NanoLithography

316.1 Overview

This support note details **NanoLithography** theory, **NanoScript™** syntax for performing lithography commands and procedures to test, build and run NanoLithography programs.

Refer to the following sections for using your NanoLithography Package:

Document Revision History: NanoLithographyy

Revision	Date	Section(s) Affected	Reference	Approval
A	11-12-01	New Release	DRF 0426	C. Fitzgerald L. Fukunaga

Part Number: 013-316-000

316.2 New NanoLithography Package

Scanning Probe Microscope (SPM) Lithography or **NanoLithography** functions are now available in an optional package. The NanoLithography enhancements include:

- Building custom lithography programs
- Building (and debugging) larger programs to control the NanoScope.

The new package includes an industry standard compiler as well as three sample templates to successfully test and run your Lithography programs. The program files are in the form of dynamic-link library (DLL) files for loading in to the NanoScope system software.

316.2.1 Package Contents

The optional NanoLithography package includes:

- **This Support Note** [New]**—**Detailing NanoLithography theory, Macro language commands, procedures and sample programs for use as templates.
- **Compiler** [New]**—**An industry standard, C/C++ compiler to build dynamic link libraries (DLL).

Note: The current compiler is Microsoft ® Visual C++ Standard Edition™, Version 6.0.

- **gui.h** [New]—File of the graphical user interface (GUI) functions to add dialog boxes, messages and notes, etc. for user input.
- **litho.h**—File of Lithography function declarations (i.e., functionally the same as previous versions) to run the basic lithographic functions.
- **z.lib**—Library of NanoScope functions (i.e., linked in to your program).
- **Sample Programs—**Three sample programs to test, modify and write Lithography programs.

316.2.2 Terms and Definitions

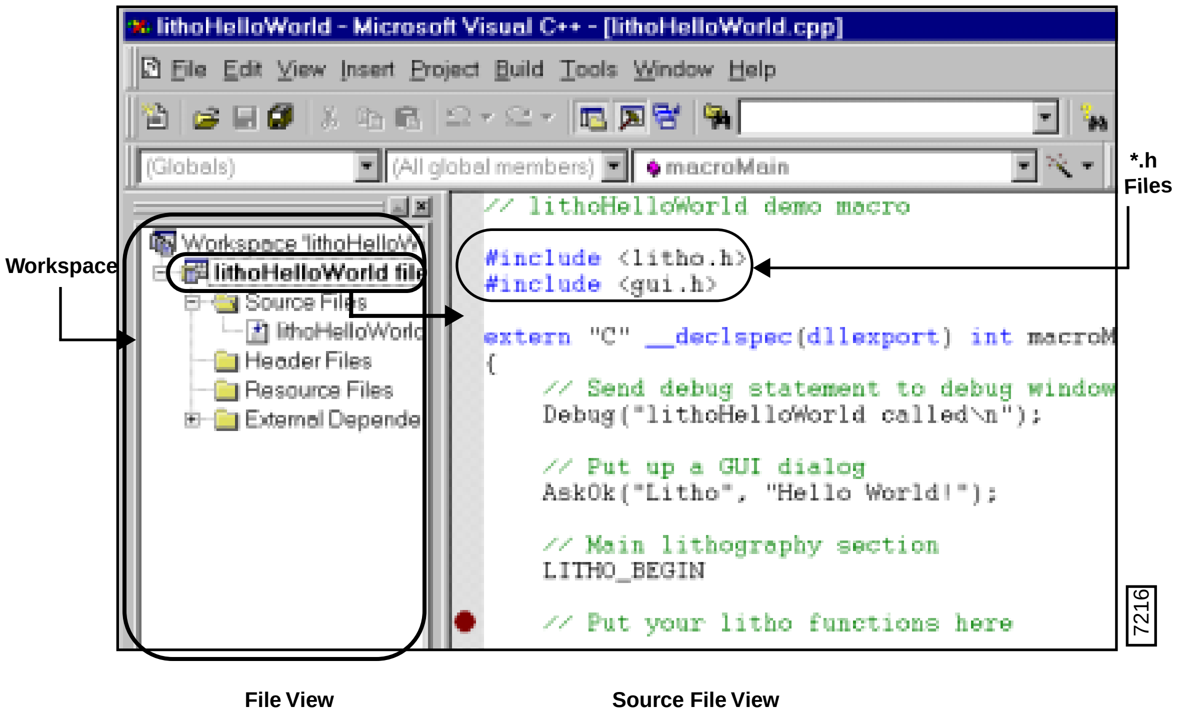
In order to understand the processes detailed in this support note, it may be helpful to become familiar with specific terms:

Table 316.2a NanoLithography Terms and Definitions

Term	Definition
Compiler	The compiler (i.e., Visual C++ Studio compiler) is responsible for building the project files in to a dynamic link library (DLL) file. Visual C++ provides an Integrated Development Environment (IDE) that allows you to write, build, and debug C/C++ programs (i.e., the basis for Lithography programs). The compiler environment also provides easy navigation of your source code.
Dynamic Link Libraries (DLL)	A dynamic-link library (DLL) is an executable file that acts as a shared library of functions, which contain one or more commands that are compiled, linked, and stored separately. DLLs also facilitate the sharing of data and resources. The NanoScope software searches and loads the DLL file to run the Lithography program.
Header Files (*.h)	Header Files or "Include Files" contain the C/C++ declarations of the functions you use for NanoScript or lithography. In the C/C++ environment, functions must be declared before they are used. Your macro source file must explicitly include the header file that contains the function you want to call. (ex. "**#include <litho.h>**"). Litho.h in this example includes all the NanoScope lithography functions that are available. If you want to call GUI functions, include gui.h. (ex. "#include <gui.h>") These header files should be located in the **Include** subdirectory in the SPM folder.
NanoScript Language	NanoScript is a fully C-capable language extension that includes over 200 library functions written by Digital Instruments' programmers. For further details, see **NanoScript Macros:** Section 316.6 on Page 37.
Project	A project is similar to a folder. It consists of a set of files, which act together to perform the Litho functions (See Figure 316.2a).
Source Files	In the Microsoft Project files, the source files include the NanoScript Language information. When selected, code is visible in the right window to verify, edit or modify the NanoLithography settings. The source files contain exported functions (i.e., _declspec modifier), internal functions, and output functions for the DLL.
Workspace	A window in the C++ compiler that consists of a set of objects, files and folders. The folders contain specific project information for the Lithography program. Figure 316.2a displays a workspace.

Term	Definition
Z.lib	A library of NanoScope functions (i.e., linked in to your program). This import library (Z.LIB) file contains information that the link (Project > Settings > Link tab) needs for resolving external references to exported DLL functions. The purpose is for the system to locate the loaded DLL file and then export the NanoScope Lithography functions in real time mode. For example, to call the **AskOK** function, you must link the code with the import library Z.LIB. The reason is that **AskOK** resides in the NanoScope system DLL. The file Z.LIB is the import library used to resolve the call to apply the **AskOK** command in your code.

Figure 316.2a Workspace and Project Files



```
// lithoHelloWorld demo macro

#include <litho.h>
#include <gui.h>

extern "C" __declspec(dllexport) int macroM
{
    // Send debug statement to debug window
    Debug("lithoHelloWorld called\n");

    // Put up a GUI dialog
    AskOk("Litho", "Hello World!");

    // Main lithography section
    LITHO_BEGIN

    // Put your litho functions here
```

316.3 NanoLithography Theory

The **NanoLithography** feature allows for performing movements in nano scale areas. The lithography programs direct the microscope to inscribe or move items on the sample surface. Figure 316.3a shows an STM (Scanning Tunneling Microscopy) lithograph of concentric shapes (i.e., polygon and circles) on a poly carbonate. This lithography uses a specially designed scanner called a **Closed Loop XY** scanner.

Note: For additional information on using a Closed Loop XY scanner, contact your Digital Instruments, Veeco Metrology Group representative.

Figure 316.3a Lithography Image

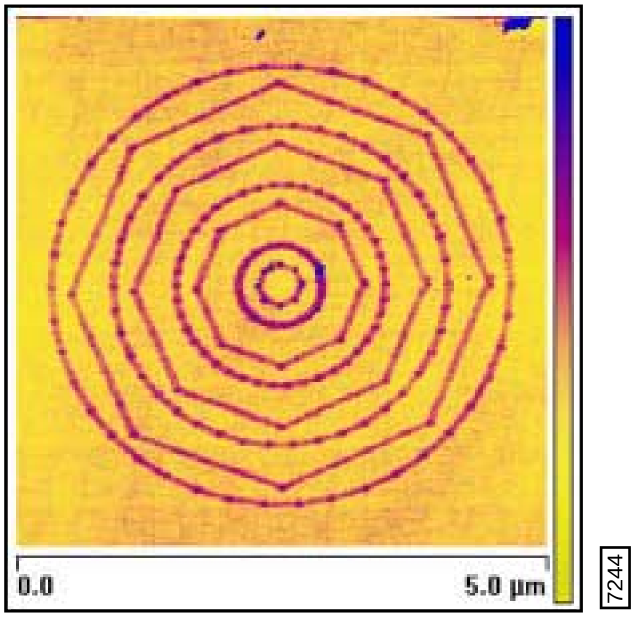


Image is Courtesy of Debra Cook, Application Scientist, Digital Instruments, Veeco Metrology Group

316.3.1 Mechanical Properties

NanoLithography consists of using the tip as an electro or mechanical tool to scribe (indent or create a ditch) on various material surfaces. Lithography uses C programming language along with NanoScript™ macro Litho functions to manipulate the tip relative to the sample surface.

The area **Scan size** (Real Time > **Scan Controls** > **Scan Size** parameter setting) defines the allowable dimensions of your Lithographic image(s). There are no safeguards to guarantee against tip or surface damage. To allow for full control of your Lithography functions, you must carefully define the physical limits, then execute commands which do not exceed those limits. In selected instances, the software warns you when executing commands beyond limits in the X-Y plane (e.g., trying to move the tip outside the bounds of the maximum **Scan size**). Most commands assume the tip is within its physical limits, such as when the tip is plunged into a surface, then dragged through material.

Applications

Lithography programs may be run in Scanning Tunneling Microscopy (STM), Contact Atomic Force Microscopy (AFM), and TappingMode AFM. Each mode produces its own unique results.

STM. Scanning Tunneling Microscopy (STM) can be used to modify surfaces at the nano scale level. By applying voltage pulses (e.g., see **LithoPulse:** Section 316.7.12 on Page 42) of varying magnitude and frequency, structures can be created. By programming the tip to move in a pre-determined fashion, you can also indent the surface.

Selecting an SPM Mode and Probe for Nanolithography

There are many SPM techniques for modifying a surface using Nanolithography. Some techniques rely on mechanical (contact) interactions between the probe and the sample; others rely on an electrical current flowing between the probe and the sample; yet others use magnetic interactions; and the list grows with every user. The choice of the SPM technique and probe depends on the sample and the desired results.

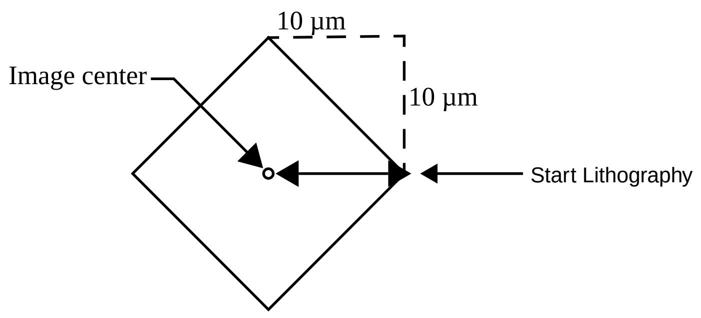
NanoLithography is a rapidly evolving field of research. The best source of information on the choice of probes and techniques is peer-reviewed technical literature and other technical journals and websites.

Note: For a sample list of the probes available from Digital Instruments,Veeco Metrology Group, see also *The Command Reference Manual Version 5.12B*, *Appendix A - Tip Selection Guide* as well as your system manuals.

Example: Scribing with the Lithography Program

In this Sample #2: Diamond program, the tip plunges 20 nm into the surface after moving 10 µm from the center of the scan field creating a diamond with sides of 20µm.

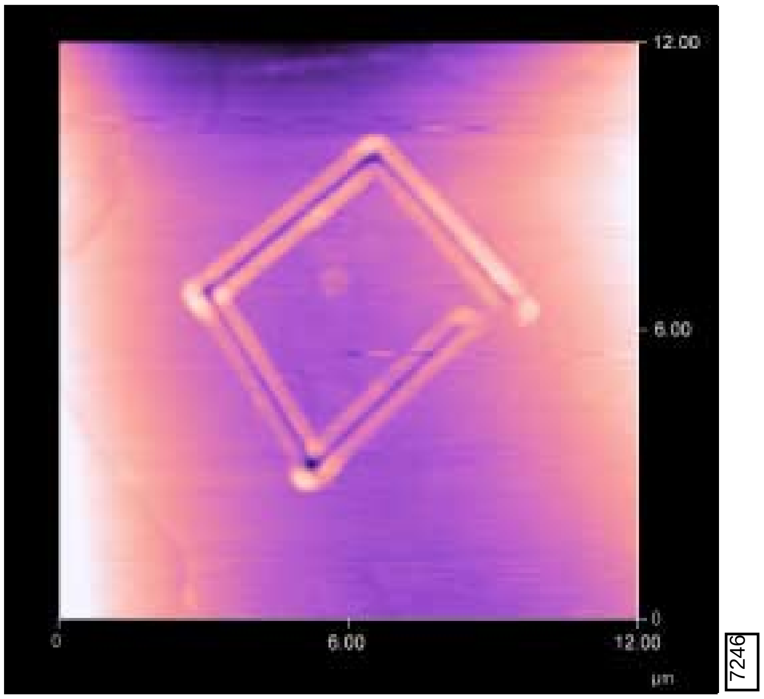
Figure 316.3b LithoTranslate Movement



The macro command, **LithoTranslate,** moves the tip from center, then to the three o'clock position, then moves counterclockwise to the twelve o'clock position at a set rate of 20 µm/s. The tip then continues to draw the additional sides of the diamond shape on the sample surface.

Figure 316.3c shows a diamond-shaped lithography pattern on a poly carbonate sample using a standard scanner. See Section 316.5.2 (i.e., sample program: **Diamond.dll**) to perform this lithography shape.

Figure 316.3c Diamond-shaped Lithography Image



To perform NanoLithography, please refer to **Procedures to Perform NanoLithography:** Section 316.4 on Page 8.

