

Basic of NanoMaker Editor

Operational manual
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BASIC OF NANOMAKER EDITOR

GDB file

NanoMaker editor is designed for creating and editing multi-layer hierarchical lithographic structures. Designed lithographic structures are saved in data files with the *.GDB extension. GDB file format has been specifically designed for the efficient storage and quick access to essential information on the lithographic structures. The data in the GDB file is stored in binary form. In what follows narrative the terms "GDB file" and "lithographic structure" will be synonymous.

The main structural unit of lithographic structure and GDB file, respectively, is named Structure. Each GDB file includes one or may be more structures. Each structure in turn comprises a set of geometric objects - elements located in the plane.

Resolution

Each GDB file is characterized by a parameter Resolution. Resolution is the smallest editor cursor step which can be used when creating elements. Furthermore, value of Resolution determines the maximal spatial limits of a structure. Resolution should be defined at the time of GDB file creation. By default, a new file is created with Resolution of 1 nm. In that file a structure dimensions are limited from -1000 mm to 1000 mm in each direction. When choosing a Resolution follow by the rule that the value of Resolution should be at least an order of magnitude better than the minimal size of projected elements that will ensure sufficient accuracy of their design. Resolution can not be changed after creating of a GDB file. If, however, at designing, the Resolution of a structure needs to be changed, create a new file with a required Resolution and copy the already created elements to it.

Structure

Each structure must have a name. Name of a structure must be unique within GDB file. The name is limited to 255 characters. Name of a structure may be formed in the Latin alphabet, numbers and some other characters. Structure names are case-sensitive. I.e. in one file can be two different structures, one of which may be named, for example, a1, and the other A1.

At the creation of a GBD file, by default, is created a structure named MAIN. This structure can not be removed from a file nor renamed. As required, additional structures can be added in the file. Their maximum number in a file can not exceed 32767 ($2^{15}-1$).

Elements

Currently, there are eight types of elements in the GDB file format. Three of them are basic - Point, Line and Contour (Polygon). More specific are Time&Date, Comments, Structure reference, Dose map and Reference map, which are turned into a set of basic elements directly before exposure. Furthermore, for the convenience at design stage, there are several derivatives of Contour elements which are converted to the contours immediately after completion of input. These include: Rectangle, Ring, Circle and Text.

Basic elements are defined by an appropriate set of coordinates and are characterized by the following attributes: exposure dose (Dose), 3D attribute (3D Attribute), layer (Layer). Where,

Exposure dose - relative value in percentage of resist sensitivity (T/T0), showing how many times the exposure of one point of a given element differs from the exposure time of a one point of the element with 100% dose. The value of this attribute can vary from 0% - 3200% with an accuracy of 0.1%. For more information about the resists sensitivity see the product Help.

3D attribute - relevant only for 3D structures, when you need to create three-dimensional structure with the specified profile. It may have different meanings depending on the task (e.g. thickness or phase shift). However, it can be reduced to the resist thickness by linear transformation. Value of this attribute can range from -3200% - 3200% with an accuracy of 0.1%.

Layer - the value determines whether of this element belongs to one of 256 layers of a structure. The value of this attribute may vary in the range of 0 - 255.

The specific elements have some additional attributes, which will be listed below in the description of these elements.

Layers

Each structure can contain 256 layers (from 0th to 255th) and allows one to distribute elements by these layers for technological needs, such as multilayer lithography with layer by layer alignment, for example.

3D attribute

To create a three-dimensional (3D) structure the 3D characteristic must be defined when you create a new GDB file.

Cutting Grid (Database Cells)

To optimize the solutions of some tasks associated with data preparation or directly with the exposure, the interior structure can be divided into square cells by a grid. Grid spacing can be arbitrary value. Elements, which intersect by a grid, cut into separate elements on the boundaries of the grid. In the presence of the grid, all operations with elements are executed sequentially when traversing the grid cells, one after another. At first, an operation is performed with the elements within a current cell and only then with the elements of the next cell. I.e. a grid organizes sequence of operations with elements of a structure. In order to make an exposure with stage displacements, cutting a structure by grid is mandatory. In that case, grid organizes subfields (their size is determined by the grid), between which movements are made. Cutting grid drawn in orange.

Editor Window and Menu Commands

When you open an existing or create a new GDB file at least one window is opened – a view, which shows structure MAIN. Each structure contained in GDB file can be opened in a separate window for viewing and editing.

To create a new GDB file, click the **New Database...** in the menu **File (File->New Database...)**. In the **New Database File** dialog leave all fields unchanged and click **OK**.

There is only one structure in a new file, which is named as MAIN and initially empty, i.e. does not include any elements.

The title of the editor window displays file name, structure name, attribute of spatial dimension (2D or 3D) and the window serial number, separated by a colon, as for example in Fig. 1.

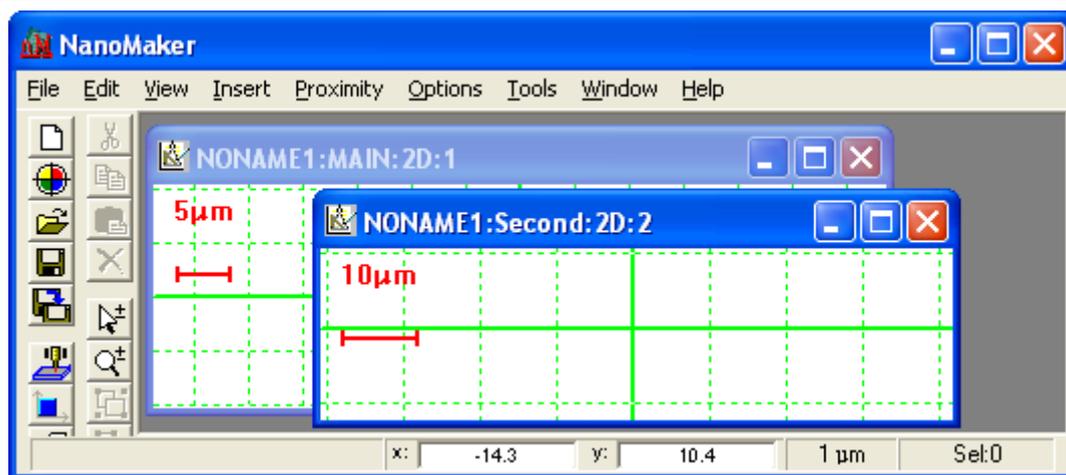


Fig. 1 Editor windows for just created MAIN and Second structures

With the default settings, an editor window displays the scale bar in red in the upper left corner, and window space is lined by coordinate grid that is drawn in green. This is the design grid. Two mutually perpendicular thickened lines traverse through the centre of the coordinate system marking the coordinate axes. Grid spacing is always equal to size of the scale bar.

