.0um), asperities (2.0 to 5.0um), particles (5.0 to 20um) and contamination (greater than 20um). All samples will be plotted with the same defect thresholds if possible. A text file will be provided that shows all individual defects by classification, spatial size, height, radius and angular location.

Nano-Scan (Pits): Full surface tests with defect polar plots to show the defects by spatial size, nano-pits (0.1 to 0.6um), micro-pits (0.6 to 2.0um), pits (2.0 to 5.0um), voids (5.0 to 20um) and digs (greater than 20um). All samples will be plotted with the same defect thresholds if possible. A text file will be provided that shows all individual defects by classification, spatial size, depth, radius and angular location.

Test Capabilities:

Filtered Waviness: This test is really broken down into two major divisions and four subdivisions. The two major divisions are roughness and waviness tests. Filtered waviness tests are performed by feeding the laser velocity signal through a band-pass filter. Upper and lower frequency cutoffs are set to the desired wavelength and the laser velocity signal is processed by an RMS circuit. The sample is taken over a sector, typically 1024 sectors per disk revolution, and passed to the data acquisition system at the end of each sector. Filtered waviness tests are a direct measurement of the surface contribution for fly height modulation or head-media separation as defined by Flyability™.

Roughness Tests: These tests cover the wavelength range from 0.5um to 50um. They are divided into four groups, nano-roughness from 0.5um to 5.0um, micro-roughness from 5.0um to 15um, roughness from 15um to 25um and macro-roughness from 25um to 50um. These ranges are comparable to AFM measurement ranges with the understanding that the AFM wavelength range is twice the field of view and has no lower wavelength cutoff. For example, a 5um measurement area with the AFM will measure everything from 0.5um (approximate tip size) to 10um, twice the “field of view” where a 10um measurement area with the AFM will measure everything from 0.5um (approximate tip size) to 20um, twice the “field of view”.

Nano-roughness, micro-roughness and roughness have feature lengths that are normally associated with air flow and drag characteristics. Ultra-smooth surfaces can be problematic with stiction-friction and lube based head to disk issues. Ultra rough surfaces can be problematic with fly height control. Uneven surfaces with areas of rougher and smoother finish can cause the head to fly in an unstable manner and generate fly height modulation resulting in high data error rates. Macro-roughness has more impact on the head stability as the heads get smaller and the fly heights continue to drop.

Waviness tests: These tests cover the wavelength range from 50um to 5,000um. They are divided into four groups, nano-waviness from 50um to 100um, micro-waviness from 100um to 400um, waviness from 400um to 2,000um and macro-waviness from 2,000um to 5,000um. These ranges are comparable to large scale AFM measurement ranges with the understanding that the AFM wavelength range is twice the field of view and has no lower wavelength cutoff. For example, a 100um measurement area with the AFM will measure everything from 0.5um (approximate tip size) to 200um, twice the “field of view”. They are also comparable to Microxam or New View measurements with the difference being that these instruments have a short wavelength cutoff in the 40um to 80um wavelength.

Nano and micro-waviness are critical to fly height modulation, sometimes called HMS or Head-Media Separation. These features typically need to be controlled to less than one Angstrom which dictates a measurement capability to one-tenth of that or 0.1Angstrom and repeatability should be one half of that or 0.05Angstrom. Features in the micro-waviness wavelength start to affect the head pitch. Longer wavelengths, waviness and macro-waviness, have features with wavelengths that are longer than the slider length. These features can affect the stability of the entire head support structure.

Power Spectral Density (PSD) testing: PSD tests cover the full spectrum from nano-roughness through macro-waviness. This test is designed to provide extreme detail across the full spectrum of surface morphology. 128 measurements are taken from 0.5um to 5,000um wavelength. The center frequencies are spaced at even logarithmic values and the bandwidths of each measurement insure a continuous and full spectrum measurement. The measurements are performed using the same circuitry and methodology as the filtered waviness tests. The advantage to the PSD test is that it provides extreme detail and resolution in a fully automated test at up to four user programmed radii.

Flatness testing (RVA – Runout, Velocity and Acceleration): Flatness, or more commonly, RVA testing measures the surface flatness. This normally is used to examine surface features that have a wavelength longer than macro-waviness which would be longer than 5mm. The flatness test is performed dynamically to simulate actual use. There are two critical measurements, flatness, also called runout or TIR (Total Indicated Runout) and acceleration.