316.4 Procedures to Perform NanoLithography

This section details the setup and load of a sample lithography program provided with your NanoLithography package. The objective is to practice the procedures thoroughly in order to understand additional NanoLithography program procedures.

Refer to the following sections to perform NanoLithography on your NanoScope system:

- **What You Will Need:** Section 316.4.1 on Page 8
- **Testing Your System [LithoHelloWorld.dll]:** Section 316.4.2 on Page 9
- **Testing Your System [Diamond.dll]:** Section 316.4.3 on Page 15
- **Modifying a Lithography Program:** Section 316.4.4 on Page 19
- **Writing a New Lithography Program:** Section 316.4.5 on Page 24
- **Exporting Older Programs into Version 5.12 or Later:** Section 316.4.6 on Page 30
- **Performance Tips:** Section 316.4.7 on Page 31

316.4.1 What You Will Need

To perform Lithography on the NanoScope, you must have the following components:

- **Microsoft Visual C++ Compiler** (provided with your NanoLithography option)
- **Internet Explorer ™ browser** 4.0 or above is necessary to install the Visual C++ compiler.
- **NanoScope Software** (5.12 or above)

Note: Older versions of the NanoScope software require additional functions to run NanoLithography in the manner detailed in this support note. For exporting older Lithography files for use in the 5.12 NanoScope software, see **Exporting Older Programs into Version 5.12 or Later:** Section 316.4.6 on Page 30.

- **NanoLithography Program files** (e.g., litho.h, z.lib, gui.h, sysdefs.h and three sample programs)

In general, NanoLithography includes the following abbreviated steps:

1. Perform the necessary steps for placing all files in the SPM directory.
2. Verify, edit or modify the lithography program in the C++ compiler source files.
3. Build the DLL file in the C++ compiler.
4. Engage the tip on the surface and obtain an image in the NanoScope.
5. Determine the lithography site on the sample surface.

6. Load and run the macro lithography program (DLL).
7. Continue to image the site.
8. Capture the lithographic image.

316.4.2 Testing Your System [LithoHelloWorld.dll]

The NanoLithography package includes one sample to test the features in using the C++ compiler and NanoScript interface. This section details the procedures to run the sample program, **lithoHelloWorld**. This program loads a dialog box that displays the phrase, “**Hello World!**”.

Note: The **LithoHelloWorld** test sample does not require hardware to load and run. Its purpose is to test the procedures and ability to load a DLL file in the NanoScope. For testing a simple program that uses the hardware, see **Testing Your System [Diamond.dll]:** Section 316.4.3 on Page 15.

Locate the Necessary Lithography Files

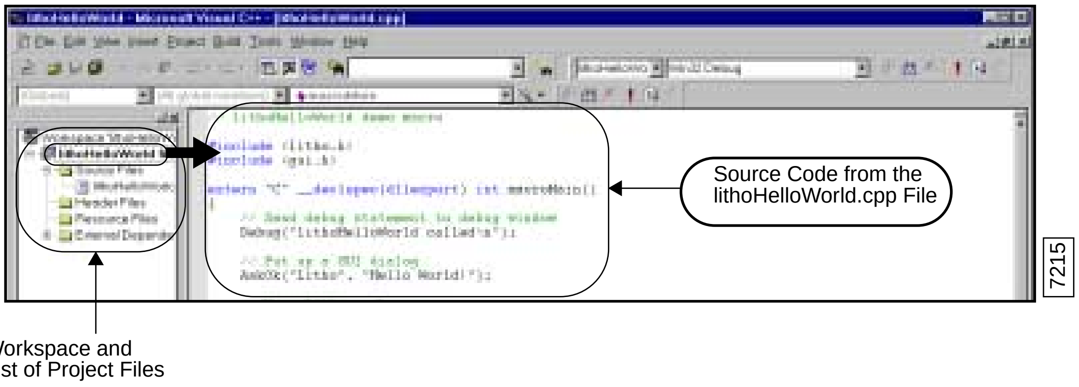
When running the macro files, the program looks in specific directories for running the commands. Complete the following procedures to verify that the files are in the correct directory structure.

1. Verify or place the sample program (e.g., LithoHelloWorld) file in your **SPM** directory. This folder, containing the C++ source files, should be located in the same directory as your NanoScope software executable file (i.e., z.exe).
2. Locate or place the **litho.h**, **gui.h**, **sysdefs.h** header files in your **SPM/Include** directory.

   Note: The **Include** directory must be at the same level as your **Z.exe** SPM executable file.
3. Verify that the **z.lib** file is in the SPM directory. This folder should be located in the same directory as your **Z.exe** NanoScope software executable file.
4. Open a Workspace in The Microsoft Visual C++
5. Locate the sample program folder (e.g., LithoHelloWorld) and open the folder to display the list of files.
6. Double-click on the workspace file (i.e., the file with an ***.dsw** file extension).

   Note: This will open the Microsoft Visual C++ compiler and workspace (See Figure 316.4a).

Figure 316.4a C++ Compiler File View


LithoHelloWorld - Microsoft Visual C++ - [lithoHelloWorld.cpp]
File Edit View Insert Project Build Tools Window Help
Workspace 'lithoHelloWorld'
lithoHelloWorld
Source Files
lithoHelloWorld.cpp
Header Files
Resource Files
External Dependencies
Source Code from the lithoHelloWorld.cpp File
Workspace and List of Project Files
7215

```
// LithoHelloWorld demo macro

#include <litho.h>
#include <gui.h>

extern "C" __declspec(dllexport) int macroMain()
{
    // Send debug statement to debug window
    Debug("LithoHelloWorld called\n");

    // Put up a GUI dialog
    AskOk("Litho", "Hello World!");
```

Note: If the source code is not open in the client window, expand the **Source files** in the workspace and double-click the *.cpp file to display the source code information.

Note: For specific details of the source code in this sample, see **Sample #1: LithoHelloWorld:** Section 316.5.1 on Page 33.

Verify Project Settings

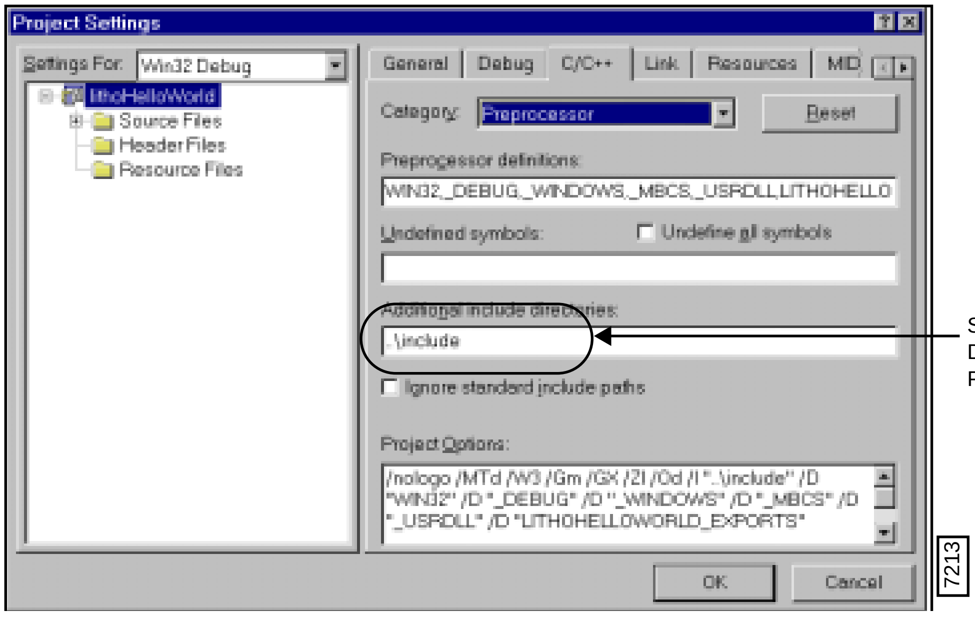
In order for the files to link and place output files in the correct directories, you must verify the project settings.

1. In the Visual C++ menu bar, select **Project** > **Settings** to open the **Project Settings** dialog box.

2. Select the **C/C++** tab (See Figure 316.4b).

   a. Change the **Category** to **PREPROCESSOR**.

Figure 316.4b C/C++ Tab



Settings For: Win32 Debug

Category: Preprocessor

Preprocessor definitions:
WIN32,_DEBUG,_WINDOWS,_MBCS,_USRDLL,LITHOHELLO

Undefined symbols:

☐ Undefine all symbols

Additional include directories:
..\include

☐ Ignore standard include paths

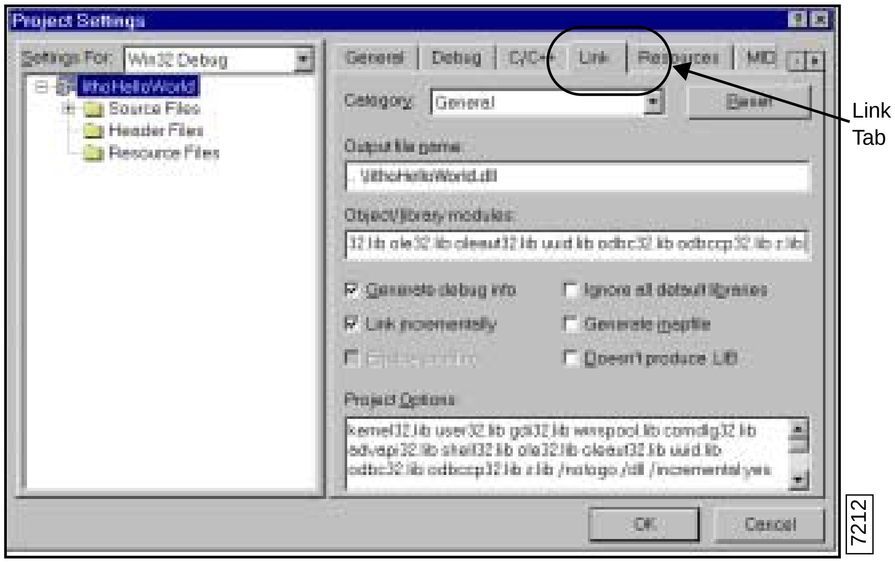
Project Options:
/nologo /MTd /W3 /Gm /GX /ZI /Od /I "..\include" /D "WIN32" /D "_DEBUG" /D "_WINDOWS" /D "_MBCS" /D "_USRDLL" /D "LITHOHELLOWORLD_EXPORTS"

b. In the **Additional Include Directories** window, the path displays two dots, a backward slash and the **include** file name. This allows the program to look one level up from the lithography folders in the SPM/Include directory.

Note: Remember to verify the correct header files are in the SPM/Include directory (e.g., **litho.h** and **gui.h** for this example).

3. Select the **Link** tab and verify that the **Category** window displays **GENERAL** (See Figure 316.4c).

Figure 316.4c Project Properties Dialog Box



Settings For: Win32 Debug

- lithoHelloWorld
  - Source Files
  - Header Files
  - Resource Files

Category: General

Output file name: ..\lithoHelloWorld.dll

Object/library modules: 32.lib ole32.lib oleaut32.lib uuid.lib odbc32.lib odbccp32.lib z.lib

[✓] Generate debug info
[✓] Link incrementally
[ ] Enable profiling
[ ] Ignore all default libraries
[ ] Generate mapfile
[ ] Doesn't produce .LIB

Project Options:

```
kernel32.lib user32.lib gdi32.lib winspool.lib comdlg32.lib
advapi32.lib shell32.lib ole32.lib oleaut32.lib uuid.lib
odbc32.lib odbccp32.lib z.lib /nologo /dll /incremental:yes
```

a. In the **Output file name** window, verify that the display reads two dots, a backward slash and the output **FILE NAME** (e.g.,**..\lithoHelloWorld.dll**).

Note: This notation places the file at one level up (or out) from the project folder and allows for this DLL file to be at the **Z.exe**, or SPM executable file level.

b. In the **Output file name** window, you may replace the two dots and backward slash with the exact location of the directory structure (e.g., **D:/SPM/LithoHelloWorld.dll**).

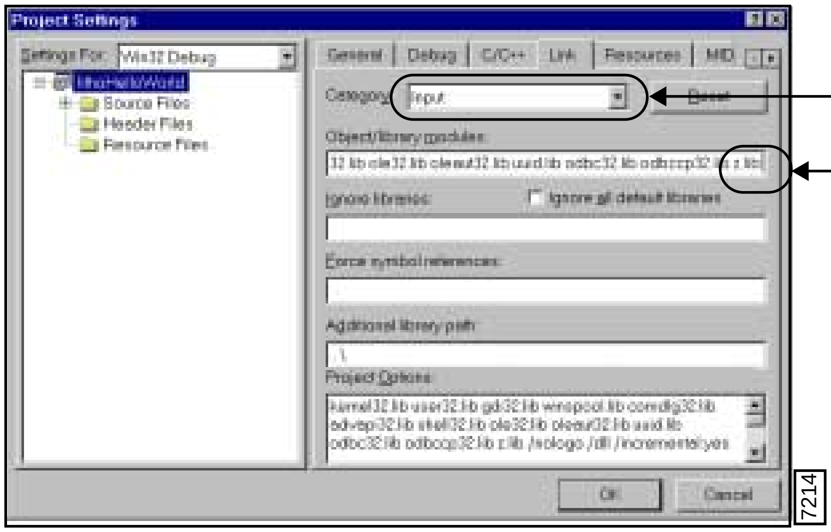
Note: If the file name already exists, the new DLL file will overwrite the old file automatically. If the file name does not exist, the final DLL file is added to the SPM directory.

4. In the **Link** tab, change the **Category** to **Input** (See Figure 316.4d).

   a. In the **Object/library modules** window, verify that **z.lib** follows that last item in the horizontal list of library files and each library module is separated by a space.

   b. Verify that the **Additional Library Path** displays two dots and backward slash (i.e., **..\**) to direct the path to the **z.lib** file.

Figure 316.4d Link Tab



Settings For: Win32 Debug

Category: Input

Object/library modules: 32.lib ole32.lib oleaut32.lib uuid.lib odbc32.lib odbccp32.lib z.lib

Additional library path: ..\

Project Options: kernel32.lib user32.lib gdi32.lib winspool.lib comdlg32.lib advapi32.lib shell32.lib ole32.lib oleaut32.lib uuid.lib odbc32.lib odbccp32.lib z.lib /nologo /dll /incremental:yes

Building a Dynamic Link Library (DLL) File

In order to run lithography, the programs need to be “built” in the form of DLL files. Veeco Instruments, Inc. uses an industry standard, C/C++ compiler to build the DLLs. Complete the following procedures to build your DLL file from the set of project files.