The cursor is always attached to the mouse pointer and its current coordinates are displayed in two editable fields lying on status bar at the bottom frame of the program. These coordinates are shown in microns invariably. To the right of them, in the next field, the cursor step is displayed in the appropriate units. In the utmost right field is shown a number of selected elements (see Fig.1).

Toolbar

The toolbar at the left frame of the main window gives quick access to basic functionality of the program (see Fig.1). Its buttons are arranged in two vertical rows - the left line provides access to main functions and dialogs and the right to the editor commands.

Scale

When you open an editor window the scale is chosen such that the whole structure is visible. Later on, if you change the scale of displayed structure, the scale bar will be resized and, accordingly, grid spacing will be changed.

For quick zooming, use mouse wheel or press / and * on the numeric keypad. Note that increase or decrease of displayed fields realized relative to the current cursor position. Thus, for convenience of editing, different areas of a structure design can be moved to centre of the window while increasing or decreasing the display scale.

In order to move the displayed fragment of a structure without changing the scale, click and hold the left mouse button, drag the cursor to desired position in the window and release button.

In order to see the structure entirely, press the = key.

Cursor Step

Cursor step - is the distance at which the cursor moves in the editor window after pressing any arrow key on keyboard. Cursor step can be set over a wide range, which also depends on the file Resolution. When you create a new file with the default Resolution of 1 nm, the Cursor step is 1 μm, which is quite convenient.

To quickly change the Cursor step use the + and - keys on the numeric keypad.

In order to accurately move the cursor to the nearest node of the design grid, for example, when creating a new element, press **Shift** key.

Display Mode

NanoMaker Editor can display elements in a few modes.

Contour displaying mode

By default, when you open new editor window the Contour (Layers) mode is always set. In this mode, elements in visible layers are displayed as coloured outlines. Outline colour depends on the layer number. Correspondence is given via a palette dialog box (shown in Fig. 2). Totally possible to set 16 different colours that will encode the first 16 layers and will periodically repeated in all subsequent layers.

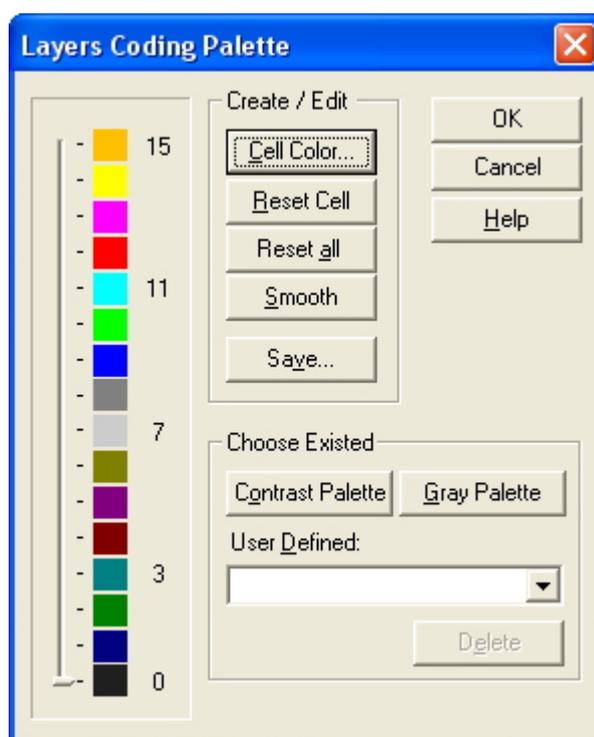


Fig. 2 Defining of the layer's coding palette in *Layers Coding Palette* dialog

To set Contour displaying mode select **View->Redraw->Contour** menu command or press **Alt+C** shortcut keys or press  button on the toolbar.

Dose displaying mode

In Dose mode all elements in visible layers are displayed as coloured shaded areas. Each shading colour encodes a certain dose range. When this mode enabled, the additional panel with colour scale divided into 16 such intervals is opened.

The range of displayed doses is given in **Min Level [%]** and **Max Level [%]** fields of **Editor** tab in **View Options** dialog (to open the **View Options** dialog choose **Options->View...** menu command). Compliance of a dose range with a colour is defined via the **Dose Coding Palette** dialog. To open this dialog click **Dose Palette...** button in **Editor** tab. The **Dose Coding Palette** dialog is similar to that shown in Fig. 2 for color coding of layers. It is possible to set 16 different colors, which will encode 16 dose intervals within a chosen range. If dose of an element lies outside the lower or upper limits of the defined range, the element will be displayed in the colors of the lowermost or uppermost interval, respectively.

The **Contrast Palette** is set by default to code dose intervals in chosen dose range, but you can override it on your own.

To set Dose displaying mode select menu command **View->Redraw->Dose** or press **Alt+D** shortcut keys or press  button on the toolbar.

3D Attribute displaying mode

In 3D Attribute mode all elements in visible layers are displayed as coloured shaded areas. Each shading colour encodes certain 3D attribute range. When this mode enabled, the additional panel with colour scale divided into 16 such intervals is opened. Compliance of a 3D attribute range with a colour is defined via the **3D Attribute Coding Palette** dialog, where you can set a correspondence between given 3D attribute ranges and different colours.

To set 3D Attribute displaying mode select menu command **View->Redraw->3D Attribute** or press **Alt+3** shortcut keys.

Displaying of layers (active layers)

There are other options of showing elements in the editor window, for example, show or hide elements lying in some layers. By default, each structure is set in mode to show all elements in all available layers. To hide any of the available layers, choose the menu command **View->Redraw->Layers...** or press the **Alt+Y** shortcut keys. Then, in the opened **Active Layers** dialog find the layers in list, deselected them and then click **OK** button to close dialog. Conversely, to make some layers visible, it is necessary to select them in the list.

Important! Most of the editorial operations (delete, transform, grouping, ungrouping, etc.), as well as exposure are performed only for elements in visible (active) layers, even if these elements were selected before they appeared in no displayable layers.

Hierarchy levels

When a hierarchical structure is displayed in the editor window, the top (0th) level of the hierarchy is demonstrated by default. Press the **1**, **2**, **3** or **4** keys to show the following levels of hierarchy - first, second, third, or to the lowest level, respectively. Switching the levels of hierarchy can also be performed via **View->Hierarchy** menu command.

Structure design

Creating of a new structure

As mentioned above, when opening a new file, it contains only one structure, which is named MAIN. To add new structures to the file - open **Edit Structure** dialog (**Edit->Structure...**) and then click the **New** button. In the opened **New Structure** dialog, enter a name of a new structure, which must be unique within the file (see Fig. 3). Click **OK** to close the **New Structure** dialog and to create the structure. The structure's name you will find in list in the **Edit Structure** dialog. Similarly you can add any number of new structures. To open the newly created structure in editor window, select it in the list and click **Edit** button.

