2D material Detector &

Transfer System

User Manual

Model: SLG8

V 3.0

Sejong Scientific Instruments Co., Ltd.

Chapter 1. Product Background

Two-dimensional (2D) materials are key materials for a wide range of advanced technologies, including the Internet of Things (IoT), flexible electronics, ultra-low-power devices, next-generation batteries, water purification systems, and aerospace applications. A 2D material consists of atoms arranged in a planar crystal structure with a thickness of only a single atomic layer, typically on the order of one nanometer.

Depending on their electrical properties, 2D materials can be classified as conductors, semiconductors, or insulators. Representative examples include graphene (conductor), transition metal dichalcogenides (TMDCs) and black phosphorus (semiconductors), and hexagonal boron nitride (hBN) (insulator).

Graphene, one of the most well-known 2D materials, was originally discovered using a technique known as mechanical exfoliation. In this process, adhesive tape is repeatedly used to peel atomically thin layers from bulk graphite. Although simple, this method remains widely used because it produces the highest-quality 2D materials available.

However, after exfoliation, identifying monolayer flakes under an optical microscope is a time-consuming task. In addition, prolonged exposure to air can lead to oxidation of sensitive materials. The yield is also extremely low, with only a few monolayer flakes typically found within a square centimeter of substrate area.

To address these limitations, the 2D Material Detector was developed. The system automatically identifies exfoliated 2D materials and records their locations for subsequent device fabrication and analysis.

If the microscope image appears unusually dark due to camera settings, select Device → White Balance On. The software will automatically adjust the camera parameters and restore normal image quality.

The system can also be equipped with an integrated 2D Material Transfer System, allowing immediate transfer of detected flakes without moving the sample to another instrument. The transfer module includes a heated stage and a vacuum chuck for secure wafer handling during transfer operations.

Chapter 2. Operation Guide (Control Panel)

Power-On Procedure

Turn on the power switches of both the stage controller and the LED illumination unit.

The illumination intensity can be adjusted using the brightness control knob or buttons. For most applications, a brightness level of approximately 40–50% of the maximum output is recommended.

The camera USB cable must be connected to a USB 3.0 port on the PC. In addition, the controller communication cable located on the rear panel must also be connected to the PC for normal operation.

Sample Loading and Height Adjustment

Place the sample so that its lower-left corner is located near the system origin.

The origin can be identified by gradually increasing the LED brightness until the white illumination spot becomes visible beneath the objective lens. If the illumination is centered near the lower-left region of the sample, the sample is correctly positioned.

The objective lens has a working distance of approximately 20 mm. Adjust the sample height so that the distance between the sample surface and the bottom of the objective lens is close to this value.

Height adjustment can be performed manually using the microscope focusing lever or the Z-axis adjustment knob.