1. In the C++ compiler, with the source file open, verify that the source code is correct (i.e., edit the settings).

   Note: Prior to building you can modify the source code. Once you build the program, the DLL locks all program settings in to the DLL file. If changes are made to the source code, you must rebuild the DLL file.

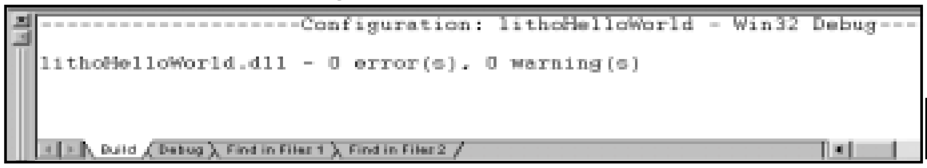
2. Open the **Build** menu, select the **Build** command.

Debugging the Program

Verify that the **Build** window displays file code being compiled into the DLL file.

1. Upon completion of the build, check the number of errors. (See Figure 316.4e).

Figure 316.4e Build Window



```
--------------------Configuration: lithoHelloWorld - Win32 Debug---
lithoHelloWorld.dll - 0 error(s), 0 warning(s)
```

   a. For a successful build, the error log shows **0**.

2. If errors exist in the source code, scroll up in the **Build** window, double click to read the error message and an arrow appears in the source code where the error exists.

   a. Make necessary changes in the setting or syntax.

3. Once the errors are fixed, select the **Build** > **Rebuild** menu command.

Using the NanoScope Software and Running Your Litho Programs

Once you build and debug a program, the DLL file is ready to load in the NanoScope software to run lithography. In **lithoHelloWorld**, hardware is not necessary to test the macro load features.

Open the NanoScope Debug Window

While in the NanoScope software, it is helpful to have the **NanoScope Debug** window showing. Complete the following while in the NanoScope software:

1. Click on the Control Monitor and hit **Ctrl-Alt-D**.
2. Select the **Filter** menu and check **Litho**, **SayError**, and **LogAllChecked**.
3. Close the filter box.

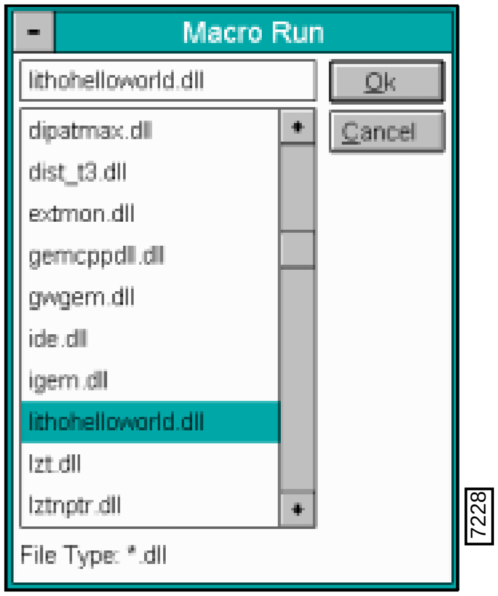
   Note: You should then see debug msgs in the black debug window.

Run the Lithography Macro (DLL)

1. Open the Real Time mode operations.
2. Open the **DI** menu and select the **NanoScript** command.

3. In the **NanoScript** screen, select **Macro** > **Load** to access the list of DLL files (See Figure 316.4f).

Figure 316.4f Lithography DLL Files



lithohelloworld.dll

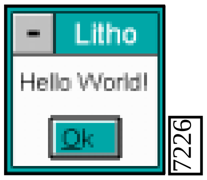
dipatmax.dll
dist_t3.dll
extmon.dll
gemcppdll.dll
gwgem.dll
ide.dll
igem.dll
lithohelloworld.dll
lzt.dll
lztnptr.dll

File Type: *.dll

4. Browse to select the DLL file to load and click **OK**.

Note: In this sample, a dialog box appears on the screen with the phrase, “Hello World!” for testing the Macro loading procedures.

Figure 316.4g LithoHelloWorld Dialog Box



Hello World!

Note: *See also*, **Testing Your System [Diamond.dll]:** Section 316.4.3 on Page 15 for details on interfacing with hardware to test your Lithography programs.

316.4.3 Testing Your System [Diamond.dll]

The NanoLithography package includes one sample to test the features in using the C++ compiler and NanoScript interface. This section details the procedures to run the sample program, **Diamond**. This program loads a program that scribes a diamond shape on the sample surface.

Note: This test sample requires hardware to load and run. Its purpose is to test the procedures and ability to load a DLL file in the NanoScope and run the system. For testing a simple program that does not require the hardware, see **Testing Your System [LithoHelloWorld.dll]:** Section 316.4.2 on Page 9.

Locate the Necessary Lithography Files

When running the macro files, the program looks in specific directories for running the commands. Complete the following procedures to verify that the files are in the correct directory structure.

1. Verify or place the sample program (e.g., **Diamond**) file in your **SPM** directory. This folder, containing the C++ source files, should be located in the same directory as your **Z.exe** NanoScope software executable file.
2. Locate or place the header files (e.g., litho.h, gui.h, sysdefs.h) in your **SPM/Include** directory.

   Note: The I**nclude** directory must be at the same level as your **Z.exe** SPM executable file.
3. Verify that the **z.lib** file is in the SPM directory. This folder should be located in the same directory as your **Z.exe** NanoScope software executable file.
4. Open a Workspace in The Microsoft Visual C++
5. Locate the sample program folder (e.g.,**Diamond**) and open the folder to display the list of files.
6. Double-click on the ***.dsw** workspace file.

   Note: This will open the Microsoft Visual C++ compiler and workspace.

Verify Project Settings

In order for the files to link and place output files in the correct directories, you must verify the project settings.

1. In the Visual C++ menu bar, select **Project** > **Settings** to open the **Project Settings** dialog box.
2. Select the **C/C++** tab.
   a. Change that the **Category** to **PREPROCESSOR**.

b. In the **Additional Include Directories** window, the path displays two dots, a backward slash and the **include** file name. This allows the program to look one level up from the lithography folders in the SPM/Include directory.

Note: Remember to verify the correct header files are in the SPM/Include directory (e.g., **litho.h** and **gui.h** for this example).

3. Select the **Link** tab and check that the **Category** window displays **GENERAL**.

a. In the **Output file name** window, verify that the display reads two dots, a backward slash and the output file name (e.g.,**..\lithoHelloWorld.dll**).

Note: This notation places the file at one level up (or out) from the project folder and allows for this DLL file to be at the SPM executable (i.e., z.exe) level.

b. In the **Output file name** window, you may replace the two dots and backward slash with he exact location of the directory structure (e.g., **D:/SPM/LithoHelloWorld.dll**).

Note: In naming the exact directory structure, forward slashes are acceptable to show the the path.

Note: If the file name already exists, the new DLL file will overwrite the old file automatically. If the file name does not exist, the final DLL file is added to the SPM directory.

4. In the **Link** tab, change the **Category** to **Input** (See Figure 316.4d).

a. In the **Object/library modules** window, verify that **z.lib** follows that last item in the horizontal list of library files (i.e., each library module is separated by a space).

b. Verify that the **Additional Library Path** displays two dots and backward slash (i.e., **..**\) to direct the path to the **z.lib** file.

Building a DLL File

In order to run lithography, the programs need to be "built" in the form of DLL files. Veeco Instruments, Inc. uses an industry standard C/C++ compiler to build the DLLs. Complete the following procedures to build your DLL file from the set of project files.

1. In the C++ compiler, with the source file open, verify that the source code is correct or edit the settings.

Note: Prior to building you can modify the source code. Once you build the program, the DLL locks all program settings in to the DLL file. If changes are made to the source code, you must rebuild the DLL file.

2. Open the **Build** menu, select the **Build** command.

Debugging the Program

Check that the **Build** window displays file code being compiled in to the DLL file.

1. Upon completion of the build, check the number of errors.
   a. For a successful build, the error log shows **0**.
2. If errors exist in the source code, scroll up in the **Build** window, double click to read the error message and an arrow appears in the source code where the error exists.
   a. Make necessary changes in the setting or syntax.
3. Once the errors are fixed, select the **Build** > **Rebuild** menu command.

Using the NanoScope Software and Running Your Litho Programs

Once you build (and debug) a program, the DLL file is ready to load in the NanoScope software to run lithography.

Open the NanoScope Software Debug Window

While in the NanoScope software, it is helpful to have the **NanoScope Debug** window showing. Complete the following while in the NanoScope software:

1. Click anywhere on the Control Monitor.
2. Select **Ctrl-Alt-D**.

   Note: A filter box appears.

3. Select the **Filter** menu and check **Litho**, **SayError**, and **LogAllChecked**.
4. Close the filter box.

   Note: You should then see debug msgs in the black debug window.

Preparing the Microscope for a Lithography Program. In addition to the standard setup requirements to run the microscope, it is necessary to verify the following components for desired results:

- **Sample**—The sample depends on the method of lithography (i.e., scribing, indenting, manipulating surface topography or oxidizing using advanced methods of Lithography).
- **Tip**—Standard (Silicon Nitride) Contact mode tips are recommended on the two sample templates requiring tip movement. On additional applications, follow the guidelines for your desired results.
- **Real Time Settings**—The Real Time control panels should reflect the type of lithography desired (e.g., for scribing a diamond, you set the microscope profile and settings to Contact mode operation).

1. Once the hardware and software components are set, open the Real Time mode operations.

   Note: For this example, the NanoScript commands are accessed in Real Time or Offline mode.

2. Verify that the sample is on the chuck (or stage) and complete the necessary steps to focus surface and tip.

3. Set your microscope profile to Contact mode (Real time > Microscope > Profile > Contact Mode).

   Note: Set the mode to tapping for specific applications.

4. Engage the tip on the surface and view your imaging mode.

5. Open the **DI** menu and select the **NanoScript** command.

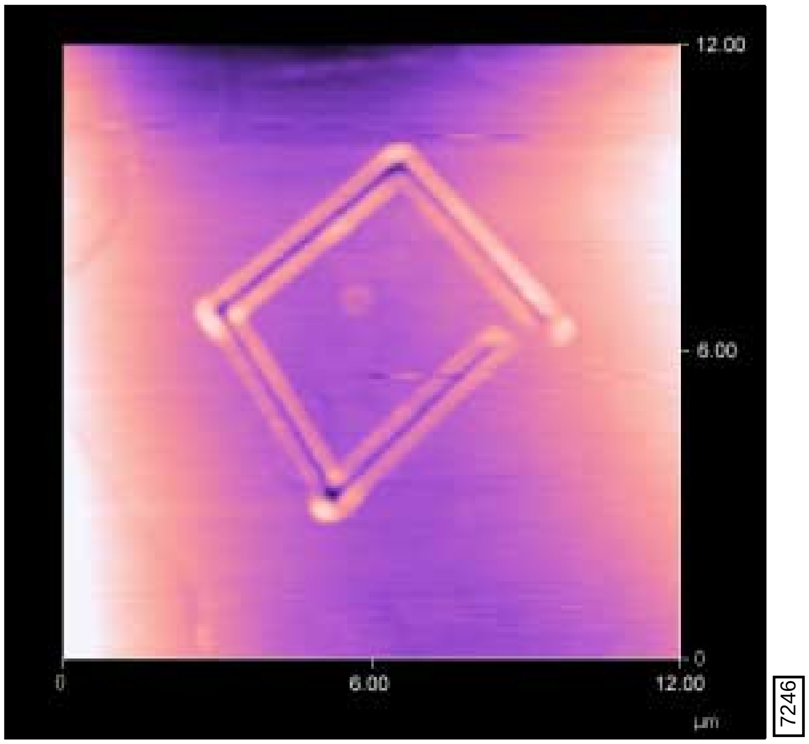
Run the Lithography Macro (DLL)

1. In the **NanoScript** screen, select **Macro** > **Load** to access the list of DLL files.

2. Browse to select the **DIAMOND.DLL** file to load and click **OK**.

   Note: The imaging appears to stop while the debug window displays the program instructions. Once the lithography is complete, a diamond shape is inscribed on the sample surface (See Figure 316.4h).

Figure 316.4h Diamond Test Program



316.4.4 Modifying a Lithography Program

In this example, the Diamond lithography program is modified by changing the tip X and Y movement dimensions from 10µm to 5µm.

Locate the Necessary Lithography Files

When running the macro files, the program looks in specific directories for running the commands. Complete the following procedures to verify that the files are in the correct directory structure.

1. Verify or place the sample program (e.g., LithoHelloWorld) folder in your **SPM** directory. This file, containing the C++ source files, must be in a folder, which is in the same directory as your **Z.exe** NanoScope software executable file.
2. Locate or place the **litho.h**, **gui.h**, **sysdefs.h** header files in your **SPM/Include** directory.

   Note: The I**nclude** directory must be at the same level as your **Z.exe** SPM executable file.
3. Verify that the **z.lib** file is also in the same directory as your **Z.exe** NanoScope software executable file.

Open a C++ Workspace

1. Locate the sample program folder (e.g. **Diamond**) and open the folder to display the list of files.
2. Double-click on the ***.dsw** workspace file.

   Note: The Microsoft Visual C++ compiler and workspace opens (See Figure 316.4i).
3. Verify that the **File View** tab is selected to view the list of Source files.

   Note: If the source code is not open in the client window, expand the **Source files** in the workspace to display **Diamond.cpp**, double-click the **Diamond.cpp** file to display the source code information (See Figure 316.4i).

   Note: For details of the source code in this sample, see **Sample #2: Diamond:** Section 316.5.2.

Modify the Source File

In this example, the source code modification includes changing the tip travel distance from 10µm to 5µm in the X and Y direction.

1. In the line, **double size = 10;// 10 um from center of diamond to point**, change the **10** to **5** and update the comment to your new specifications (See Figure 316.4i).

   Note: This changes the tip travel distance in the X and Y direction from 10µm to 5µm. You may also change the **Scan size** in the **Scan Controls** panel to suit the new dimensions. In this example, the dimensions are lowered, so changing the **Scan size** is not necessary.