A new structure can be created on base of the design of the existing structure. For example, if you want to moved or copy some of the elements to a separate structure, select them and choose the **Edit->Group...** command from the menu. As a result, the **Group to Structure** dialog will be opened. Specify a name for the new structure and check **Delete Elements** checkbox, if you want to move selected elements in the new structure. Check **In New Editor Window** checkbox, if you want to show the newly created structure in editor window after closing the dialog

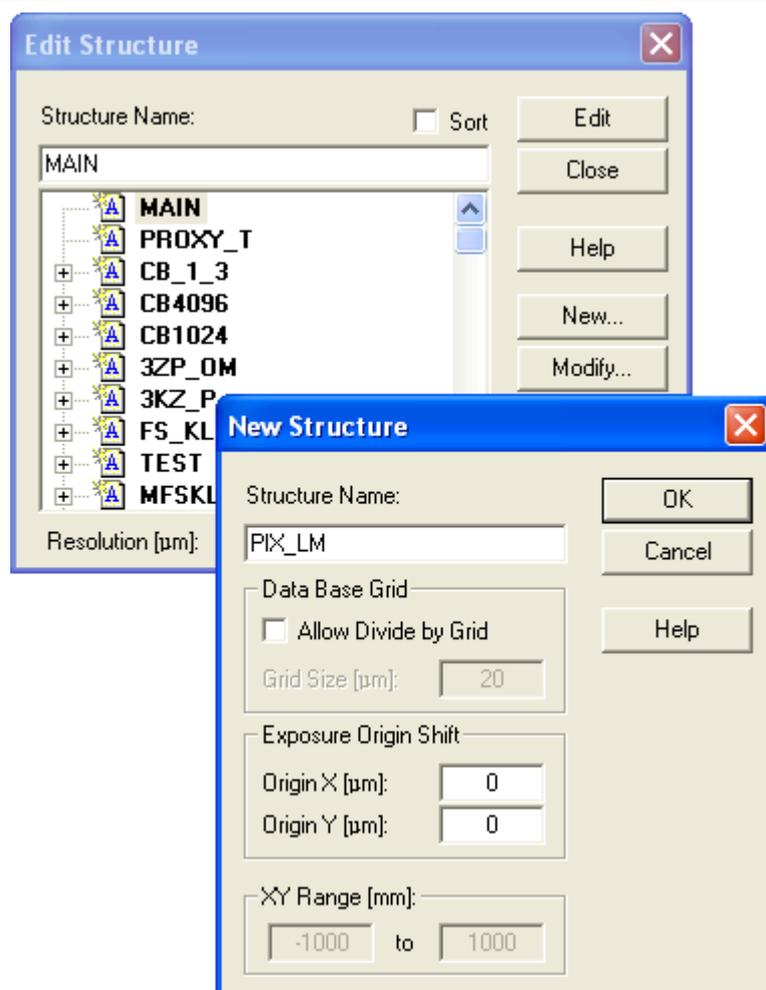


Fig. 3 Creation of a new structure in **New Structure** dialog

Deletion of a structure

To delete an existing structure, open **Edit Structure** dialog (**Edit->Structure...**), select the structure in list, and then click **Delete** button. As a result of this operation, the structure and all its elements will be permanently deleted. This doesn't work if there are references to this structure in the file. In that case you should remove the references from the other structures first and only then try to delete the structure.

Changing of attributes of existing structure

To rename an existing structure, open **Edit Structure** dialog (by **Edit->Structure...** menu command), select the structure from list, and then click **Modify** button. In the opened **Modify Structure** dialog, change the structure's name. A new name also must comply with the rule of structure naming that has been described above in the Structure section.

Furthermore, **Modify Structure** dialog allows you to change size of the cutting grid.

If grid was not set yet, check the **Allow Divide by Grid** checkbox and set desired grid size in the **Grid Size [um]** field.

If, conversely, you want to cancel the cutting grid, uncheck the **Allow Divide by Grid** checkbox.

Further, dialog allows to determine the structure origin shift relatively to center of the writing field (Scan Field). The structure origin is the same as the design origin (point with 0, 0 coordinates).

Often structures are designed unsymmetrical relatively to the center of coordinates. So, sometimes, exposed structure can not fit in the Scan Field, even though its own dimensions not exceed the dimensions of the Scan Field. This is because the structure origin coincides with the center of Scan Field by default. To resolve this problem, set an offset of the structure origin in the fields **Origin X [um]** and **Origin Y [um]**.

Parameters **XY Range [mm]** give an information about the maximum possible dimensions of the structure at this Resolution of the file. More information about the maximum possible dimensions was mentioned above under Resolution section.

Click **OK** button to close the dialog box and make changes.

Summary of structure

To display summary information about the structure choose menu **View->Summary...** or press the **Alt+=** shortcut keys. The **Summary of "<name>" Structure** dialog displays information about the structure's dimensions, total number of elements, number of references to structures and number of selected elements. This is followed by information about attributes, such as, Resolution, Cutting Grid size and 3D availability. And below follows information about layers (see Fig. 4).

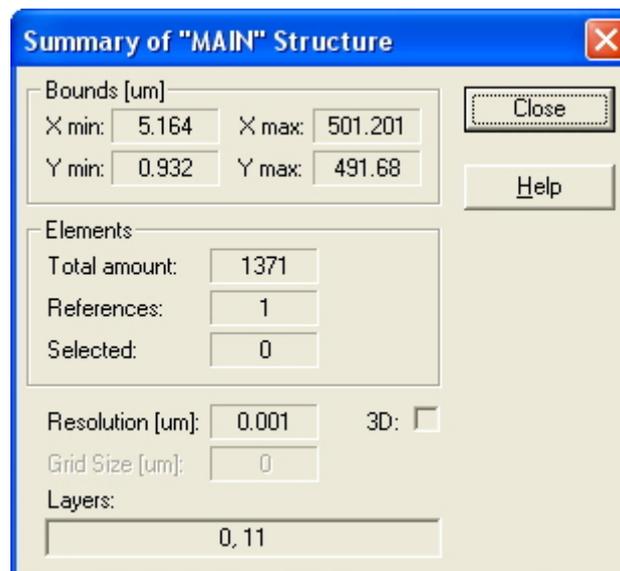


Fig. 4 A summary of the structure

Defining the current values of attributes for a new elements

So, in order to start designing a new structure or edit an existing design, you need to open an editor window containing this structure. How to do this is written in the previous section.