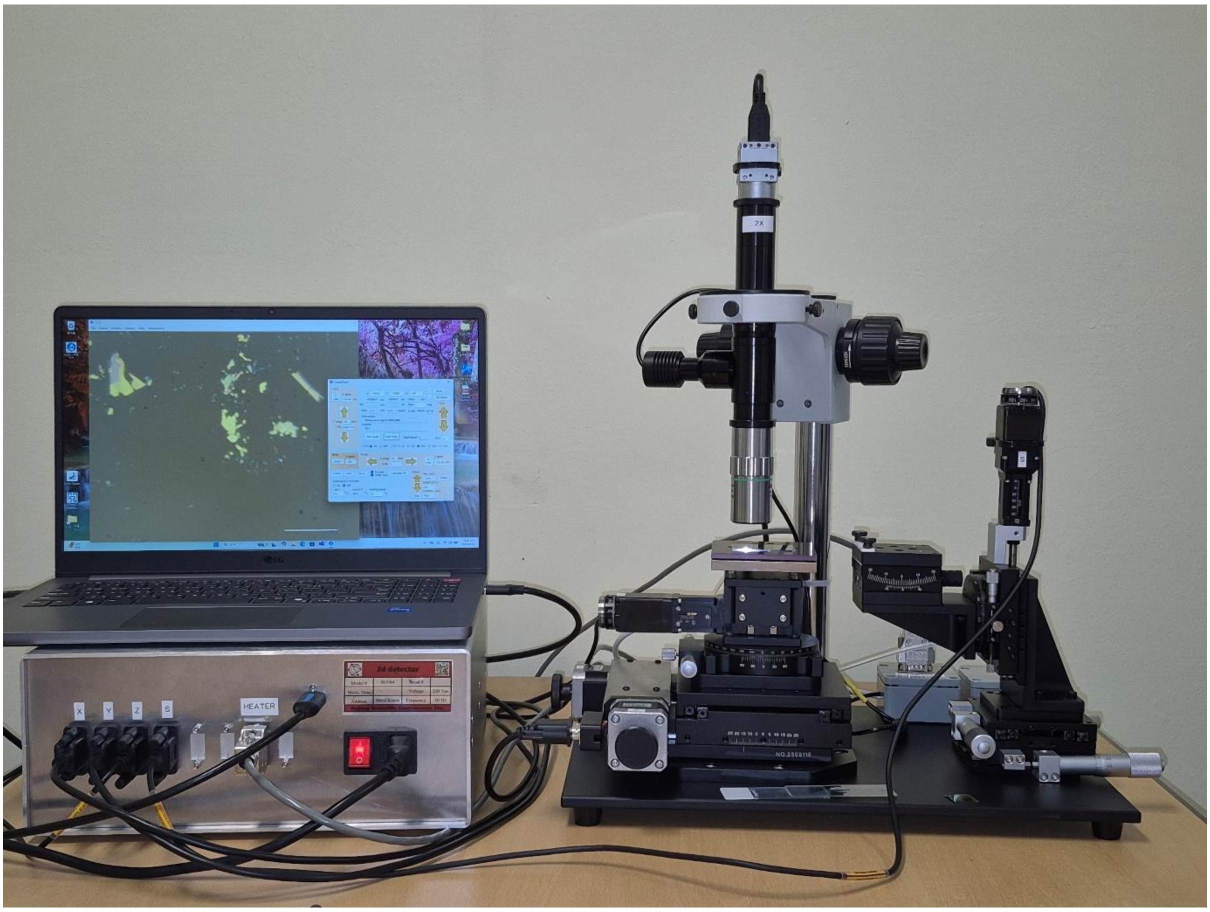

Figure 1. Overall System View

Launching the Software

Double-click the **SLG8** software icon on the control PC to launch the application.

Stage Position Control

The X, Y, and Z coordinate fields allow direct positioning of the stage.

Enter a coordinate value and press **Enter**, or click the **Move** button to move the stage to the specified position. The current position is displayed below the input field.

If the sample is rotated using the rotation stage, enter the rotation angle into the **Theta** field. The software calculates and displays the corresponding rotated coordinates in the **Rot** fields for user convenience. These coordinates are provided for reference only and are not used for automatic stage control.

To define the current position as a new scan origin, click "**Set Origin**".

Autofocus Operation

The main window displays the live microscope image, while the Control Panel is shown on the right side of the screen.

If the image is out of focus, the autofocus functions can be used:

Coarse Focus

Used when the sample is significantly out of focus. The system performs a large-range focus search.

Fine Focus

Used for precise focus adjustment when the sample is already near the focal plane.

Focus

Performs high-precision autofocus and determines the optimal focus position.

When one of these functions is activated, the Z-axis motor automatically adjusts the sample height until focus is achieved.

If the image is far outside the focus range, perform a coarse adjustment first and then press the Focus button for final optimization.

Once focus has been established at the scan starting point (Origin), the corresponding Z-position is stored in the **Z Depth** field. This value is later used as the reference height for scanning and tilt correction.

Note: In this manual, "Origin" refers to the scan starting position and does not necessarily correspond to the coordinate (0, 0, 0).

Camera Status

The **Cam On/Off** indicator shows whether live image acquisition is active.

- **On**: Camera is operating normally.
- **Off**: Live image acquisition has stopped and the LED illumination is turned off.

The system automatically enters this state after an extended period of inactivity.

Objective Lens Selection

The radio buttons labeled **5x, 10x, 20x, 50x, and 100x** indicate the currently installed objective lens.

The system is supplied with a 20× objective lens as standard, and the 20× option should normally be selected.

If a different objective lens is installed, select the corresponding magnification. The selected objective determines:

- Field of view (FOV)
- Scale bar size
- Scan step size
- Image calibration parameters