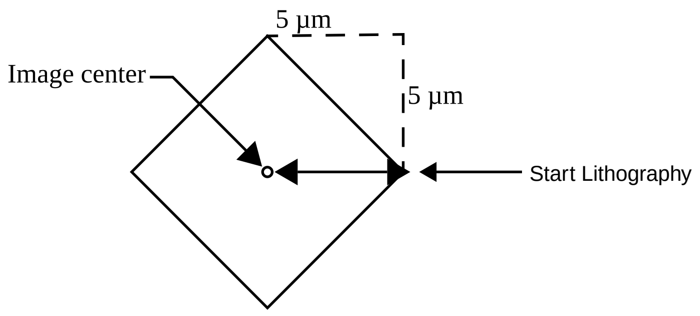
Figure 316.4i Modified Source Code

Modification

```
// diamond.cpp
// Example  - Modifying a Lithography Program

#include <litho.h>

extern "C" __declspec(dllexport) int macroMain()
{
LITHO_BEGIN

LithoDisplayStatusBox();// display litho status box

LithoScan(false);// turn off scanning
LithoCenterXY();// move tip to center of field

double size = 5;// moves the tip from center of diamond  5 um in X and Y.
double rate = 20;// move the tip in X-Y at 20 um/s

double depth = -0.020;// push the tip in 20 nm to draw lines
double z_rate = 0.040;// move the tip down at 40 nm/s
```

The modification causes the tip to move to the center and then move outward to the 3-o'clock position a distance of 5µm (See Figure 316.4j).

Figure 316.4j LithoTranslate Movement



Verify Project Settings

In order for the files to link and place output files in the correct directories, you must verify the project settings.

1. In the menu bar, select **Project** > **Settings** to open the **Project Settings** dialog box.
2. Select the **C/C++** tab.
   a. Change the **Category** to **PREPROCESSOR**.
   b. In the **Additional Include Directories** window, the path displays two dots, a backward slash and the **include** file name. This allows the program to look one level up from the lithography folders in the **SPM/Include** directory.

Note: Remember to verify the correct header files are in the SPM/Include directory (e.g., **litho.h** and **gui.h** for this example).

3. Select the **Link** tab and verify that the **Category** window displays **GENERAL**.

   a. In the **Output file name** window, verify that the display reads two dots, a backward slash and the output file name (e.g.,**..\DiamondGui.dll**).

   Note: This notation places the file at one level up (or out) from the project folder and allows for this DLL file to be at the SPM executable (i.e., z.exe) level.

   b. In the **Output file name** window, you may replace the two dots and backward slash with **D:/ SPM/DiamondGui.dll**.

   Note: If the file name already exists, the new DLL file will overwrite the old file automatically. If the file name does not exist, the final DLL file is added to the SPM directory.

4. In the **Link** tab, change the **Category** to **Input** (See Figure 316.4d).

   a. In the **Object/library modules** window, verify that **z.lib** follows that last item in the horizontal list of library files and each library module is separated by a space.

   b. Verify that the **Additional Library Path** displays two dots and backward slash (i.e., **..**\) to direct the path to the **z.lib** file.

Building a DLL File

In order to run lithography, the programs need to be "built" in the form DLL files. Veeco Instruments, Inc. uses an industry standard C/C++ compiler to build the DLLs.

Complete the following procedures to build your DLL file from the set of project files:

1. In the C++ compiler, with the source file open, verify that the source code is correct or edit the settings.

   Note: Prior to building you can modify the source code. Once you build the program, the DLL locks all program settings in to the DLL file. If changes are made to the source code, you must rebuild the DLL file.

2. Open the **Build** menu, select the **Build** command.

Debugging the Program

During a build, verify the project settings scroll through the code to build a DLL file. If syntax errors occur in the program, the build will not be successful.

1. Check the number of errors in the **Build** window. (See Figure 316.4e).

   a. For a successful build, the error log shows **0**.

2. If errors exist in the source code, scroll up in the **Build** window, double click to read the error message and an arrow appears in the source code where the error exists.

   a. Make necessary changes in the setting or syntax.

3. Once the errors are fixed, select the **Build** > **Rebuild** menu command.

Open the NanoScope Software

Once you build and debug a program, the DLL file is ready to load in the NanoScope software to run a lithography on the sample surface.

Open the NanoScope Debug Window

While in the NanoScope software, it is helpful to have the **NanoScope Debug** window showing. Complete the following while in the NanoScope software:

1. Click on the Control Monitor and hit **Ctrl-Alt-D**.
2. Select the **Filter** menu and check **Litho**, **SayError**, and **LogAllChecked**.
3. Close the filter box.

   Note: You should then see debug msgs in the black debug window.

Prepare the Microscope for a Lithography Program. In addition to the standard setup requirements to run the microscope, it is necessary to verify the following components for desired results:

- **Sample**—The sample depends on the method of lithography (i.e., scribing, indenting, manipulating surface topography or oxidizing using advanced methods of Lithography).
- **Tip**—Standard (Silicon Nitride) Contact mode tips are recommended on the two sample templates requiring tip movement. On additional applications, follow the guidelines for your desired results.
- **Real Time Settings**—The Real Time control panels should reflect the type of lithography desired (e.g., for scribing a diamond, you set the microscope profile and settings to Contact mode operation).

1. Once the hardware and software components are set, open the Real Time mode operations.
2. Open the **DI** menu and select the **NanoScript** command.

Run the Lithography Macro DLL

1. In the **NanoScript** screen, select **Macro** > **Load** to access the list of DLL files.
2. Browse to select the DLL file to load and click **OK**.

Note that in the image window, scanning appears to halt. This means that the Lithography program is loading. If your debug window appears, the program instructions display as the Lithography program is running. Upon completion, the real time scan continues.

3. View your new diamond shape on the surface (See Figure 316.4k).

Note: Figure 316.4k is a lithographic image captured using a Closed Loop XY scanner. For additional information on a Closed Loop XY scanner, contact your Digital Instruments, Veeco Metrology Group representative.

Figure 316.4k Diamond-shaped Lithography Image

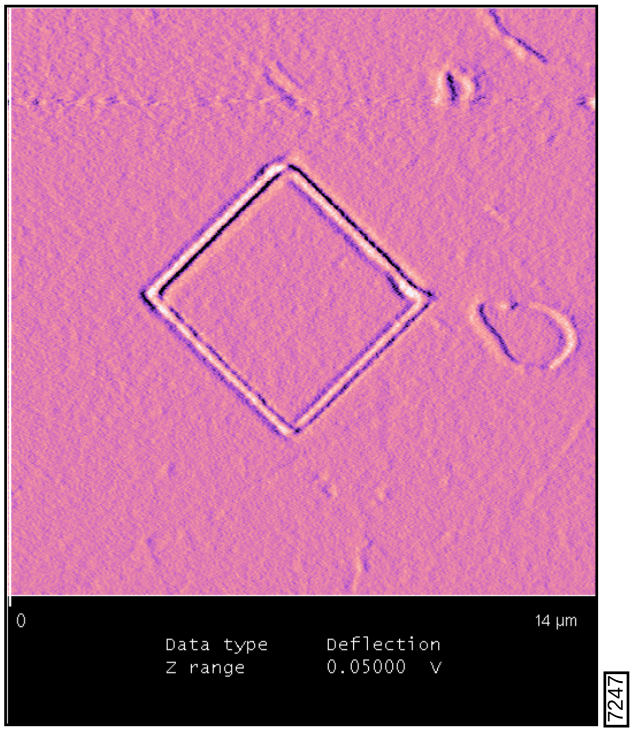


Image is Courtesy of Debra Cook, Application Scientist, Digital Instruments, Veeco Metrology Group

4. Select **Capture** > **Capture Filename** to name the file.

5. Select the **CAPTURE** button or **Capture** menu > **Capture** command.

6. View this image in offline mode to modify (e.g., **Flatten**) or analyze the image.

316.4.5 Writing a New Lithography Program

Writing a new lithography program requires using the Microsoft Visual C++ compiler, understanding the NanoScript macro language and C programming language syntax. For more complex programs, intermediate to advanced knowledge of C programming is needed. For example, one method to scribe concentric lithographic shapes requires understanding the concept of **For Loops** in C programming.

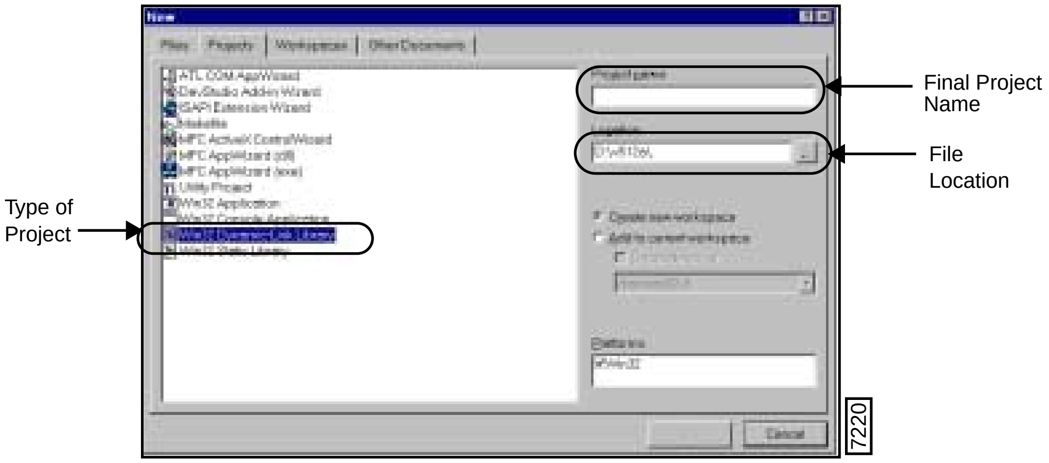
This sections details the procedures to open a new project, connect the source files to the project, set the project settings and build the project. The sample templates with this option are helpful to write your programs. For the first program, it is recommended to copy one of the sample programs into a blank source code (*.cpp) file then customize it for desired results. This allows for keeping specific language declarations in place. In this section, you will open a new project, verify all output file names and copy/paste the source code from Sample #2: Diamond.

The following sections detail the general procedures to build new lithography programs.

Open a New Project

1. Open the C++ compiler.
2. Select **File** > **New** to access the **New Project** dialog box (See Figure 316.4l).
3. Select the **Projects** tab to designate the type of project, output file name and output location.

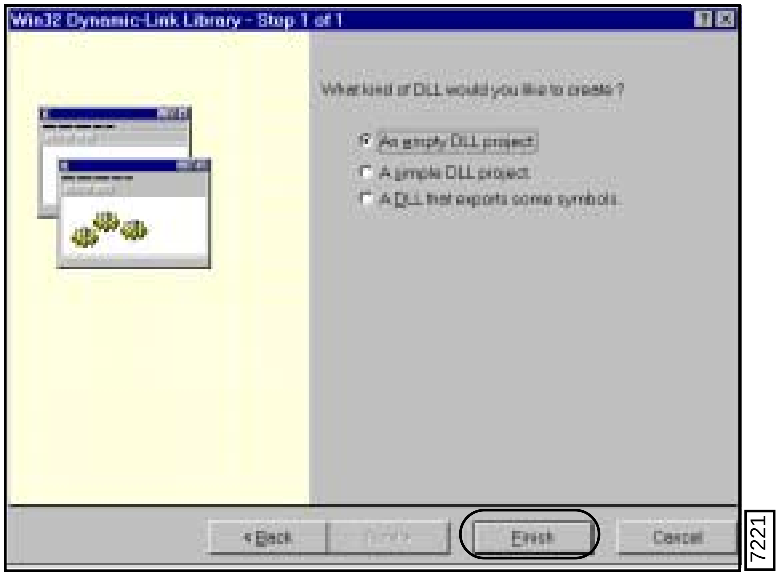
Figure 316.4l New Project Dialog Box



4. Select the **Win32 Dynamic-Link Library** to designate the type of project to load.
5. Enter your project folder name (e.g., Diamondpolycarbon) in the **Project name** window.
6. In the **Location** window, enter the Directory location and the **`FILENAME`** (e.g., **`D:\SPM\SMDIAMOND`**).
7. Select the **Create a new workspace** option.
8. Select **OK** to continue.

Note: A new project wizard opens (See Figure 316.4m).

Figure 316.4m New DLL Wizard Dialog Box



What kind of DLL would you like to create ?

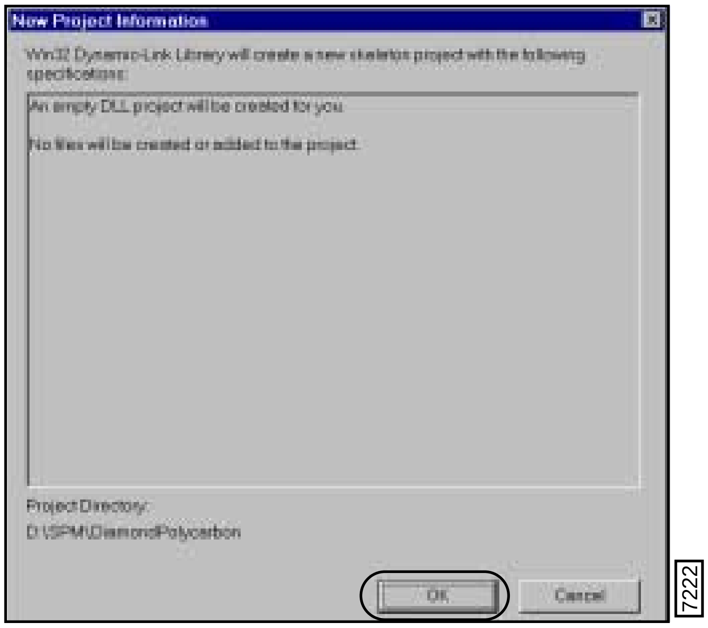
- [✓ An empty DLL project]
- A simple DLL project
- A DLL that exports some symbols

9. Select **An empty DLL project** option.

10. Click **FINISH**.

Note: A warning prompt appears to display the project information (See Figure 316.4n).

Figure 316.4n New Project Information



Win32 Dynamic-Link Library will create a new skeleton project with the following specifications:

An empty DLL project will be created for you.