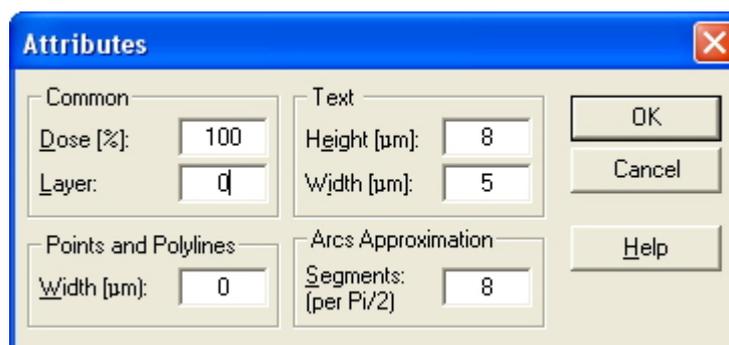


Fig. 5 Defining initial values of the attributes in the *Attributes* dialog

Before creating of a new element, open the **Attributes** dialog (by **Insert->Attributes...** menu command or by pressing **A** hotkey) to set values of the several parameters that will define attributes of new element.

In the initial settings of the dialog (see Fig. 5):

Dose is equivalent to 100%;

Layer is set to 0;

Width of polylines and points equivalent to 0 μm ;

Height and **Width** of input text characters is equivalent to 8 μm and 5 μm , respectively;

Number of Segments to approximate $\pi/2$ degrees arc when entering rings and circles equal to 8.

Change the settings, if necessary, and close the dialog by pressing **OK** button. Now, each newly created element will have attribute values in accordance with the values set in this dialog. If later, after inserting a certain number of elements, you will need to change any of the attribute for subsequent input elements, reopen the **Attributes** dialog and change the value.

Creating new elements

There are several ways to enter the basic elements using the keyboard and mouse. Let's consider an example of a rectangular element input. To introduce insert mode, you can use the menu command **Insert->Rectangle** or simply press **R** hotkey (or click  button in the toolbar). As evidence of transition to

this mode will be appearance of the corresponded cursor  and capture of the mouse pointer within editor window. Then you can use these techniques:

Graphical input with a mouse

Move mouse pointer to point of the first vertex of the future element. For exact hit in the coordinates you need, turn mouse wheel to zoom in to a sufficient accuracy. Click the left mouse button to enter the first vertex. If necessary, zoom out and move pointer to position of the next (the opposite in the case of a rectangle) vertex. Zoom in again if it is necessary for exact hit in the coordinates. Click the left mouse button to complete the insertion of the element. As long as the input is not completed, undo of the previous vertex can be done by right-clicking.

Graphical input from the keyboard

Move mouse pointer close to point of the first vertex and leave the mouse alone. Further, using the Arrow keys, move cursor to the coordinates you need. At the same time, to accurately hit the desired position, use jointly:

- the **Shift** key to set cursor exactly in the closest node of coordinate grid,
- the **-** and **+** keys for adjusting the cursor step,
- the **/** and ***** keys to scale view.

When eventually the cursor is in the correct position, press **Space** to enter the vertex. In case of error, press **Backspace** to cancel just inserted vertex. Then, using the arrow keys (or mouse), move the cursor to the next (opposite) vertex. If necessary, use again the **-** and **+** keys for changing the cursor step and the **/** and ***** keys for scaling. When the cursor is end up in the correct position, press **Space** to enter the vertex and finish entering of the rectangular element.

Keyboard input in digital form

Press **X** hotkey, to set the keyboard focus in the field, which is used to display (and input) current coordinate of the cursor, and is a part of the program

status bar (at the bottom of main window). Enter numerically the X-coordinate of the first vertex of the element. Press **Tab** key to move the input focus in the field, which displays Y- coordinate and enter into this field in numerical form Y-coordinate of the vertex. Press **Enter** to return focus to the editor window. Press **Space** to enter the vertex of the element. Again press **X**, to move the keyboard focus in the field, which displays position of the cursor and repeat all the steps above to enter the next vertex of the element.

Any of the following methods can be combined in an arbitrary way on the base of personal preference.

For your convenience use Multiple Insert mode at entering a number of similar type elements. You can set this mode by choosing **Insert->Multiple Mode** menu command (either by pressing **H** hotkey or by pressing the lowest button  on the toolbar). In this mode, a few elements of the same type, for example rectangles, can be entered successively, one by one, by choosing the insertion command only once before the first input. To exit the Multiple Insert mode press **Esc**.

In general, when you enter different types of elements with an arbitrary number of vertices, a vertex input is usually done by pressing the **Space** bar or the left mouse button. Completion of an element input is fulfilled by pressing the **Enter** key or double-clicking the left mouse button. Cancel of the newly introduced vertex is performed by pressing the **Backspace** key or right mouse button. Quitting the input is accomplished by pressing the **Esc** key or double-clicking the right mouse button.

Digital input using dialog

There is also possibility to introduce the basic elements in a digital form using input fields in the dialog. To insert, for example, a rectangle, choose the **Insert->Numerically->Rectangle** menu command. In the opened dialog, select the first row in the **Element's Nodes [μm]** window, which contains coordinates of one of the vertices of a rectangle (conventionally it is termed as <left-bottom> vertex). Make the row editable by pressing **Space** bar (or click the left mouse button or selecting **Edit** from the context menu that pops up after clicking the right mouse button on the row). Enter coordinates of the vertex instead of present numbers in a row. Be sure to leave separating space between **X** and **Y** coordinate. Go to the second row in the window and edit coordinates of the opposite vertex. Click **Apply** button to enter the element without exiting the dialog and continue typing coordinates of next rectangle in this manner.

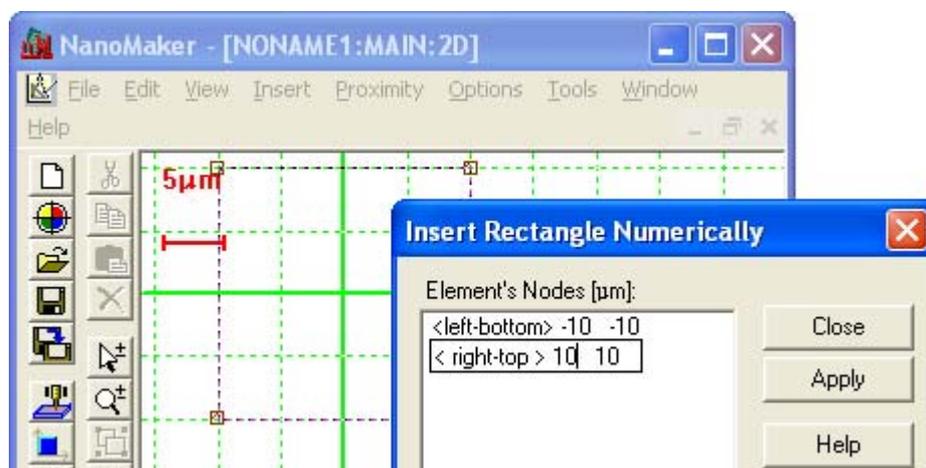


Fig. 6 Inserting of an rectangle with the **Insert Rectangle Numerically** dialog

Similarly may be entered points (**Points**), polylines (**Polyline**), rectangles (**Rectangle**), contours (**Contour**), circumferences (**Circle**) and rings (**Ring**).