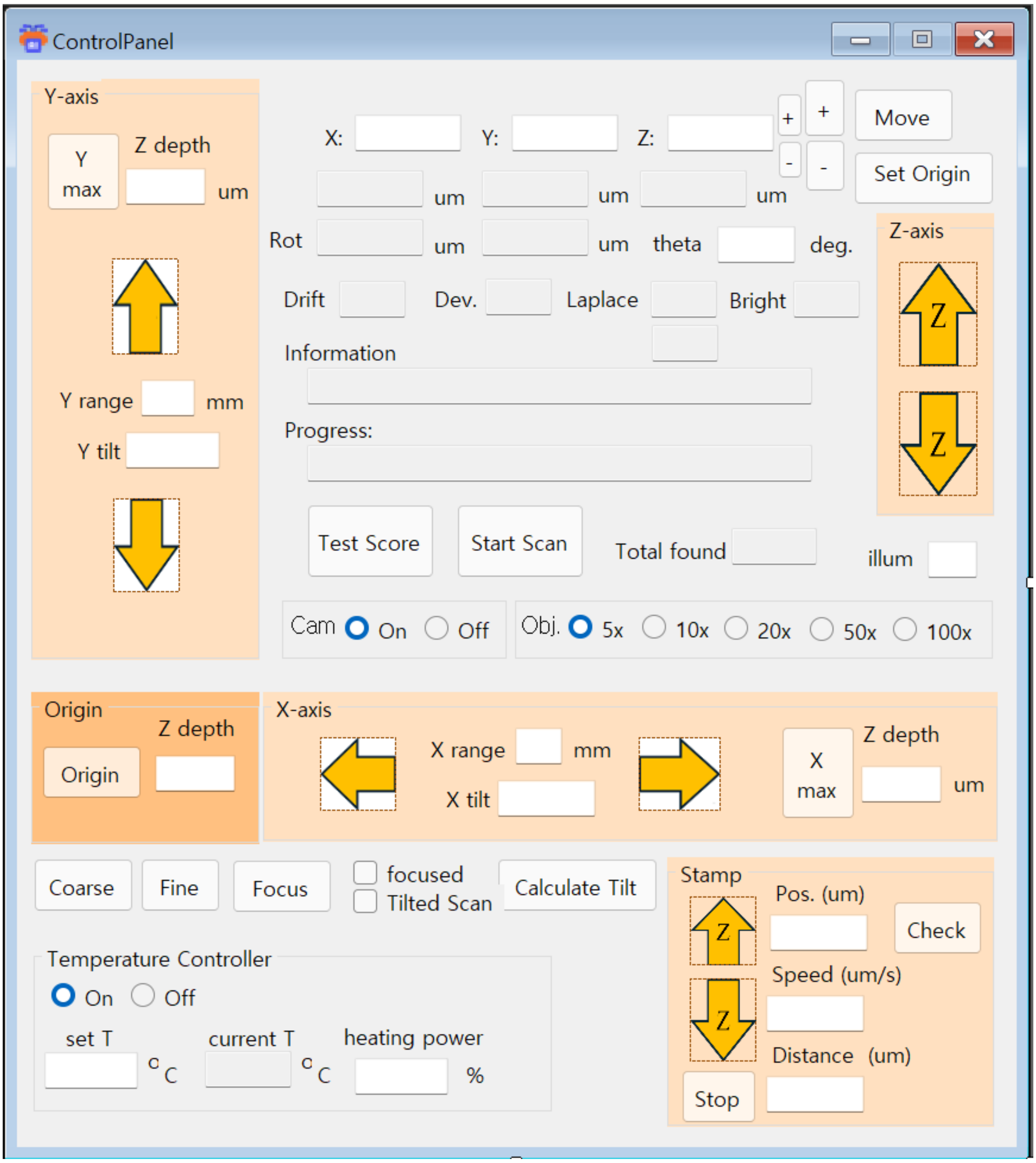

Figure 1 Control Panel

The X-axis, Y-axis, and Z-axis sections highlighted in orange display the movement, scan range, and tilt information of each axis. By clicking the arrow buttons in these sections, the user can move the stage one step at a time in the corresponding direction.

Scan Range Configuration

Verify that the default values for **X Range** and **Y Range** displayed in the Control Panel are appropriate for your sample. The scan range can be set from **1 mm to 50 mm** and should be adjusted according to the sample size.

To verify the configured scan range, click the **X Max** button located on the right side of the Control Panel. The X-axis stage will move to the maximum position defined by the current X-range setting. At this position, perform either automatic or manual focusing, then press the **Focus** button to record the **Z-depth (focus height)** at the X Max position.

Similarly, click the **Y Max** button to move the stage to the maximum Y-axis position. Adjust the focus and press the **Focus** button again to record the **Z-depth** at the Y Max position.

For fine manual focus adjustment while observing the live microscope image, use the **+** and **–** buttons next to the **Z** field. Each click changes the Z position by **1 µm**, and the adjusted value is automatically stored as the new Z-depth.

The **Origin** corresponds to the lower-left corner of the sample area to be scanned. Move the X and Y stages until the LED illumination is positioned over the desired starting location, adjust the focus (Z position), and then click **Set Origin**. The selected position will be stored as the reference point from which scanning begins.

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Performing a Scan

The system supports two scanning modes:

1. **Tilt-Corrected Scan**
2. **Constant-Height Scan (without tilt correction)**

To perform a tilt-corrected scan, enable the **"Tilted Scan"** option located in the lower-right corner of the Control Panel. When this option is selected, the system compensates for sample tilt during the scanning process.

If the **"Tilted Scan"** option is not selected, the scan is performed at a constant Z-height without any tilt compensation.

For samples smaller than approximately **5 mm**, tilt correction is generally not required, and scanning can be performed using the constant-height mode without significant loss of performance.

Tilt-Corrected Scanning

To perform a **Tilted Scan**, the **X-Tilt** value (center-bottom) and **Y-Tilt** value (center-left) must be defined.

If the tilt fields are left blank and the **"Tilted Scan"** option is enabled, pressing the **"Start Scan"** button will cause the system to automatically measure the sample tilt before beginning the scan.

When manual tilt adjustment is required, the Z-depth values at the **Origin**, **X Max**, and **Y Max** positions must first be determined. Move the stage to each of these locations and adjust the focus while observing the live microscope image.

For manual fine focus adjustment, use the **+** and **–** buttons next to the **Z** field. Each click changes the Z position by **1 µm**, and the updated value is automatically stored as the new Z-depth. Alternatively, pressing the **Focus** button performs automatic focusing and stores the resulting focus position as the Z-depth value.

Once the Z-depth values for the **Origin**, **X Max**, and **Y Max** positions have been recorded, click **"Calculate Tilt"**. The system will calculate the X- and Y-tilt values and display them on the screen.

After the tilt values have been determined, click **"Start Scan"** to begin scanning immediately.

To stop a scan at any time, simply click anywhere on the image display area with the mouse. The scanning process will be terminated immediately.

Monitoring Scan Progress

During scanning, the **Information** and **Progress** boxes located in the center of the Control Panel display the current scan status and the estimated remaining time.

In addition, the lower fields beneath the **X**, **Y**, and **Z** coordinate displays continuously show the current stage position in real time as the scan progresses.

Once the scan is completed, the system automatically stops operation, returns the stage to the **Origin** position, and switches back to normal microscope mode.

To save the current microscope image, press the **Enter** key or select **Save Image** from the menu.

Viewing Saved Images

Images containing detected **2D material flakes** are automatically saved during the scanning process. The images are stored in the **"image data"** folder located on the desktop, within a subfolder named according to the current date and time.

Each image filename includes the corresponding **sample coordinates**, allowing the user to easily identify the location of the detected flake.

An image captured at the **Origin (0,0)** position is always saved together with the detected flake images and serves as a reference image.

Detected 2D material flakes are highlighted with **red rectangular boxes** in the saved images.