By using a dual side flatness testing, processing the data in analog circuitry and capturing the resultant, thickness variation can be measured. Flatness testing can also be used to measure disk resonance properties with minor variations in the test setup and a special set of display graphics.

Runout: Flatness testing is normally performed on a static tool to examine the surface preparation grinding or turning, initial polish or warpage (i.e. heat relief effect on metal disks in the sputter process). On the THoT tool, this is a dynamic test and is intended to measure the disk as it would be applied in the drive. Evenly spaced data points are gathered over a user selectable number of radii.

Acceleration: This measurement is not as well understood and is the direct measurement of allowable surface topography variation that the head can fly over. Any head design will have a critical “climb / descend rate”. These are the rates at which the head will be able to follow a rising or falling distortion of the disk surface. This rate of surface rise or fall is measured as surface + or – acceleration.

Thickness variation testing: The upper and lower laser channels are combined as “A” plus “B” inverted. If both beams show the disk rising or falling above the normal mounting surface (this would be defined as runout), the combined output is zero. If the surfaces separate and either increase, the disk becomes thicker, or decrease, the disk becomes thinner, this variation is captured and mapped as thickness variation.

Resonance: A disk resonance test can be performed by holding the laser at one track position while the disk speed is increased. The disk will display a natural resonance as it passes through its critical excitation rotation speeds. This test is performed at the outer diameter and is normally performed as a study of the material properties.

Reflectivity testing: Reflectivity is a relative measurement of the energy reflected from the surface. To date there are no standards for reflectivity and one surface may be darker or lighter, more or less reflective based on the process chemistry or conditions. However, changes in reflectivity are typically indicative of problems such as wash stains or problems between the various layers, nickel to aluminum, magnetics to glass or metal, carbon to magnetics, etc. The reflectivity test can be performed in two manners referred to as “contour” and “defect”. In both tests, the reflected energy from the surface is measured using a logarithmic amplifier.

Reflectivity contour: This test is analogous to the flatness test. A fixed number of data points and radii are selected over the test area and measurements of the reflected energy are made. This method is designed to capture large area stains and haze such as “drip lines”, out-gassing, water marks, etc.

Reflectivity defects: This test is analogous to defect testing. The surface is scanned and the reflected energy level is captured as a peak value in each sector of the track (normally 1024 data transfers per revolution). The entire surface (both sides) can be mapped, quantified and plotted.

Asperities (Optical Glide™): An optical scan using a positive velocity impulse channel to detect anomalies that rise above the normal surface. Roughness and longer wavelengths are filtered out. These defects are normally associated with glide defects on finished disks or contamination on post wash disks. Four data acquisition channels are used to monitor the upper and lower surfaces and defects are captured by a positive peak capture and hold circuit. The highest positive velocity value is captured in each sector and the system software calculates the defect height.

Pits and scratches (Optical Certification™): An optical scan using a negative velocity impulse channel to detect anomalies that are depressions into the normal surface. Roughness and longer wavelengths are filtered out. These defects are normally associated with magnetic defects on finished disks or scratches and pits on polished or textured surfaces. Four data acquisition channels are used to monitor the upper and lower surfaces and defects are captured by a negative peak capture and hold circuit. The highest negative velocity value is captured in each sector and the system software calculates the defect depth.

Nano-Scan (Asperities): An optical scan using a positive velocity impulse channel to detect anomalies that rise above the normal surface. This test uses the Optical Glide test as the basis but then steps over the defect in micro-steps. The data gathered in these micro-steps is analyzed to determine the defect spatial size and then a deconvolution calculation is applied to determine the actual defect height. Defects with a spatial size greater than the beam size have a unity deconvolution multiplier. Defects are sorted by spatial size and listed by classification, location and height.

Nano-Scan (Pits): An optical scan using a negative velocity impulse channel to detect anomalies that are depressions into the normal surface. This test uses the Optical Certification test as the basis but then steps over the defect in micro-steps. The data gathered in these micro-steps is analyzed to determine the defect spatial size and then a deconvolution calculation is applied to determine the actual defect depth. Defects with a spatial size greater than the beam size have a unity deconvolution multiplier. Defects are sorted by spatial size and listed by classification, location and depth.

Specialized Tests: There are several very specialized tests that can be performed. Both of these tests require the fabrication of custom hardware.

Texture Zone Analysis: This is actually a sub-set of the asperities (Optical Glide) test. The texture zone is scanned, the edges automatically located, the zone is divided into inner and outer sections and 128 segments (8 sectors by the number of tracks). The mean, peak and standard deviation are calculated and displayed.