When entering a circumference or a ring the coordinates in first row determine the position of centre, and subsequent row(s) determine radius(radii) of the circle(s).

Creating of other more complex types of elements will be described later.

Selection of elements

Any operation in the editor to transform geometry or attributes of elements, as well as deletion and copying runs only for selected elements. Number of selected elements in the structure can be seen in the rightmost field of the program status bar.

To select all elements in a structure, press **Alt+A** shortcut keys or select the **Edit->Select->All** menu command.

To select only relevant elements, use one of the commands in the menu **Edit->Select**:

- **In** - allows to select elements that are entirely within arbitrarily delineated rectangular area. Use mouse or keyboard to draw the enclosed area;
- **At** - allows to select element which is located under the cursor;
- **Layer...** - allows to select elements lying in the chosen layers;
- **Reference...** - allows to select elements, which are references to selected in list structures.

To deselect all elements in structure, press the **Shift+Alt+A** shortcut keys.

To deselect only relevant elements, use one of the commands in the menu **Edit->Unselect**:

- **In** - allows you to deselect elements that are entirely within arbitrarily delineated rectangular area;
- **At** - allows to deselect element which is located under the cursor;
- **Layer...** - allows to deselect elements lying in the chosen layers;
- **Reference...** - allows to deselect elements, which are references to selected in list structures.

In addition to the above options, you can use Select/Deselect modes of the mouse pointer. To set Select/Deselect cursor mode, choose the **Edit->Select**

Mode menu command or press the **Alt+M** shortcut keys (or press the  button in the toolbar). In Select mode:

- Double-clicking the left mouse button in editor window allows to select all elements of a structure;
- Single click with the left mouse button over the element allows to select only this element.
- Drawn with the pressed left mouse button the dashed rectangular outline selects all elements placed inside the rectangle.
- Clicking the right mouse button turns selection mode, for example, from Select to Deselect. In Deselect mode:
 - Double-clicking the left mouse button in editor window allows to deselect all elements of a structure.
 - Single click with the left mouse button over the element allows to deselect only this element.
 - Drawn with the pressed left mouse button the dashed rectangular outline deselects all elements placed inside the rectangle.

- Each new right mouse click inverts selection mode. Current selection mode easily ascertained by type of the cursor. In Select mode, there is a plus sign in the cursor . While a minus sign is present in cursor in Deselect mode.

To exit cursor selection mode, press the Esc key or double-click the right mouse button .

Deletion

To delete some elements of a structure, first select them and press the **Delete** key (or choose **Edit->Clear** menu command or click  button in the toolbar) then.

Cutting (moving to the clipboard)

To delete some elements with the possibility of subsequent pasting them to a structure, first selects the elements and press **Shift+Delete** key combination (or choose the **Edit->Cut** menu command or click  button in the toolbar) then.

Copying

To copy (put on the clipboard) one or more elements of a structure, first selects them. Then select the **Edit->Copy** menu command, or press **Ctrl+Insert** key combination (or the  button in the toolbar).

Pasting

In order to paste an element (or group of elements) previously placed on the clipboard as a result of Copy or Cut operation, select the **Edit->Paste** menu command or press **Shift+Insert** key combination (or the  button in the toolbar). Immediately thereafter, the insert mode is activated: the pointer is captured in the window, a special cursor appears, contours of the inserted elements are drawn in dashed lines in the window, and **Transform Info** panel opens. The geometric center of the contours is marked by dashed crosshair. When mouse cursor is over the image of the elements within an imaginary rectangular area that outlines its outstanding vertexes, the cursor takes form of the pointer with a crosshair . If the mouse pointer is outside an imaginary rectangular area, the cursor takes form of a pointer with open circle , symbolizing the rotation operation.

To move the contours to the right place in structure, place the cursor inside the imaginary rectangular area, grab the image by pressing the left mouse button and hold it while dragging to the right place.

If you want to rotate the contours, place the cursor out of an imaginary rectangular area, grab the image by pressing the left mouse button and hold it while moving the cursor along arc of a big circle, which outlines the image, as long as the contours will get the desired position.

Before dragging, move mouse pointer close to geometric center of the image at a distance less than half the cursor step. Now, when you press the left mouse button, the pointer will jump to the position of the geometric center. And thus, at the further dragging, it is easier to control position of the image. For greater convenience and accuracy, use the arrow keys to move the image with cursor steps. If necessary, use the - and + keys to change the cursor step, as well as / and * keys (or mouse wheel) to scale.

To paste the elements in the right place press **Enter** key or double-click the left mouse button.

To cancel paste, press the **Esc** key or double-click the right mouse button.

By the way, it is possible to paste elements not only in structure where they have been copied, but in any other in this file and in other lithographic structure as well.

Undo/Redo of last actions

In order to undo/redo last action on delete/paste elements, use the **Edit->Undo/Edit->Redo** menu commands (or **Ctrl+Z** / **Ctrl+Shift+Z** shortcut keys, respectively).

Creation of other elements

Text

To add labels to a structure design it is convenient to use the Text element.

By using the edit field in the **Insert Text** dialog, which is called by the **Insert->Text...** menu command (or by pressing **T** hotkey), you can type the text you want and format it properly. In the text you can use uppercase and lowercase letters, digits and other keyboard symbols. After closing the dialog by pressing **OK** button, insert mode is activated: the mouse pointer is captured in the

window, the corresponded cursor appears , to which the input text image hooked. Move the cursor to desired location in the structure and place the text as need. Use the **/** and ***** keys (or mouse wheel) to scale the editor window, the **Shift+ /** and **Shift+*** key combinations to change size of symbols in the text, the **Shift+R** key combination to rotate the image by 15 degrees.

To enter the element, press **Return** key or the left mouse button. When entering, the Text is transformed into a set of independent contours and does not exist as a single element any more.

Time&Date

This is the special element that is embedded in the design of structure in order to mark the date and time of an exposure process.

To insert the element, select the **Insert->Time&Date** menu command (or click  button in the toolbar). Further, in insert mode, use the actions and commands described above for the Text element, to fit in the Time&Date element with the desired dimensions in the requisite location of the structure.

Unlike the Text element, when you insert the Time&Date element, it is not transformed into a set of contours, but exists as a single object with some specific properties. For example, overall dimensions of an element are defined approximately and depend on the format of date and time presentation, and continually fluctuate within a small range in accordance with the current time. You need to take this into account when insert this element in the design of a structure. Next, when set a dose for Time&Date element, be aware that the proximity effect correction procedure does not adjust the dose and do not take into account its presence near the corrected elements.