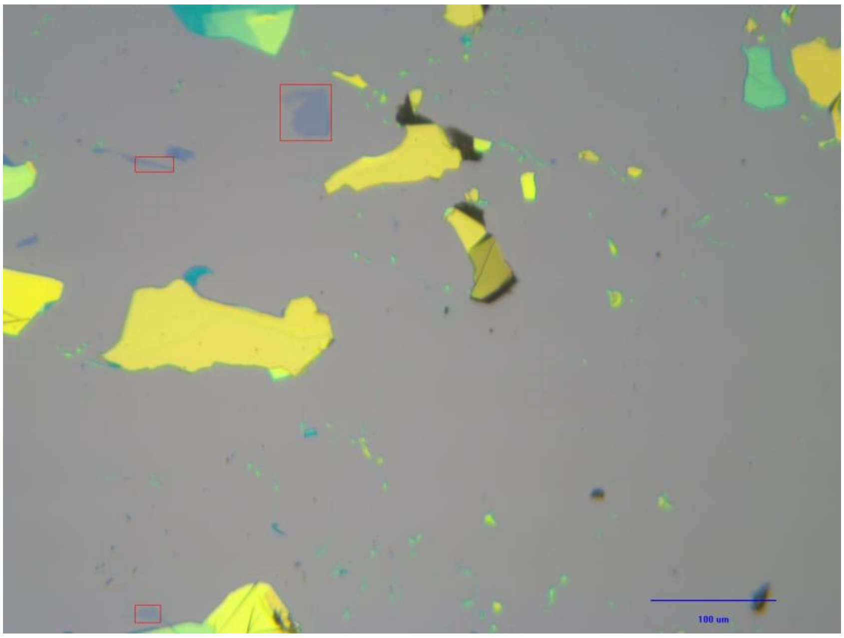
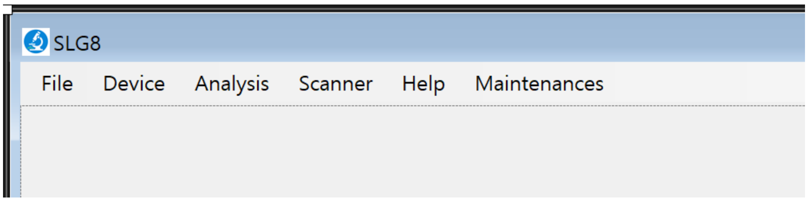


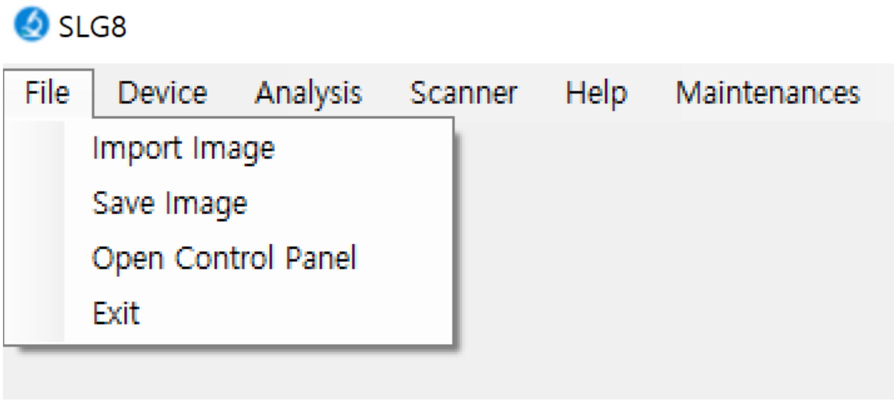
Figure 3 Saved Image

Chapter 2-2: Operation Guide (Using the Menu)

The main application window contains six menu items, as shown below. These menus provide access to image management, system configuration, analysis tools, maintenance functions, and other advanced features of the 2D Material Detector and Transfer System.



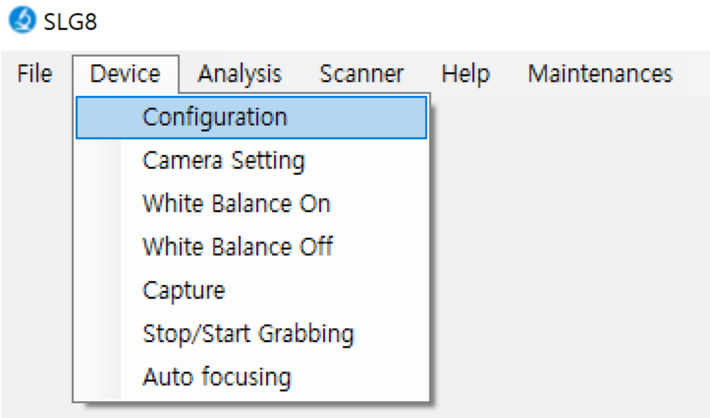
The **Import Image** option in the **File** menu is used to load previously saved images for offline analysis. This feature is generally not required for routine 2D material detection and is intended primarily for post-processing and detailed image analysis.



Save Image is used to save the image currently displayed on the screen. When this menu item is selected, the image is saved to the **Data** folder located on the desktop.

Open Control Panel restores the Control Panel window if it has been hidden or minimized.

The **Device** menu provides access to hardware configuration and system settings for the instrument.



Device Configuration

If the **XYZ stage controller (MCU)** or the **camera** is not properly connected, disconnect the USB cable, reconnect it, and then click the **Initialize** button to re-establish communication.

The **MCU COM Port** number can be found in the Windows **Device Manager** under **Ports (COM & LPT)** as a **USB Serial Device**. If an incorrect COM port number is entered, the motors will not operate. In this case, enter the correct port number and click **Initialize** to reconnect the controller.

Focusing Interval specifies how often the system automatically refocuses during long scans. This feature compensates for stage drift that may cause the sample to gradually move out of focus. The autofocus routine is executed once every specified interval.