Disk drive testing: A disk drive can be tested to examine the runout, clamp distortion and disk flutter. This requires special drive mounting hardware and typically the drive manufacturer motor control hardware. Disk drive testing is fairly straight forward and is generally a sub-set of the flatness testing.

Flyability™: This can be performed in a disk drive or with a disk and head combination. The drive level test requires the disk drive testing above while the disk and head combination requires a special head mount. Two laser beams are used with one focused onto the head mechanism and the second onto the disk surface. Specialized software is utilized to capture and manage the data to show the head-to-disk interaction.

Recommended Tests:

Recommended tests depend on the task to be accomplished or process stage at which the examination is performed.

Function:	Pre-polish substrate qualification or development	Suggested Tests:	Flatness Macro-waviness Pits / Scratches (Optical Certification) Reflectivity Resonance
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Function:	Pre-sputter or Pre-super polish substrate qualification or development	Suggested Tests:	Flatness Macro-waviness Waviness Micro-waviness Nano-waviness Macro-roughness Roughness Micro-roughness Nano-roughness Power Spectral Density Asperities (Optical Glide) Pits / Scratches (Optical Certification) Nano-Scan (Asperities) Nano-Scan (Pits) Reflectivity
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Function:	Finished disk qualification	Suggested Tests:	Flatness Macro-waviness Waviness Micro-waviness Nano-waviness Macro-roughness Roughness Micro-roughness Nano-roughness Power Spectral Density Asperities (Optical Glide) Pits / Scratches (Optical Certification) Nano-Scan (Asperities) Nano-Scan (Pits) Reflectivity Resonance
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Function:	Slurry development or qualification	Suggested Tests:	Micro-waviness Nano-waviness Macro-roughness Roughness Micro-roughness Nano-roughness Power Spectral Density Pits / Scratches (Optical Certification) Nano-Scan (Asperities) Nano-Scan (Pits)
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Function:	Polish process qualification or development	Suggested Tests:	Flatness Macro-waviness Waviness Micro-waviness Nano-waviness Macro-roughness Roughness Micro-roughness Power Spectral Density Pits / Scratches (Optical Certification) Asperities (Optical Certification) Nano-Scan (Asperities) Nano-Scan (Pits)
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Function:	Texture process qualification	Suggested Tests:	Micro-waviness Nano-waviness Macro-roughness Roughness Micro-roughness Nano-roughness Power Spectral Density Pits / Scratches (Optical Certification) Asperities (Optical Certification) Nano-Scan (Asperities) Nano-Scan (Pits)
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Function:	Polish pad qualification	Suggested Tests:	Micro-waviness Nano-waviness Macro-roughness Roughness Micro-roughness Nano-roughness Power Spectral Density Pits / Scratches (Optical Certification) Asperities (Optical Certification) Nano-Scan (Asperities) Nano-Scan (Pits)
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Function:	Substrate grind or turning	Suggested Tests:	Flatness Macro-waviness Waviness Pits / Scratches (Optical Certification)
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Function:	1st stage polish	Suggested Tests:	Flatness Macro-waviness Waviness Micro-waviness
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Function:	2nd stage polish	Suggested Tests:	Waviness Micro-waviness Nano-waviness Macro-roughness Roughness Micro-roughness Power Spectral Density Asperities (Optical Glide) Pits / Scratches (Optical Certification)
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Function:	Post-polish clean	Suggested Tests:	Asperities (Optical Glide) Pits / Scratches (Optical Certification) Nano-Scan (Asperities) Nano-Scan (Pits) Reflectivity
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Function:	Super-Polish	Suggested Tests:	Micro-waviness Nano-waviness Macro-roughness Roughness Micro-roughness Power Spectral Density
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Function:	Pre-sputter clean	Suggested Tests:	Asperities (Optical Glide) Pits / Scratches (Optical Certification) Nano-Scan (Asperities) Nano-Scan (Pits) Reflectivity
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Function:	Post sputter	Suggested Tests:	Asperities (Optical Glide) Nano-Scan (Asperities) Filtered Waviness Power Spectral Density Reflectivity
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Function:	Final Test	Suggested Tests:	Filtered Waviness Power Spectral Density Asperities (Optical Glide) Pits / Scratches (Optical Certification) Nano-Scan (Asperities) Nano-Scan (Pits)
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