To change format of date and time presentation, and may be, add some comments into string - selects only this Time&Date element and use the **Edit->Modification...** menu command. Detailed description of the presentation formats and examples can be found in the program Help.

Additional attributes of the Time&Date element are format string of date and/or time representation, as well as matrix of coordinate transformation.

Comments

This element, as well as the Text, can be used to add labels and comments in structure design. To insert element, select the **Insert->Comments** menu command and in the opened dialog, type the comment text. String length is limited to 255 characters. Click **OK** button, in insert mode, use the actions and commands described above for the Text element, to place Comments as desired, with the right size in the right place of a structure design.

Unlike the Text element, where the inscription can be formatted into multiple lines, text in the Comments exists as a single line. As the Time&Date element, Comments is not transformed into a set of contours at insertion and exists as a single unit with specific properties. In particular, the comment text can be completely overridden by a special command at exposure in batch mode (for details, see the Help for Batch mode). Replacing of a text may change size of an element. This fact must be taken into account when you insert this element in design of a structure. Next, when set a dose for Comments element, like for Time&Date, be aware that the proximity effect correction procedure does not adjust the dose and do not take into account its presence near the corrected elements.

To change the text of the commentary at the design stage - selects only this element and use the **Edit->Modification...** menu command.

Additional attributes of the Comments element are commentary line, as well as matrix of coordinate transformation.

Structure reference

To optimize design of a structure and reduce size of the data file the duplicate elements may be transposed into a new separate structure in this file, and then, the reference to new structure can be inserted into the original structure into the right place. Thus, the original structure becomes hierarchical comprising a link to another structure in this file. Similar references to new structure (Structure reference elements) can be inserted as many times as need to arbitrary locations of the original structure. Each reference to a structure at insertion can be repeated many times at given steps in the horizontal and vertical directions (so called Array of Structure references), rotated to any angle, and zoomed in or out. In turn, each of inserted structures may include references to other structures from this GDB file, thus, forming the next level of the hierarchy and etc.

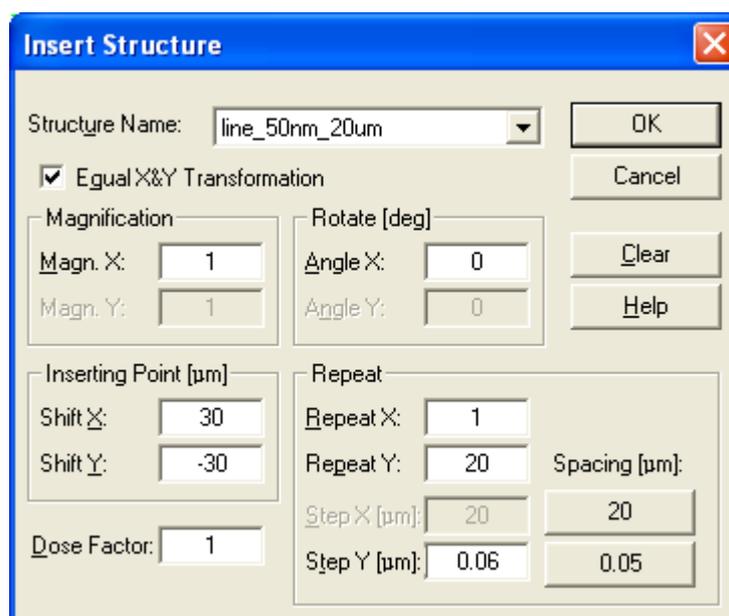


Fig. 7 Insertion of a Structure reference element by using **Insert Structure** dialog

However, recursive looping of references is forbidden, and so, the program is watching for this and doesn't allow to perform such insertion.

In order to insert a Structure reference choose the **Insert->Structure...** menu command and in the opened dialog select a structure to be referenced from the **Structure Name** list. Specify an insertion point as a shift of the structure origin in the **Inserting Point** fields. Set, if necessary, rotation angles in the **Rotate** fields, scale factors in the **Magnification** fields, number of repetitions and steps in the **Repeat** fields, dose change factor for elements of the structure in the **Dose Factor** field and press **OK**.

Structure reference element is drawn by rectangular area bounded by thickened blue contour. The boundary of the area passes through the protruding vertexes of the elements in the inserted structure. Through the center of the element passes the inscription in red, which contains the name of the referenced structure. If structure is referenced as array, then number of repetitions in square brackets is added in the inscription also as you can see on Fig. 8.

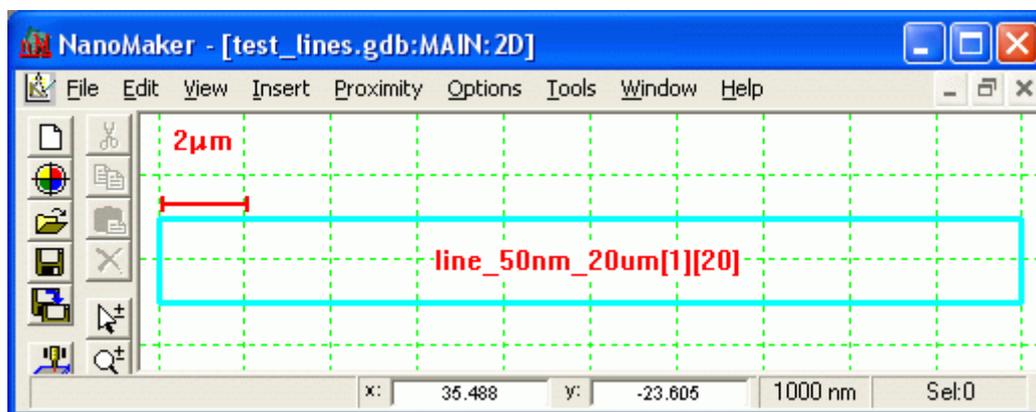


Fig. 8 Array of structure `line_50nm_20um` references in the MAIN structure

A file of one of the supported formats GDB, ELM, GDS, and DXF can be inserted as Structure reference. To insert other file as Structure reference to the current file, choose the **Insert->File...** menu command and, in the **Open** dialog, browse and select the file you want to load. All structures of the selected file will be copied to the current file. The former MAIN structure from the selected file in the current file will be named after its former file. If the selected file doesn't contain MAIN structure, then an empty structure named after its former file will be added to the current file. The new Structure reference element will refer to a structure named after the inserted file.

To display elements of a referenced structure on the first level of the hierarchy, press **1** on keyboard.

The Structure reference element has no such attributes as dose, 3D attribute, layer and always is listed in the 0 layer. Its attributes are: insertion point, rotation angles, zoom factors, number of repetitions and steps as well as dose change factor.