Focusing Depth defines the Z-axis search range used during autofocus. A larger value should be used when significant focus drift is expected, while a smaller value is sufficient when drift is minimal. Note that increasing this value will also increase the autofocus time.

Focus Factor is a parameter used to optimize autofocus performance. Since the measured **Laplacian value** depends on the sample characteristics, this parameter may require adjustment for different types of samples. A value of **1.5** is generally recommended. For samples with few flakes or highly distinct features, a lower value of approximately **1.0** may improve performance. Conversely, for samples containing many flakes, increasing the value to **2–3** often results in faster autofocus operation.

The **Objective Lens** setting is used to specify the magnification of the currently installed objective lens. Enter the objective magnification in the **Mag.** field, and the system will automatically calculate the corresponding **Field of View (FOV)** and **Scan Step** values.

The **Gain** and **Exposure** settings control the camera sensitivity and exposure time, respectively. Under normal operating conditions, the default values should not be changed unless special imaging conditions require adjustment.

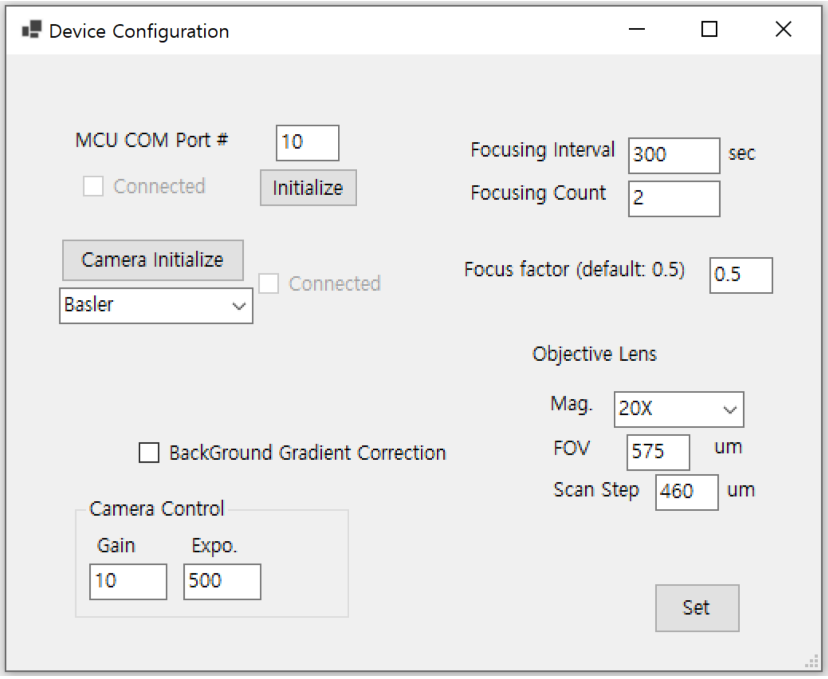


Figure 8 Device -> Configuration menu window

Contrast Ratio Configuration

To access the contrast ratio settings, select Configuration from the Analysis menu.

In the Materials (Known) section, choose the desired 2D material and substrate. The system will automatically display the theoretically calculated default contrast ratio values (R, G, and B).

These values can also be adjusted manually by the user. The Tolerance parameter, which defines the acceptable deviation range for detection, can likewise be modified. Increasing the tolerance may improve sensitivity but can also introduce additional noise, while setting it too low may cause weak or faint 2D materials to be missed.

User-defined settings can be saved by clicking the Register As button. Saved configurations will appear under Materials (User Registered).

Although the tolerance value can be determined automatically, a practical guideline is to set it to approximately half of the largest contrast value among R, G, and B.

The Score Threshold parameter determines whether a detected region is classified as a 2D material. Increasing this value causes the system to select only flakes that are large, clearly visible, and highly uniform in color. However, excessively high values may result in missing genuine 2D material flakes that are small, fragmented, or non-uniform. A value of approximately 60 is recommended for most applications.

Flake Size Range Configuration

To define the size range of flakes to be detected, enter the desired minimum and maximum values in the fields next to Size (μm^2).

For the settings to be valid, the maximum value must be greater than the minimum value.

To verify whether the current detection parameters are appropriate, click the Test Now button. The system will analyze the current image, highlight the boundaries of detected 2D material flakes, and display the classification results on the screen.