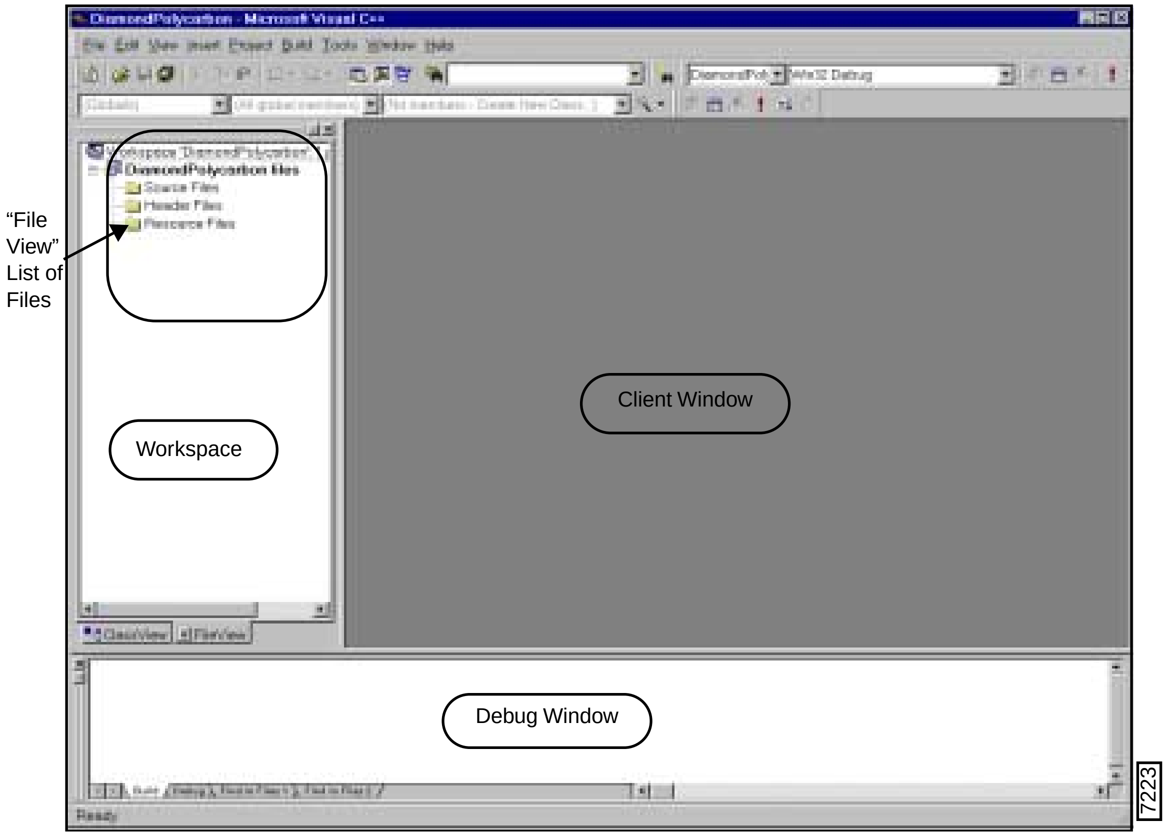
No files will be created or added to the project.

Project Directory:
D:\SPM\DiamondPolycarbon

11. Select **OK**.

Note: The C++ compiler screens appear with a new workspace (See Figure 316.4o).

Figure 316.4o New Workspace


DiamondPolycarbon - Microsoft Visual C++
File Edit View Insert Project Build Tools Window Help
Workspace 'DiamondPolycarbon'
DiamondPolycarbon files
Source Files
Header Files
Resource Files
"File View" List of Files
Workspace
Client Window
Debug Window
ClassView
FileView
Ready
7223

Create the Source and Header Files

The list of files in the workspace include **Source** and **Header** files. At this point, the files are empty. The files in the source files include the source code. The header files include *.h files directed in the source code.

To add source files, you may choose one of the following methods:

Add New Code

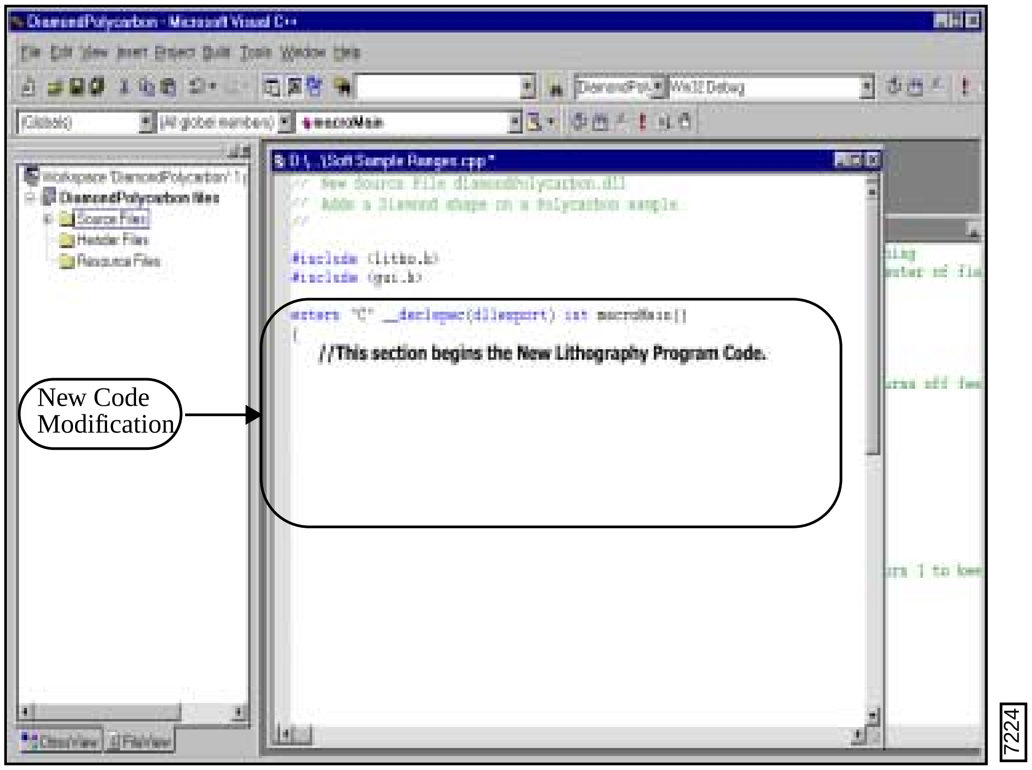
1. Select **File** > **New** > **Files** tab. Select the **C++ Source** files and name the new source file.
2. Click **OK** and a blank notepad appears in the client window.
3. Type in new code.

Copy Source Code from Samples or Older Programs

1. Browse to locate a sample *.cpp file (e.g., Sample #2: Diamond in your SPM directory).

2. Open the *.cpp file, copy and paste the code in to the blank source file.

Figure 316.4p New Source Files



```
// New Source File diamondPolycarbon.dll
// Adds a Diamond shape on a Polycarbon sample
//

#include <litho.h>
#include <gui.h>

extern "C" __declspec(dllexport) int macroMain()
{
    //This section begins the New Lithography Program Code.
```

DiamondPolycarbon - Microsoft Visual C++
File Edit View Insert Project Build Tools Window Help
Win32 Debug
(Globals)
(All global members)
macroMain
Workspace 'DiamondPolycarbon'
DiamondPolycarbon files
Source Files
Header Files
Resource Files
ClassView
FileView
D:\...\Soft Sample Ranges.cpp*
New Code Modification
7224

Delete, Edit or Modify the Copied Source Code

You are now ready to create your source code. Refer to your knowledge of modern C/C++ programming or the sample templates and create the settings related to your desired results.

Modifying Older Programs

To modify pre-5.12 NanoScope software Lithography programs, change the following:

1. Replace the **main** syntax with the following:

   extern "C" __declspec(dllexport) int macroMain()

2. If the file **sysdef.h** is in your **Include** directory, the function **LithoScan (FALSE)** works properly.

Note: "**FALSE**" and "**TRUE**" as upper case words, were defined in NanoScript's **sysdefs.h** header file.

a. If you do NOT have the **sysdef.h** in your include directory, replace **LithoScan (FALSE)** with the following:

LithoScan (false)

3. Add the following line to the end of the main section at the bottom of the code below "LithoEnd" and above the last bracket "}":

return 0;   // 0 makes macro unload

Note: See also, **Exporting Older Programs into Version 5.12 or Later:** Section 316.4.6 on Page 30.

Verify Project Files and Settings

It is important to know the location of your SPM files and the **Z.exe** file that runs your hardware. Verify the location of the following lithography files:

1. Verify the **z.lib** file in the SPM directory.
2. Verify the header files (.h) in the source code. In this sample, the header files include **litho.h** and **gui.h**. Verify that both files are in the **SPM/Include** directory.

Verify Project Settings

In order for the files to link and to output files in the correct directories, you must verify the project settings.

1. In the Visual C++ menu bar, select **Project** > **Settings** to open the **Project Settings** dialog box.
2. Select the **C/C++** tab.
   a. Change the **Category** to **PREPROCESSOR**.
   b. In the **Additional Include Directories** window, the path displays two dots, a backward slash and the **include** file name. This allows the program to look one level up from the lithography folders in the SPM/Include directory.

   Note: Remember to verify the correct header files are in the SPM/Include directory (e.g., **litho.h** and **gui.h** for this example).
3. Select the **Link** tab and verify that the **Category** window displays **GENERAL** (See Figure 316.a).
   a. In the **Output file name** window, verify that the display reads two dots and a backward slash. The two dots and a slash mean to place the file at one level up (or out) from the source folder allowing for this DLL file to be at the SPM executable level.

b. The exact location of the directory structure may also be named for this window (e.g., **D:/SPM/`YOUR FILENAME`.dll**) in the place of the two dots and a backward slash.

Note: In naming the exact directory structure, forward slashes are acceptable to show the the path.

c. Verify that the output file name is correct with the DLL extension. If the file name exists, the new DLL file will overwrite the old file automatically. If the file name does not exist, the final DLL file is added to the SPM directory.

4. In the **Link** tab, change the **Category** to **Input**.

a. In the **Object/library modules** window, verify that **z.lib** follows a space and is the last item in the horizontal list of library files and each library module is separated by a space.

b. Verify that the **Additional Library Path** displays two dots and backward slash to direct the path up one level to the **z.lib** file.

5. Select **OK**.

Build the DLL File

In order to run lithography, the programs need to be “built” in the form of DLL files. Veeco Instruments, Inc. uses an industry standard, C/C++ compiler to build the DLLs.

Complete the following procedures to build your DLL file from the set of project files:

1. In the C++ compiler, with the source file open, verify that the source code is correct or edit the settings.

   Note: Prior to building you can modify the source code. Once you build the program, the DLL locks all program settings in to the loadable DLL file.

2. Open the **Build** menu, select the **Build** command.

   Note: In the lower window, you will see the project scroll through the code to build a DLL file. If syntax errors occur in the program, the build will not be successful.

3. Check the number of errors in the **Build** window. (See Figure 316.4q).

   a. For a successful build, the error log shows **0**.

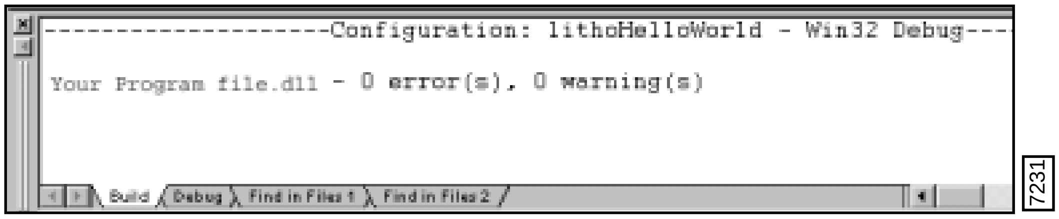
   b. To check errors, double-click on the error message in the **Build** window.

   Note: An arrow appears in the Source code where the error exists.

   c. Make the necessary changes in the settings or syntax.

4. Once the errors are verified and fixed, select the **Build** > **Rebuild** menu command.

Figure 316.4q Build Window



```
--------------------Configuration: lithoHelloWorld - Win32 Debug---
Your Program file.dll - 0 error(s), 0 warning(s)
```

Run the NanoScope and Load the New DLL

1. After creating a new DLL file, open the NanoScope software.
2. Open the Real Time mode, engage the surface and obtain an image.

   Note: It may be necessary to adjust the sample, using **Stage** commands if available, and/or use **X** and **Y offsets** to position the lithography site at the center of the screen.

3. Select the **DI** > **NanoScript** command.
4. In the NanoScript screen, select **Macro** > **Load** and browse to locate the new project.dll file.
5. Browse in the **Macro Run** dialog box to select the desired DLL file.
6. Click **OK** to begin the NanoLithography program.

   Note: When the program is complete, the system returns to Real Time engage mode.

7. Continue to image until the Lithographic feature is seen in the image window.
8. Select the **Capture** command to save the image in the **Capture** directory.

316.4.6 Exporting Older Programs into Version 5.12 or Later

For users with pre-5.12 programs, slight modifications allow for using these programs to perform NanoLithography in Version 5.12 or later NanoScope software.

Note: If you are copying code from an older version of software, you must also make these changes.

To modify older programs, change the following:

1. Replace the **main** syntax with the following:

   extern "C" __declspec(dllexport) int macroMain()

2. If the file **sysdef.h** is in your **Include** directory, the function **LithoScan (FALSE)** works properly.

Note: "**FALSE**" and "**TRUE**" as upper case words, were defined in NanoScript's **sysdefs.h** header file.