To change attributes of the Structure reference - selects only this element and choose the **Edit-> Modification...** menu command to open the **Modification of Structure Reference** dialog.

A special case of Structure reference insert is the insertion of a file, as was mentioned above. By inserting a file, you are actually creating a reference to structure MAIN of the inserted file (to former structure MAIN, which is copied to current file and renamed after its former file name). After inserting the data from the file, its further presence is not required.

Dose map

NanoMaker allows to design lithographic structures on the basis of information contained in raster images. To perform this task there is the Dose map element. Such element is created on base of image parameters and references to basic structure. The simplest basic structure may contain a single circle, single square or polypoint. At creation of the element a matrix of the basic structure inserts (array of Structure references) is formed, where the number of rows and columns equal to width and height of the image in pixels, respectively. Thus, each pixel in the image corresponds to one of the references to the basic structure. The intensity of a pixel, which is calculated as $(R+G+B)/3$, is used as a multiplication factor in determination of resultant dose for elements from inserted basic structure. By default, the steps in array of Structure references have chosen equal dimensions of the structure, so that the inserts fit tightly to each other as the pixels in the original image. If desired, the steps may be changed. Furthermore, the matrix can be rotated and scaled. GDB file, containing Dose map elements, must be moved together with the images, which are used to design these special elements.

You can create a Dose map element in one of two ways:

- import an image by command **File->Import->**(using **TIFF Image Files (*. TIF)** or **Bitmap Image Files (*. BMP)** templates);
- use the **Insert->Structure with Dose Map...** menu command and insert into current structure an array of references to some structure from this file based on the selected image.

Fig. 9 shows a dialog that opens when you import the image data from the chosen file. In this case the selected file is `splnano_15.bmp`, which will be the basis for a Dose map element. As filling structure the `CIRCLE_(D_1μm)` is selected, which consists of a circle of 1 μm diameter.

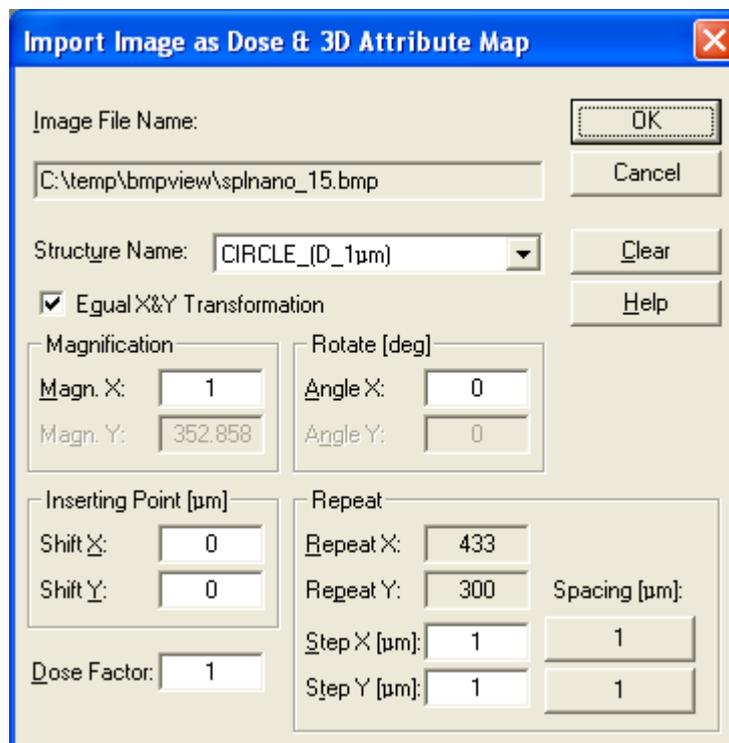


Fig. 9 Creation of a Dose map element on base of `splnano_15.bmp` image file and `CIRCLE_(D_1μm)` structure.

To display elements of an inserted structure on the first level of the hierarchy, press **1** key. To display doses press the **Alt+D** shortcut keys.

Dose map element has the same attributes as the Structure reference and additionally stores file path to linked image.

The resulting structure after insertion of Dose map element at the first level of hierarchy in Dose displaying mode is shown on Fig. 10.

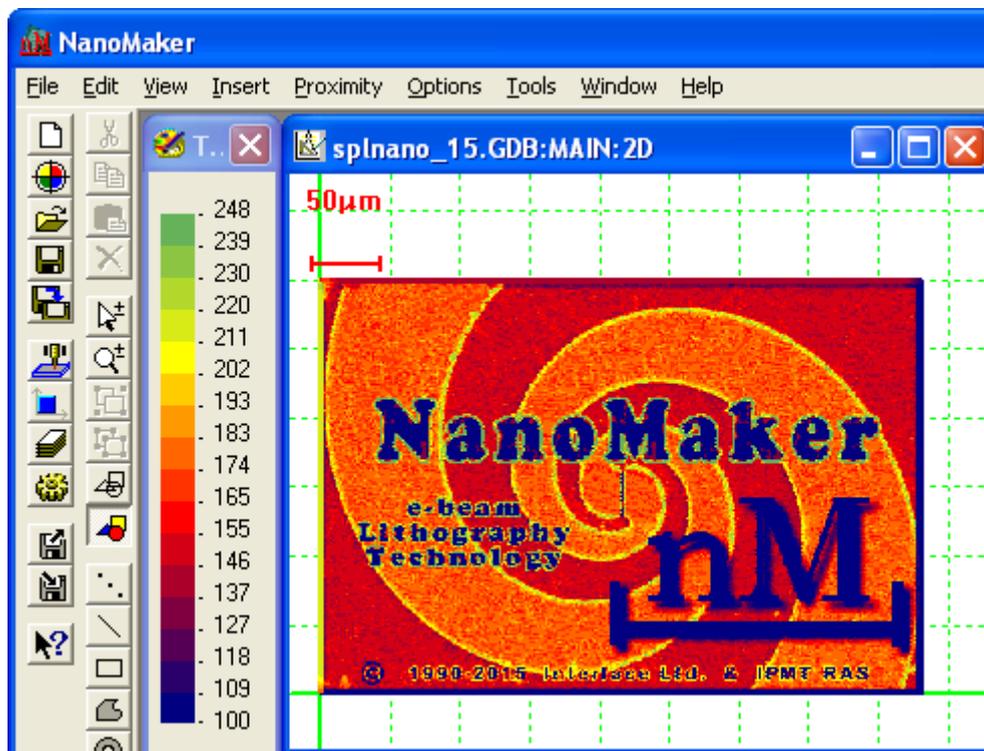


Fig. 10 The resulting structure after insertion of Dose map element

To change Dose map attributes - selects only this element and use the **Edit->Modification...** menu command.