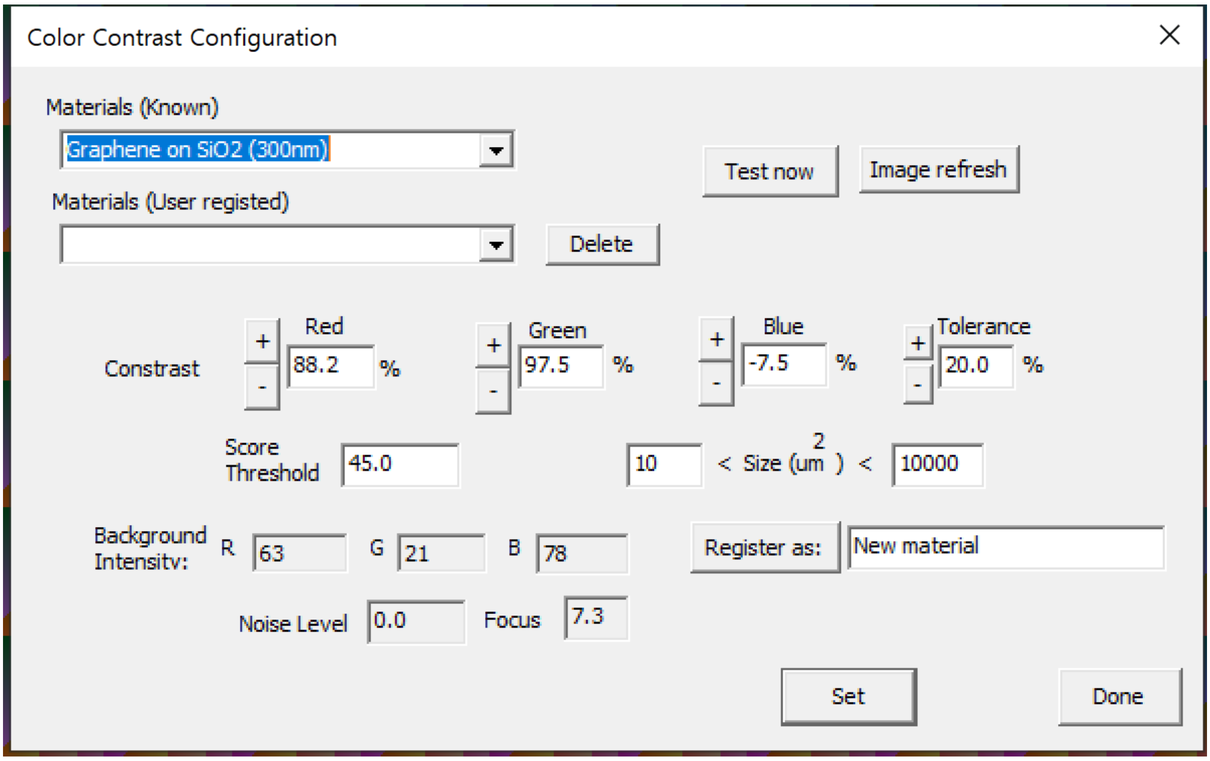


Figure 4 configuration window

Automatic Calculation of Theoretical Contrast Ratios

The **Contrast Calculation** function can be accessed from the **Analysis** menu.

The **Materials (2D)** section contains a list of commonly studied 2D materials. When a specific material is selected, the system displays its **complex refractive index** values. Because the refractive index varies with wavelength, separate values are provided for the **R, G, and B** channels. The thickness of a single layer is also displayed. Users may specify the desired number of layers by entering a value in the **# of Layers** field.

The **Materials (Substrate)** section contains commonly used oxide layers on silicon substrates. When a substrate material is selected, its complex refractive index is displayed. The oxide thickness is shown in the **d2** field and can be modified by the user. The theoretical calculations assume a silicon (Si) substrate beneath the oxide layer.

Click the **Calculate** button to compute the theoretical contrast values using the **Fresnel interference equations**. The calculated contrast ratios for the **R, G, and B** channels are displayed in the **Contrast R**, **Contrast G**, and **Contrast B** fields, respectively.

If the calculated values are to be used directly for material detection, click the **Set** button. The new contrast ratio values will then be automatically applied to the **Color Contrast Configuration** settings.

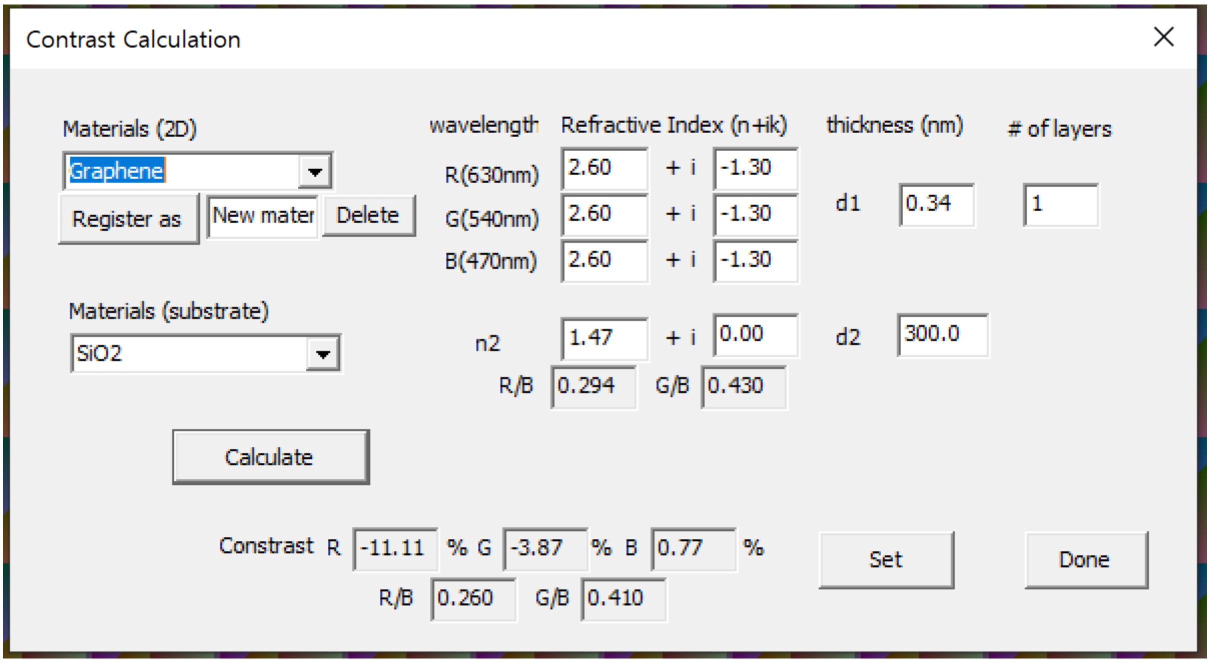


Figure5 contrast calculation window

Sample Position Control Using the Keyboard and Mouse

The sample can be moved in the **up, down, left, and right directions** by pressing the keyboard arrow keys (↑, ↓, ←, →). Each key press moves the stage by **400 μm**.