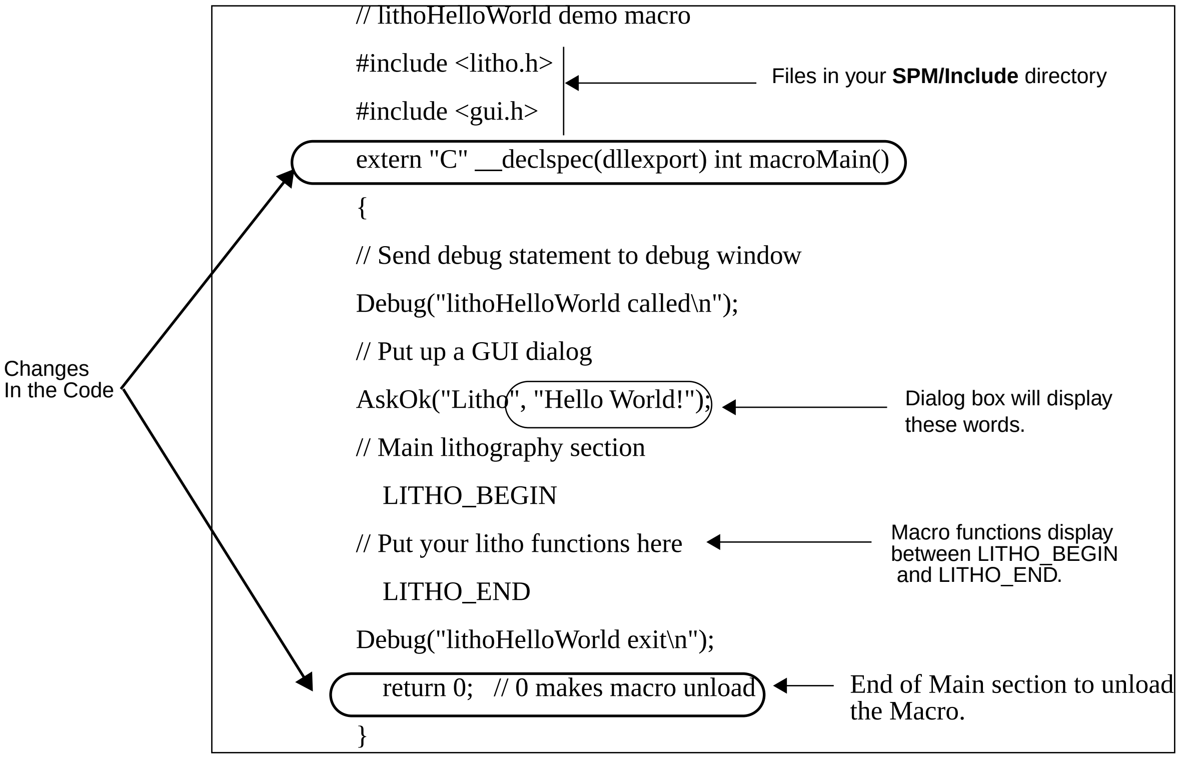
a. If you do NOT have the **sysdef.h** in your include directory, replace **LithoScan (FALSE)** with the following:

LithoScan (false)

3. Add the following line to the end of the main section at the bottom of the code below "LithoEnd" and above the last bracket "}":

return 0; // 0 makes macro unload

Figure 316.4r Sample of Changes to Older Lithography Programs



```
// lithoHelloWorld demo macro
#include <litho.h>
#include <gui.h>
extern "C" __declspec(dllexport) int macroMain()
{
// Send debug statement to debug window
Debug("lithoHelloWorld called\n");
// Put up a GUI dialog
AskOk("Litho", "Hello World!");
// Main lithography section
   LITHO_BEGIN
// Put your litho functions here
   LITHO_END
Debug("lithoHelloWorld exit\n");
   return 0;   // 0 makes macro unload
}
```

Files in your **SPM/Include** directory
Changes In the Code
Dialog box will display these words.
Macro functions display between LITHO_BEGIN and LITHO_END.
End of Main section to unload the Macro.

316.4.7 Performance Tips

Experimenting with the sample templates will help you to optimize your Lithography results. This section details additional known performance tips for optimization.

Open the NanoScope Debug Window

While in the NanoScope software, it is helpful to have the **NanoScope Debug** window showing. Complete the following while in the NanoScope software:

1. Click on the Control Monitor and hit **Ctrl-Alt-D**.

2. Select the **Filter** menu and check **Litho**, **SayError**, and **LogAllChecked**.

3. Close the filter box.

Note: You should then see debug msgs in the black debug window.

General Performance Tips

The following list are general hints to optimize your lithography programming:

- Set the **Scan size** to encompass the entire sample area which you intend the lithography program to affect.

- If you use a **LithoTranslate** command while **feedback** is set to **off** in the **LithoFeedback** command, perform a **Capture Plane** (**Real time** > **Capture** menu) before running the program so that the tip-to-sample distance can be accurately maintained during translation, or tip movement. Translations completed while feedback is turned **On** do not require this step.

- Translate, or maneuver the tip with **feedback** set to **on** or **off**, regardless of operating mode. If feedback is turned **off**, the tip travels at a constant height relative to the last plane captured with the **Capture Plane** command. If feedback is **on** and gains are properly set, the tip moves with constant contact force (contact AFM), or with constant tunneling current (STM).

- Scribing can be done with an STM microscope by using the **LithoMoveZ** command to partially bury the tip in the sample, then translating, or moving, the tip. For hard samples, tungsten tips may be required.

- Scribing with an AFM (e.g., MultiMode) microscope can be completed by using the **LithoMoveZ** (See Section 316.) command to plunge the tip into the sample (as with the STM), or by increasing the **Setpoint** so that the tip is pressed into the surface with a constant force.

Note: The latter of these methods tends to be superior because the surface is tracked by **feedback** during translations instead of relying on **Capture Plane** to maintain a constant tip-to-sample distance.

- The potential for the tip to scribe a surface depends upon the softness of the material.You may experiment with the **Real time** > **View** > **Force Mode** > **Step** command to observe the tip to surface impact with varying **Setpoint** values.

316.5 Sample Programs Overview

The NanoLithography package includes three sample programs to begin processing lithography macros. Use the following sample programs as a template to test and write Lithography programs.

CAUTION: Prior to writing new lithography programs, run the sample programs to avoid damaging your hardware.

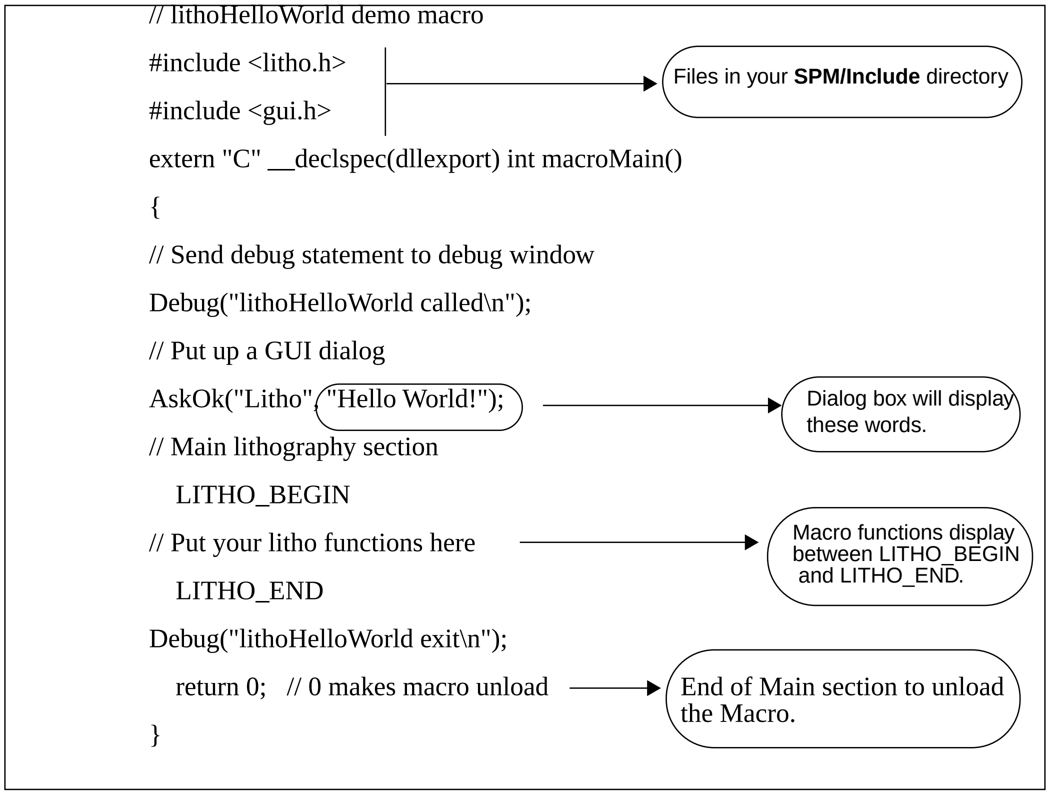
Refer to the following sections to experiment with the sample programs:

- **Sample #1: LithoHelloWorld:** Section 316.5.1 on Page 33
- **Sample #2: Diamond:** Section 316.5.2 on Page 34
- **Sample #3: DiamondGUI:** Section 316.5.3 on Page 36

316.5.1 Sample #1: LithoHelloWorld

The following sample is in the sample programs on your Lithography package disk. Verify the folder, **LithoHelloWorld,** is in the SPM directory. Figure 316.5a shows the code found in the LithoHelloWorld.cpp file.

Figure 316.5a LithoHelloWorld Code



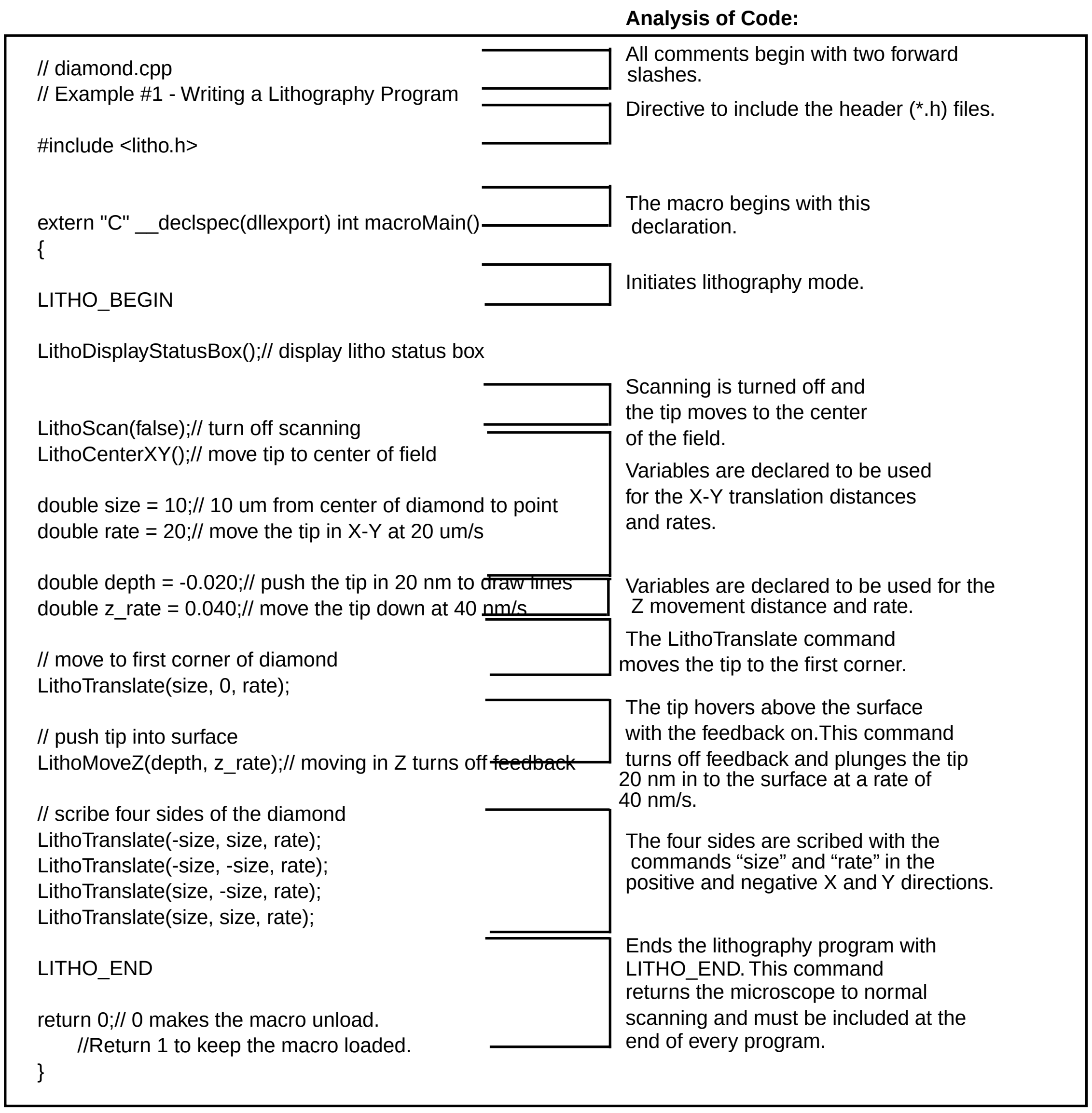
```
// lithoHelloWorld demo macro
#include <litho.h>
#include <gui.h>
extern "C" __declspec(dllexport) int macroMain()
{
// Send debug statement to debug window
Debug("lithoHelloWorld called\n");
// Put up a GUI dialog
AskOk("Litho", "Hello World!");
// Main lithography section
   LITHO_BEGIN
// Put your litho functions here
   LITHO_END
Debug("lithoHelloWorld exit\n");
   return 0;   // 0 makes macro unload
}
```

Files in your **SPM/Include** directory
Dialog box will display these words.
Macro functions display between LITHO_BEGIN and LITHO_END.
End of Main section to unload the Macro.

316.5.2 Sample #2: Diamond

Figure 316.5b shows the lithography program code that instructs the NanoScope to scribe a diamond shape. The analysis follows the line(s) of code for understanding the instructions.

Figure 316.5b Diamond Lithography Code



```
// diamond.cpp
// Example #1 - Writing a Lithography Program

#include <litho.h>


extern "C" __declspec(dllexport) int macroMain()
{

LITHO_BEGIN

LithoDisplayStatusBox();// display litho status box


LithoScan(false);// turn off scanning
LithoCenterXY();// move tip to center of field

double size = 10;// 10 um from center of diamond to point
double rate = 20;// move the tip in X-Y at 20 um/s

double depth = -0.020;// push the tip in 20 nm to draw lines
double z_rate = 0.040;// move the tip down at 40 nm/s

// move to first corner of diamond
LithoTranslate(size, 0, rate);

// push tip into surface
LithoMoveZ(depth, z_rate);// moving in Z turns off feedback

// scribe four sides of the diamond
LithoTranslate(-size, size, rate);
LithoTranslate(-size, -size, rate);
LithoTranslate(size, -size, rate);
LithoTranslate(size, size, rate);

LITHO_END

return 0;// 0 makes the macro unload.
      //Return 1 to keep the macro loaded.
}
```

Analysis of Code:

All comments begin with two forward slashes.

Directive to include the header (*.h) files.

The macro begins with this declaration.

Initiates lithography mode.

Scanning is turned off and the tip moves to the center of the field.

Variables are declared to be used for the X-Y translation distances and rates.

Variables are declared to be used for the Z movement distance and rate.

The LithoTranslate command moves the tip to the first corner.

The tip hovers above the surface with the feedback on.This command turns off feedback and plunges the tip 20 nm in to the surface at a rate of 40 nm/s.