If the image becomes out of focus during movement, the sample height (**Z-axis position**) can be adjusted using the **PgUp** and **PgDn** keys.

Manual Adjustment of 2D Material Detection Parameters

When working with a new 2D material or a new substrate, it may be difficult to estimate the appropriate **contrast ratio** values. In such cases, the user can manually search for 2D material flakes by directly observing the microscope image.

When a suspected 2D material flake is found, press the **Enter** key to save the image. Then, left-click on the suspected flake region. A message box will appear displaying the **R, G, and B contrast values** of the selected pixel.

The software will then ask whether these values should be used as the contrast ratio settings for 2D material detection. If **Yes** is selected, the contrast values of the selected pixel will be applied to the detection configuration.

If the settings are changed unintentionally, the previous values can be restored by returning to the **Configuration** menu and reloading the desired settings.

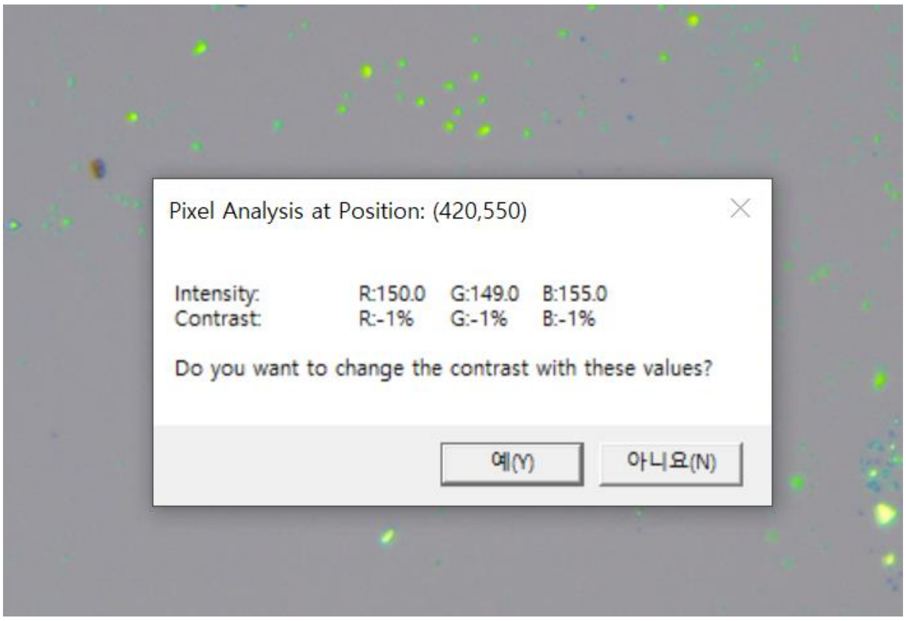
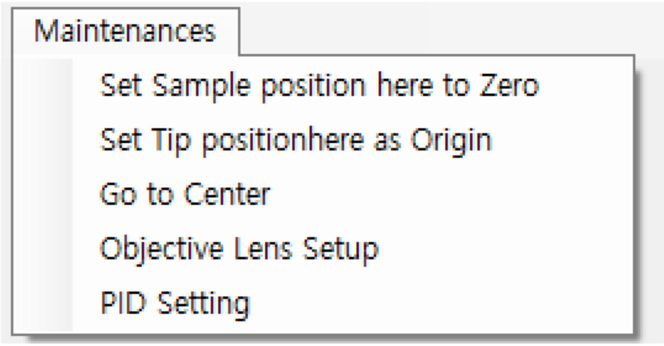


Figure 7 마우스로 선택한 Pixel의 컬러값을 보여줌

Maintenance 메뉴



Maintenance Menu

Selecting Maintenance → "Set Sample Position Here to Zero" defines the current stage position as the new coordinate origin (0, 0, 0).

This function is rarely required during normal operation and is primarily used when the center of rotation of the rotation stage needs to be recalibrated. For example, if the software closes unexpectedly and the rotational center becomes misaligned, this function can be used to redefine the coordinate system and restore proper alignment.

Selecting Maintenance → "PID Setting" allows the user to modify the PID control parameters used for heater temperature regulation.

If the optimal PID values are unknown or if the system becomes unstable after parameter adjustment, it is recommended to click the Default button to restore the factory-calibrated PID settings provided at the time of shipment.

(Transfer system)

Stamp Stage

The transfer system includes an **XYZ stage** for controlling the position of the stamp, together with a glass slide mounted on the stage.

Depending on the system configuration, the **X** and **Y** axes can be operated either manually or by motorized control. The **Z-axis** is motorized as a standard feature and is controlled through the controls located at the bottom of the Control Panel.

Clicking the **up-arrow** button moves the stamp stage upward, while clicking the **down-arrow** button moves it downward.

The movement **speed** and **travel distance** are displayed in the **Speed** and **Dist** fields, respectively. These values can be adjusted by the user as required.

To stop the stage immediately at any time, click the **Stop** button.

Heater Stage

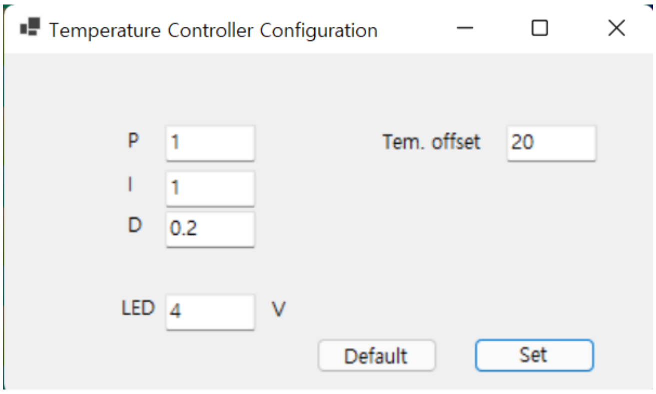
The heater stage controls are located at the bottom of the Control Panel. The current temperature is displayed in real time.

The **On/Off** button determines whether the heater operates in **automatic PID control mode** or **manual power control mode**.

- When **On** is selected, the heater automatically regulates the temperature to the value specified in the **Set Temperature** field using PID control.
- When **Off** is selected, the heater output power remains fixed at the value entered in the **Out Power** field.

Caution: The heater stage can reach high temperatures during operation. Please take appropriate precautions to avoid burns.

The PID control parameters can be adjusted through **Maintenance → PID Setting**



PID Temperature Control

The heater controller uses a standard **PID (Proportional–Integral–Derivative)** control algorithm to regulate temperature.

Definitions

$$\text{error} = \text{setpoint} - \text{input Temp}$$

where:

- **error**: Temperature error (°C)
- **setpoint**: Desired temperature (°C)
- **inputTemp**: Measured temperature (°C)
- **dt**: Time interval (s)
- **outputPercent**: Heater output power (%)

Proportional (P) Term

The proportional gain, K_p, determines how strongly the controller responds to the current temperature error.

$$P = K_p \times error$$

The unit of K_p is:

$$K_p = \frac{\%}{^\circ C}$$

For example, if **Kp = 8.0**, a temperature error of **1°C** will produce an **8% change in heater output**.

Integral (I) Term

The integral term accumulates the temperature error over time and helps eliminate steady-state errors.

$$I = K_i \int error\, dt$$

The unit of K_i is:

$$K_i = \frac{\%}{^\circ C \cdot s}$$

For example, if:

- **Ki = 0.8**
- Temperature error = **5°C**
- Duration = **10 s**

then the integral contribution is:

$$0.8 \times 5 \times 10 = 40\%$$

Therefore, the integral term contributes **40% output power**.

Derivative (D) Term

The derivative term predicts future error by monitoring how quickly the error changes with time.

$$derivative = \frac{error - previousError}{dt}$$
$$D = K_d \times derivative$$

The unit of K_d is:

$$K_d = \frac{\% \cdot s}{^\circ C}$$

For example, if:

- **Kd = 0.3**
- The temperature is changing toward the target at a rate of **1°C/s**

then the derivative contribution is:

$$0.3 \times 1 = 0.3\%$$

Thus, the derivative term contributes **0.3% to the heater output**.

The derivative term helps reduce overshoot and improves system stability by responding to rapid changes in temperature.

Vacuum Chuck

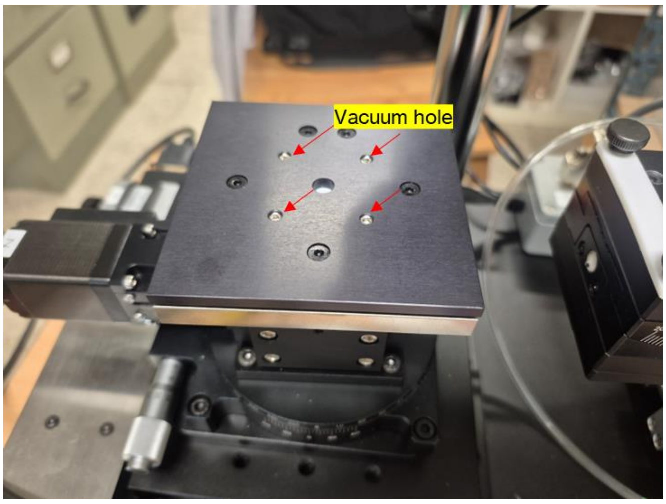
The transfer system is equipped with a **vacuum chuck** to securely hold samples during the transfer process. Before using the vacuum chuck, ensure that the **vacuum pump is turned on** and operating properly.

The vacuum chuck contains **one central vacuum port** and **four additional vacuum ports surrounding it**.

For transferring a single sample, place the sample over the **central vacuum port** and keep the four surrounding ports sealed with the provided **set screws**. These ports are sealed by default at the time of shipment.

For larger samples or when working with multiple types of 2D materials simultaneously, the set screws may be removed to activate the additional vacuum ports and increase the effective holding area.

Caution: Do **not** loosen or remove any of the other black bolts on the vacuum chuck. Only the designated set screws should be removed when additional vacuum ports are required.



Chapter 3: Equipment Maintenance and Technical Support

This concludes the operating instructions for the 2D Material Detector & Transfer System.

If you require additional information, technical assistance, or support related to the operation of the system, please contact **Sejong Scientific Instruments** through the company website:

https://www.sejongsciinst.com/

Our technical support team will be pleased to assist you.

The system is designed using standardized and modular components, making it straightforward to modify, customize, or expand the system to meet specific research requirements. We actively support users who wish to adapt the instrument for specialized applications.

A video tutorial for the system is also available at the following link:

https://www.youtube.com/watch?v=92kUt2Gia9c&t=112s

We appreciate your trust in Sejong Scientific Instruments and wish you success in your research and development activities.