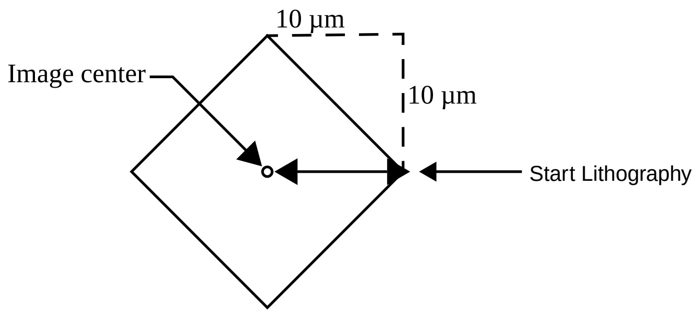
The four sides are scribed with the commands “size” and “rate” in the positive and negative X and Y directions.

Ends the lithography program with LITHO_END. This command returns the microscope to normal scanning and must be included at the end of every program.

Diamond Lithography Program Results

In the **Diamond** lithography program sample, the tip plunges 20 nm into the surface after moving 10 µm from the center of the scan field (See Figure 316.5c).

Figure 316.5c LithoTranslate Movement



The **LithoTranslate** command moves the tip from the three o’clock position counterclockwise. The command line `LITHOTRANSLATE(-SIZE,SIZE,RATE)` moves the tip to the twelve o’clock position by declaring the parameters **-size**, **size** or movements in negative X and positive Y moves and at a set rate in the `DOUBLE RATE = 20` (i.e., 20 µm/s). The tip then continues to draw the additional sides of the diamond shape on the sample surface.

Note: The tip’s ability to scribe the surface for a given amount of pressure depends upon the softness of the material.You may experiment with the **Real time** > **View** > **Force Mode** > **Step** command to observe the tip impact upon the surface for different **Setpoint** values.

316.5.3 Sample #3: DiamondGUI

The following sample combines both Sample #1: LithoHelloWorld and Sample #2: Diamond code to enhance the diamond shape lithography. In this sample, a dialog box adds the capability of modifying the dimensions of a diamond shape on the sample surface.

Figure 316.5d DiamondGUI Macro Code

```
/ diamondGUI.cpp
// Example - Writing a Lithography Program with GUI features
// Adds a dialog box to the diamond.cpp example

#include <litho.h>
#include <gui.h>

extern "C" __declspec(dllexport) int macroMain()
{
// Parameters with default values
float size = 10.0f;// 10 um from center of diamond to point
float rate = 20.0f;// move the tip in X-Y at 20 um/s
float depth = -0.020f;// push the tip in 20 nm to draw lines
float z_rate = 0.040f;// move the tip down at 40 nm/s
// Make a dialog box to prompt user for parameter values
DialogBox dlg = ModalDialog("Diamond Parameters");
AddFloatControl(dlg, "Size (um)", size, 0.0, 10.0);
AddFloatControl(dlg, "Rate (um/s)", rate, 0.0, 100.0);
AddFloatControl(dlg, "Depth (um)", depth, 0.0, 1.0);
AddFloatControl(dlg, "Z_rate (um/s)", z_rate, 0.0f, 1.01f);
AddButton(dlg, "&Do It", noID, NULL, uibClose|uibNone);
//AddButton(dlg, "&Do Litho line", noID, DoLithoLine, uibNone);
 AddButton(dlg, "&Cancel", 0, NULL, uibClose|uibNone);
// display the dialog box
int res = RunDialog(dlg);
Debug("res: %d\n", res);
if (res == 0)
return 0;   // 0 makes macro unload
LITHO_BEGIN
LithoDisplayStatusBox();// display litho status box
LithoScan(false);// turn off scanning
LithoCenterXY();// move tip to center of field
LithoTranslate(size, 0, rate);// move to first corner of diamond
LithoMoveZ(depth, z_rate);// moving in Z turns off feedback // push tip into surface

// scribe four sides of the diamond
      LithoTranslate(-size, size, rate);
      LithoTranslate(-size, -size, rate);
      LithoTranslate(size, -size, rate);
      LithoTranslate(size, size, rate);
LITHO_END

return 0;// 0 makes the macro unload. Return 1 to keep the macro loaded.
}
```

Code that Creates the Dialog Box to Enter Litho. Settings.

316.6 NanoScript Macros

For modifying or writing new programs, it is important to understand the NanoScript macros, or specific language commands for performing NanoLithography. The NanoScript macro language includes commands to translate (move) the tip and to plunge the tip in to sample material while controlling microscope parameters (e.g., **Bias** and **Setpoint)**. Section 316.7 and Section 316.8 detail the NanoScript Lithography Commands and the new GUI commands available with this option.

Note: All functions that include the word **(false)** will only work properly if the header file, **sysdef.h** is in your **Include** directory. Otherwise, for all statements where **(FALSE)** is part of the syntax, change the term to **(false)**, which works properly regardless of the sysdef.h file.

316.6.1 Background

The NanoScript macro language was developed by Digital Instruments, Veeco Metrology Group for automatic control of SPM functions.

Note: For information about adding full NanoScript capability to your microscope, contact Digital Instruments, Veeco Metrology Group.

NanoScript macro commands add NanoScope functionality to source code written in C language formats (e.g., C++). The source code exists in the same directory as the NanoScope SPM executable file. This section details the NanoScript macros associated with programming to perform **NanoLithography**.

Refer to the following function commands:

- **Litho.h Functions:** Section 316.7 on Page 38
- **Gui.h Functions:** Section 316.8 on Page 46

316.7 Litho.h Functions

For details on these commands, refer to the following sections:

- **LithoAbort:** Section 316.7.1 on Page 39
- **LITHO_BEGIN:** Section 316.7.2 on Page 39
- **LITHO_END:** Section 316.7.3 on Page 39
- **LithoDisplayStatusBox:** Section 316.7.4 on Page 39
- **LithoRemoveStatusBox:** Section 316.7.5 on Page 39
- **LithoFeedback:** Section 316.7.6 on Page 40
- **LithoSignal:** Section 316.7.7 on Page 40
- **LithoGet:** Section 316.7.8 on Page 41
- **LithoGetSoft:** Section 316.7.9 on Page 41
- **LithoMoveZ:** Section 316.7.10 on Page 41
- **LithoPause:** Section 316.7.11 on Page 42
- **LithoPulse:** Section 316.7.12 on Page 42
- **LithoRamp:** Section 316.7.13 on Page 43
- **LithoRelease:** Section 316.7.14 on Page 43
- **LithoSet:** Section 316.7.15 on Page 43
- **LithoSetSoft:** Section 316.7.16 on Page 44
- **LithoTranslate:** Section 316.7.17 on Page 44
- **LithoTrigger:** Section 316.7.18 on Page 44
- **LithoWaitFor:** Section 316.7.19 on Page 45
- **Gui.h Functions:** Section 316.8 on Page 46

316.7.1 LithoAbort

PROTOTYPE: **void LithoAbort();**

DESCRIPTION: **LithoAbort** is used inside a lithography block to jump to the **LITHO_END** command.

RETURN VALUE: None

316.7.2 LITHO_BEGIN

PROTOTYPE: **LITHO_BEGIN**

DESCRIPTION: **LITHO_BEGIN** prepares the SPM for lithography

Note: To stop the scanning, use **LithoScan(false)**. To move the tip to the center of the scan area, use **LithoCenterXY()**.

316.7.3 LITHO_END

PROTOTYPE: **LITHO_END**

DESCRIPTION: This macro is placed at the end of a set of lithography commands. Execution of this command causes the SPM to resume normal scanning.

316.7.4 LithoDisplayStatusBox

PROTOTYPES: **void LithoDisplayStatusBox();**

DESCRIPTION: Displays the lithography status box.

316.7.5 LithoRemoveStatusBox

PROTOTYPES: **void LithoRemoveStatusBox();**

DESCRIPTION: Removes the lithography status box.

316.7.6 LithoFeedback

PROTOTYPES: **bool LithoFeedback(bool on);**

DESCRIPTION: LithoFeedback turns **Z feedback** on or off.

RETURN VALUE: FALSE if the command fails.

EXAMPLE:

LithoFeedback (false);//turn off feedback

316.7.7 LithoSignal

The **LithoSignal** type is an argument, or boolean command, for several lithography commands: **LithoSet**, **LithoSetSoft**, **LithoGet**, **LithoGetSoft**, **LithoRamp** and **LithoPulse** (see descriptions below). **LithoSignal** values may be set to any of the following analog lines:

Table 316.7a LithoSignal Analog Lines

Channel		**Hard Units**	**Soft Units**
Output channels	lsX	V	nm
	lsY	V	
	lsZ	V	nm
	lsZlimit	V	nm
	lsBias	mV	
	lsSetpoint	V (AFM), nA (STM)	
	lsAna1	V	
	lsAna2	V	
	lsAna2HV	V	
	lsAna3	V	
	lsAna4	V	
Input channels	IsIn0	V	
	lsAuxA	V	
	lsAuxB	V	
	lsAuxC	V	
	lsAuxD	V	
	lsIn1	V	
	lsIn2	V	
	lsIn3	V	
	lsIn4	V	

Applications on Specific Analog Lines

Specific applications or microscope modes may only be used with the following analog lines:

- **lsBias** is available on STM microscopes only.
- **lsAna1** is available on non-EC microscopes in STM, and contact AFM microscopes only.
- **lsAna2** and **lsAna2HV** are available on AFM microscopes where input attentuation is disabled and on all STM microscopes.
- **lsAna3** and **lsAna4** are available only NanoScope IIIa controllers which have been upgraded with additional D/A converters.

316.7.8 LithoGet

PROTOTYPES: **double LithoGet (LithoSignal i);**

DESCRIPTION: Returns the current value of the specified channel in its *hard* units, (typically the signal's hardware representation). such as volts.

316.7.9 LithoGetSoft

PROTOTYPES: **double LithoGet (LithoSignal i);**

DESCRIPTION: Returns the current value of the specified channel in its *soft* units, (typically the signal's software representation), such as nanometers.

316.7.10 LithoMoveZ

PROTOTYPES: **bool LithoMoveZ(double dz, double rate);**

DESCRIPTION: **LithoMoveZ** moves the tip along the Z-axis (dz) at a specified rate. Units for **dz** are micrometers; units for rate are in micrometers per second (µm/sec). Positive values for dz moves the tip away from the sample. This command turns off feedback.

RETURN VALUE: FALSE if the command fails.

EXAMPLE:

LithoMoveZ(-0.020, 0.040);//move the tip 20 nm toward the sample at 40 nm/s.

See also, Optimizing the LithoMoveZ Command below.

Optimizing the LithoMoveZ Command

To use **LithoMoveZ** and translation for doing lithography, complete the following:

1. Disable the **Slow scan axis**, then select **Scope mode** to examine the surface slope.

   Note: This reveal the sample tilt along the X-axis.

2. Adjust the sample until this axis is level. (Several withdrawals and engages may be required to get the adjustments right.).

3. Set the **Scan angle** to **90**° so that the **Scope mode** trace reveals the sample along its Y-axis; adjust the sample again until level. Return the **Scan angle** setting to **0**° to verify the sample is still level in its X-axis. You are now ready to do your lithography.

4. Verify that the sample is level in both axes.

5. Capture the plane of the image using the **Capture Plane** command.

If the depth of your etched lines tend to slope from one end of the line to the other, this may indicate that the sample is not sufficiently level, or that you need to obtain an improved **Capture Plane**. Accurate planefit captures require good scans and flat samples. Try to use a smooth area of the sample for planefits and lithography.

316.7.11 LithoPause

PROTOTYPES: **bool LithoPause(double secs);**

DESCRIPTION: **LithoPause** halts lithography for the specified number of seconds (**secs**).

RETURN VALUE: FALSE if the command fails.

EXAMPLE: LithoPause(0.5);//pause for 0.5 seconds.

316.7.12 LithoPulse

PROTOTYPES: **bool LithoPulse(LithoSignal o, double v, double secs);**

DESCRIPTION: **LithoPulse** pulses the output to **v** (volts) for **secs** (seconds). The output then returns to its setting before pulsing.

RETURN VALUE: FALSE if the command fails.

EXAMPLE:

```
//pulse the Bias voltage to 2 volts for a period of 0.1 seconds.
LithoPulse(lsBias, 2, 0.1);
```

316.7.13 LithoRamp

PROTOTYPES: **bool LithoRamp(LithoSignal o, double start, double end, double secs);**

DESCRIPTION: Ramps the output specified in **o** from the voltage specified in **start** to the voltage specified in **end** over the specified time defined in **sec**s. The output then returns to its previous voltage and output settings.

RETURN VALUE: FALSE if the command fails.

EXAMPLE:

```
//ramp the Bias voltage from -2 to 2 volts over a period of 5 seconds.
LithoRamp(lsBias, -2, 2, 5);
```

316.7.14 LithoRelease

PROTOTYPES: **bool LithoRelease(bool allow);**

DESCRIPTION: Allows the user turn on and off user interface processing during lithography commands. This makes lithography run faster for critical timing applications but locks out all user access.

RETURN VALUE: FALSE if the command fails.

EXAMPLE:

```
//Produce a 50 ms pulse on A1. Without the LithoRelease command,
//the pulse may be significantly longer than 50 ms.

LithoRelease (false);//turn off user interface processing
LithSet(lsAna1, 10);
LithoPause(0.050);
LithoSet(lsAna1, 0);
LithoRelease (true);//turn on user interface processing
```

316.7.15 LithoSet

PROTOTYPES: **bool LithoSet(LithoSignal o, double v);**

DESCRIPTION: **LithoSet** sets the specified signal **o** to **v** in hard units, (typically the signal’s hardware representation) such as volts.

RETURN VALUE: FALSE if the command fails.

EXAMPLE:

```
LithoSet (lsAna2, -5)//sets analog line #2 to -5 volts.
```

316.7.16 LithoSetSoft

PROTOTYPES: **bool LithoSetSoft(LithoSignal o, double v);**

DESCRIPTION: **LithoSetSoft** sets the specified signal **o** to **v** in soft units, (typically the signal's software representation) such as nanometers.

RETURN VALUE: FALSE if the command fails.

316.7.17 LithoTranslate

PROTOTYPES: **bool LithoTranslate(double dx, double dy, double rate);**

DESCRIPTION: **LithoTranslate** moves the tip along the X-axis (**dx**) and Y-axis (**dy**) at a specified **rate**. Units for **dx** and **dy** are microns; units for **rate** are in microns per second (um/sec). If feedback is off, the tip will also be moved in Z according to the captured planefit in an attempt to keep the sample-to-tip distance constant.

RETURN VALUE: FALSE if the command fails.

EXAMPLE: LithoTranslate (5,0,2);//Translate the tip 5 µm along the X-axis at 2 µm/s.

316.7.18 LithoTrigger

PROTOTYPE: **bool LithoTrigger(TriggerLine line);**

DESCRIPTION: **LithoTrigger** sends out approximately 200 ns pulse (hi/lo/hi) on the specified digital line.

RETURN VALUE: FALSE if the command fails.

EXAMPLE: LithoTrigger (tlD0);//send pulse out digital line D0:

TRIGGERLINE VALUES: The **TriggerLine** type is used as an argument for the **LithoTrigger** command (see description below). **TriggerLine** values may be assigned to any of the following analog lines.

Table 316.7a TriggerLine Analog Lines

Line	**Value**
tlD0	-1
tlD1	-2
tlDR0	0x0001
tlDR1	0x0002
tlDR2	0x0004
tlDR3	0x0008

Line	**Value**
tlDR4	0x0010
tlDR5	0x0020
tlDR6	0x0040
tlDR7	0x0080
tlDR8	0x0100
tlDR9	0x0200
tlDR10	0x0400
tlDR11	0x0800
tlLine	0x4000
tlFrame	0x8000

Applications on Specific Analog Lines

Specific applications or microscope modes may only be used with the following analog lines:

- **tlD0** and **tlD**1 lines are only available on non-EC, Small Sample AFM and STM microscopes.
- **tlDR0—tlDR11**, **tlLine** and **tlFrame** are only available on SPMs with NanoScope IIIa controllers.

316.7.19 LithoWaitFor

PROTOTYPE: **bool LithoWaitFor(LithoSignal i, double v);**

DESCRIPTION: **LithoWaitFor** causes the lithography program to pause until the specified input drops below '**v**'.

RETURN VALUE: FALSE if the command fails.

EXAMPLE: LithoWaitFor (lsIn1B, 0);//wait for input 1B to drop below 0 volts.

316.8 Gui.h Functions

The functions in the **gui.h** file header allow the user to create and manage the display of standard and custom menus and dialog boxes.

Refer to the following sample list of **gui.h** function prototyes:

- **AddButton:** Section 316.8.1 on Page 47
- **AddCheckBox:** Section 316.8.2 on Page 47
- **AddFloatControl:** Section 316.8.3 on Page 48
- **AddIntControl:** Section 316.8.4 on Page 48
- **AddMenuItem:** Section 316.8.5 on Page 48
- **AddRadioButton:** Section 316.8.6 on Page 48
- **AddRadioGroup:** Section 316.8.7 on Page 49
- **AddStringEntry:** Section 316.8.8 on Page 49
- **Askxxxx: The Ask Group:** Section 316.8.9 on Page 49
- **AtMenuBuild:** Section 316.8.10 on Page 50
- **ClearMenuBar:** Section 316.8.11 on Page 50
- **CustomMenuBar:** Section 316.8.12 on Page 50
- **Debug:** Section 316.8.13 on Page 50
- **DelMenuItem:** Section 316.8.14 on Page 50
- **EraseMessage:** Section 316.8.15 on Page 51
- **FindMenuItem:** Section 316.8.16 on Page 51
- **IsMessageBoxUp:** Section 316.8.17 on Page 51
- **LockGUI:** Section 316.8.18 on Page 51
- **LockMenu:** Section 316.8.19 on Page 51
- **ModalDialog:** Section 316.8.20 on Page 52
- **NormalMenuBar:** Section 316.8.21 on Page 52
- **PasswordQuery:** Section 316.8.22 on Page 52
- **RemoveSayBox:** Section 316.8.23 on Page 52

316.8.1 AddButton

PROTOTYPES: **void AddButton(DialogBox db, char *text, int id, PFV action, UIBFlags flags);**

DESCRIPTION: Adds a button with the specified text to the dialog box specified by `ab`.

EXAMPLE:

`UIBFlags` can be any combination of the following values:
enum UIBFlags
{
uibNone= 0,
uibDefault= 0x00000100,
uibClose= 0x00000200
};

316.8.2 AddCheckBox

PROTOTYPE: **void AddCheckBox(DialogBox db, char *text, bool & checked);**

DESCRIPTION: `AddCheckBox` adds a check box with the specified text to the dialog box specified by `db`.

316.8.3 AddFloatControl

PROTOTYPE: **void AddFloatControl(DialogBox db, char *label, int & value, int min, int max);**

DESCRIPTION: AddFloatControl adds a control which allows the entry of a floating point number to the dialog box designated by db. The specified label will be displayed next to the entry field. The entered value is returned in value. The minimum and maximum values allowed are specified in min and max, respectively.

316.8.4 AddIntControl

PROTOTYPE: **void AddIntControl(DialogBox db, char *label, int & value, int min, int max);**

DESCRIPTION: AddIntControl adds a control which allows the entry of an integer to the dialog box designated by db. The specified label will be displayed next to the entry field. The entered value is returned in value. The minimum and maximum values allowed are specified in min and max, respectively.

316.8.5 AddMenuItem

PROTOTYPE: **MenuItem AddMenuItem(MenuItem parent, char *name, PFV fn);**

DESCRIPTION: AddMenuItem adds a menu item with the name specified by name to the menu specified by parent. To add an item to the menu bar, specify menuBar as the parent. The function fn is called when the item is selected by the user. If fn is NULL, no function is called.

When an ampersand (&) is placed in the character string, the character immediately following the ampersand becomes a “quick-key” for that menu item in the dialog box. (For example, `“M”` is the quick-key when `&Microscope` is specified in the text string.)

RETURN VALUE: A handle to the newly created menu item is returned. This handle may be used as the parent argument in subsequent calls to `AddMenu` to create submenus. *See also,* **FindMenuItem**, **DelMenuItem**.

316.8.6 AddRadioButton

PROTOTYPE: **void AddRadioButton(RadioGroup rg, char *label, ResID id);**

DESCRIPTION: `AddRadioButton` adds a radio button to a group of radio buttons specified by `rg`. The new radio button receives the name specified by `label`. *See also,* **AddRadioGroup**, **SelectRadioGroup**.

316.8.7 AddRadioGroup

PROTOTYPE: **RadioGroup AddRadioGroup(DialogBox db, char *title, ResID & selected);**

DESCRIPTION: AddRadioGroup adds a radio group to dialog box db, to which radio buttons can then be added. The radio group receives the name specified by title.

RETURN VALUE: A handle to the newly created radio group is returned. This handle may be used as the parent argument in subsequent calls to AddRadioButton. *See also,* **AddRadioButton**, **SelectRadioGroup**.

316.8.8 AddStringEntry

PROTOTYPE: **void AddStringEntry(DialogBox db, char *prompt, int width, char *buffer, int buflen);**

DESCRIPTION: AddStringEntry adds a string entry field to the dialog box db. The string specified by prompt will e displayed adjacent to the entry field. The entered text is stored in buffer.

316.8.9 Askxxxx: The Ask Group

PROTOTYPE:

void AskCancel(char *title, char *fmt, ...);

bool AskCancelOk(char *title, char *fmt, ...);

bool AskNoYes(char *title, char *fmt, ...);

void AskOk(char *title, char *fmt, ...);

bool AskOkCancel(char *title, char *fmt, ...);

void AskQuit(char *title, char *fmt, ...);

bool AskYesNo(char *title, char *fmt, ...);

DESCRIPTION: Each of these functions display a modal dialog box. The title of the dialog box is specified by `title`. Any messages displayed in the modal dialog box are specified by `fmt` and remaining parameters (`printf` style). In addition the box will have buttons corresponding to the name of the function called. For instance `AskYesNo` will have a ‘`yes`’ and a ‘`no`’ button. The box is closed when any button is selected.

RETURN VALUE: `TRUE` if selecting the **OK** or **YES** button; `FALSE` if box closes by selecting the exit option (i.e., “X”).

316.8.10 AtMenuBuild

PROTOTYPE: **void AtMenuBuild(void (*fn)(int));**

DESCRIPTION: The AtMenuBuild function registers the function fn such that when a menu bar is being built, the registered function (fn) is called. This allows adding custom menu items using NanoScript. *See also*, **AddMenuItem**, **FindMenuItem**, **DelMenuItem**, **ClearMenuBar**, **CustomMenuBar**.

316.8.11 ClearMenuBar

PROTOTYPE: **void ClearMenuBar();**

DESCRIPTION: The ClearMenuBar function clears all items from the current menu bar. *See also,* **FindMenuItem**, **DelMenuItem**, **AddMenuItem**.

316.8.12 CustomMenuBar

PROTOTYPE: **void CustomMenuBar();**

DESCRIPTION: The function CustomMenuBar displays a user configured menu bar. This menu bar is not used by any other portion of the NanoScope system. *See also,* **NormalMenuBar**, **AddMenuItem**, **FindMenuItem**, **DelMenuItem**, **ClearMenuBar**.

316.8.13 Debug

PROTOTYPE: **int Debug(char *fmt, ...);**

DESCRIPTION: The function `Debug` outputs a string as specified to the system debug box. The arguments are `printf` style. This box can also display by selecting `Ctrl-Alt-D`.

RETURN VALUE: Returns the number of characters output to the debug box.

316.8.14 DelMenuItem

PROTOTYPE: **void DelMenuItem(MenuItem item);**

DESCRIPTION: The function `DelMenuItem` removes the specified menu item.

316.8.15 EraseMessage

PROTOTYPE: **void EraseMessage();**

DESCRIPTION: The `EraseMessage` function erases the message box that has been displayed by the `ShowMessage` function. *See also*, **ShowMessage**, **SayError**, **SayWarning**, **SayMessage**, **RemoveSayBox**.

316.8.16 FindMenuItem

PROTOTYPE:**MenuItem FindMenuItem(MenuItem parent, char *name);**

DESCRIPTION: The `FindMenuItem` function locates a menu item with the string specified by `name` in the menu referred to by `parent`. To find an item in the main menu bar, specify `menuBar` as the parent.

RETURN VALUE: Returns the handle to the found menu item. If no matching item is found, `NULL` is returned. *See also*, **AddMenuItem**, **DelMenuItem**.

316.8.17 IsMessageBoxUp

PROTOTYPE:**bool IsMessageBoxUp()**;

DESCRIPTION: The function IsMessageBoxUp queries for the presence of the user interface message box.

RETURN VALUE: `TRUE` if yes, otherwise `FALSE`.

316.8.18 LockGUI

PROTOTYPE: **void LockGUI();**

DESCRIPTION: The function `LockGUI` locks the user interface preventing all user interaction with the system until the Unl`ockGUI` function is called. *See also*, **UnlockGUI**.

316.8.19 LockMenu

PROTOTYPE: **void LockMenu();**

DESCRIPTION: The function `LockMenu` locks the current menu bar in place preventing it from being replaced with another menu bar when the software changes modes. This is useful when the macro has put up a custom menu bar. *See also*, **UnlockMenu**, **CustomMenuBar**.

316.8.20 ModalDialog

PROTOTYPE:**DialogBox ModalDialog(char *title);**

DESCRIPTION: The function ModalDialog creates a dialog box with name as specified in title.

EXAMPLE:

The example program below creates a dialog box with a title of "*Title String.*" The box has one entry field labelled "`Size`," which allows float entries from zero to 200. The value entered by the user is stored in `size`. Additionally, there are two buttons in the dialog box; one is labelled "`Ok`" and the other "`Cancel.`"

```
{
float size = 30;
DialogBox dlg = ModalDialog ("Title String");
AddFloatControl (dlg, "Size", size, 0, 200);
AddButton (dlg, "&Ok", 1 NULL,
uibClose|uibDefault);
AddButton (dlg, "&Cancel", 0, NULL, uibClose);
if (RunDialog(dlg) == 0)
return;

}
```

RETURN VALUE: Returns the handle of the newly created dialog box.

316.8.21 NormalMenuBar

PROTOTYPE: **void NormalMenuBar();**

DESCRIPTION: The function `NormalMenuBar` displays the default NanoScope menu bar.
See also, **CustomMenuBar**.

316.8.22 PasswordQuery

PROTOTYPE: **bool PasswordQuery();**

DESCRIPTION: The function `PasswordQuery` prompts the user to enter a password.

RETURN VALUE: `TRUE` if a valid password is entered; otherwise `FALSE`

316.8.23 RemoveSayBox

PROTOTYPE: **void RemoveSayBox();**

DESCRIPTION: The function `RemoveSayBox` removes any message box from the screen that was invoked by a `Sayxxxx` function. *See also*, **SayError**, **SayWarning**, **SayMessage**.

316.8.24 RunDialog

PROTOTYPE: **int RunDialog(DialogBox db);**

DESCRIPTION: The function `RunDialog` displays the dialog box specified by parameter `db`. The function returns when the box is closed by the user.

RETURN VALUE: Returns the id of the button used to close the box. *See also*, **ModalDialog**.

316.8.25 SayError

PROTOTYPE: **void SayError(char *fmt, ...);**

DESCRIPTION: The function `SayError` displays a message box with the title of `“Error”`. The parameters specify the message to be displayed and are in `printf` style. *See also*, **RemoveSayBox**.

316.8.26 SayMessage

PROTOTYPE: **void SayMessage(char *title, char *fmt, ...);**

DESCRIPTION: The function `SayMessage` displays a message box with the specified `title` value. The remaining parameters specify the message to be displayed and are in `printf` style. *See also*, **RemoveSayBox**.

316.8.27 SayWarning

PROTOTYPE: **void SayWarning(char *fmt, ...);**

DESCRIPTION: The function `SayWarning` displays a message box with the title of `“Warning”`. The parameters specify the message to be displayed and are in `printf` style.
See also, **RemoveSayBox**.

316.8.28 SelectRadioButton

PROTOTYPE: **void SelectRadioButton(RadioGroup rg, ResID id);**

DESCRIPTION: The function `SelectRadioButton` selects the radio button specified by the `id` in the radio group `rg`. *See also*, **RunDialog**.

316.8.29 ShowMessage

PROTOTYPE: **void ShowMessage(char *title, char *fmt, ...);**

DESCRIPTION: The function `ShowMessage` invokes a message box with the title as specified by `title.` The remaining parameters specify the message to be displayed in `printf` style. While this box is up the user is prevented from interacting with the system. It must be removed using a call to `EraseMessage`. *See also*, **EraseMessage**.

316.8.30 UnlockGUI

PROTOTYPE: **void UnlockGUI();**

DESCRIPTION: The function UnlockGUI removes the lock placed by the LockGUI function preventing all user interaction with the system. *See also*, **LockGUI**.

316.8.31 UnlockMenu

PROTOTYPE: **void UnlockMenu();**

DESCRIPTION: The function UnlockMenu removes the lock placed by the LockMenu function preventing the menu bar from changing. *See also*, **LockMenu**.