Dose map element depicted in substantially the same manner as array of Structure references. Additionally, in the centre of Dose map, below the name of the referenced structure, also in red, but in a smaller font appended word DoseMap and path to the associated image file.

Reference map

To design and produce rainbow holograms a special element was developed that represents a matrix of references to named structures, which is organized on the basis of information stored in an associated image. This element is the Reference map.

Linked image is stored in a separate file of BMP or TIFF format and has a colour depth of 8 bits per pixel. Image size (number of pixels per row by the number of pixels per column) determines size of the matrix of references (and of the hologram itself). The gray level of each image pixel (a number from 0 to 255) is the key to substitution of the corresponding structure in each nodes of the matrix. This is possible because all referenced structures in Reference map are named according to a certain rule. Their names consist of an optional prefix and a number. The prefix is the same for all structures and can contain any number of characters of the Latin keyboard. The number consists of three digits value from 000 to 255. For example, if prefix is "Toy-", then names of the referenced structures in the file will be as follows: "Toy-000", "Toy-021", "Toy-205" and so forth. Thus, each Reference map can refer to 256 different named structures.

Design of real hologram can contain tens Reference map elements to create different colour, dynamic and other effects.

You can create a Reference map element in one of two ways:

- import design of rainbow hologram prepared by "RainBow" software by choosing the **File->Import->(and then the Elements Files (*.ELM) or GDSII Files (*.GDS;*.CSF) templates)** command;
- use the **Insert->Structure with Reference Map...** command to insert in the structure a matrix of references to structures from a given file. I.e., structures to be referenced must already exist in the file at the time of Reference map creation. It is also necessary to adhere to naming conventions for the structures. If referenced structures do not exist in the file, Reference map will be empty.

To check the result of element creation, open to view the first level of the hierarchy by pressing **1** key.

Reference map element is depicted in much the same way as the array of Structure references - blue rectangle limits the space of inserted structures; inscription in the centre in red colour consisting of name of the referenced structures (a prefix followed by set of symbols <xxx>, symbolizing changing number from 000 to 255), and then added in brackets the number of rows and columns. Additionally, in the centre of Reference map, below the name of the referenced structures, also in red, but in a smaller font appended word RefMap and continue the path to the linked image file.

To display elements of inserted structure on the first level of the hierarchy, press '1' key. To display doses press the **Alt+D** shortcut keys.

Reference map element has the same attributes as the Structure reference and additionally stores file path to linked image and the prefix string.

To change Reference map attributes - selects only this element and use the **Edit->Modification...** menu command.

Transformation of elements

Depending on the editing tasks and on type of element to be edited, there are several transformation methods.

1. Changing of Attributes

In order to change dose, layer (3D attribute, in the case of 3D structures) of elements it is necessary to selected them, and then open the **Change Attributes** dialog by choosing **Edit->Change Attributes...** menu command or pressing hotkey **B**.

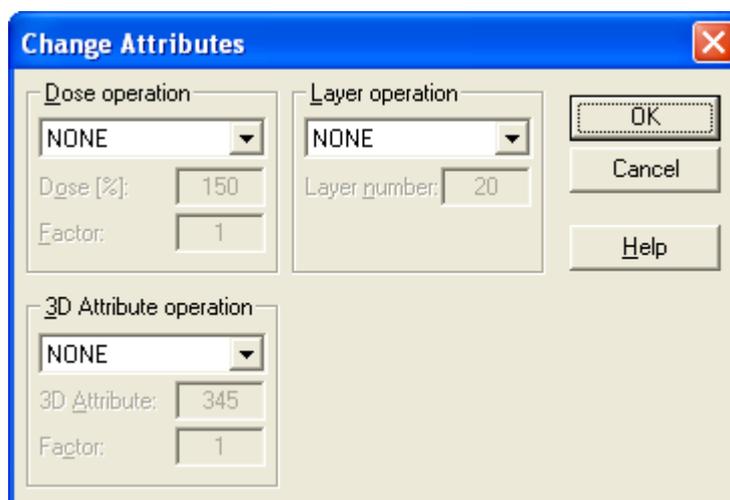


Рис. 11 Changing of element's attributes with the **Change Attributes** dialog

Since dialog allows to edit multiple attributes at the same time, pay attention that selectors of all operations are initially set in **NONE** state (see Fig. 11).

If you want to change dose - set selector of operations with dose in the state SET and enter the new value for dose in the **Dose [%]** field.

If you want to increase/decrease dose in any number of times, set selector of operations with dose in the **SCALE** state and enter the new value for factor in the **Factor** field.

If you want to change layer number - set selector of operations with layers in the SET state and enter a new layer in the **Layer Number** field.

If you want to change 3D attribute - set selector of operations with 3D attribute in the **SET** state and enter the new value for 3D attribute in the **3D attribute** field.

If you want to increase/decrease value of 3D attribute in any number of times, set selector of operations with 3D attribute to the **SCALE** state and enter the new value for factor in the **Factor** field.

Click **OK** button to perform the changing of attributes.

To change additional attributes of not the basic elements (**Time&Date**, **Comments**, **Structure reference**, **Dose map** and **Reference map**) you should selected only one of these elements and then open modification dialog by choosing the **Edit->Modification...** menu item or by pressing 'M' key. A set of attributes available for changing and dialog appearance depend on the type of selected element:

- for Comments element only string of information is available for correction;
- for Time&Date elements output format and string of comments may be adjusted;
- For Structure reference, Dose map and Reference map elements the parameters of transformation matrix, insertion point, coefficient of dose changes, as well as referenced structure (or structures) are available for changing. For Dose map and Reference map you can also change linked image.

2. Changing of geometry

Skew

To change shape of a basic element, first selects only this element, and then choose **Edit->Transform->Skew** menu command (or use the **Ctrl+Shift+S** shortcut keys).

Small brown rectangles will mark the active areas of control points at the vertices of the element, which is subjected to transformation. To change position of a vertex, grab its control point using the left mouse button and drag to a new place. For precise positioning of the control point, use the mouse and keyboard jointly. While holding the left mouse button, use the arrow keys to move the control point one by one cursor step. Use the **Shift** key for cursor jump to the closest node of design grid, the - and + keys for changing the cursor step, / and * keys for scaling of the view.

During the operation, the control points (vertices) can be added and/or removed to form the desired configuration of the element.

To insert a new control point, right-click on one of the existing control points, and then click **Add Vertex** item in the popup menu. New control point is inserted in the middle of the segment connecting the selected point and the adjacent, in a counterclockwise direction.

To remove an existing control point, right-click on it and choose **Delete Vertex** item in the popup menu.

To complete the transformation, double-click the left mouse button or press **Enter**. To cancel the procedure, press **Esc**.

Numeric Transformation

Transformation by changing numeric values of the parameters via dialog is performed for an arbitrary number of selected elements. By using this procedure, the elements can be reproduced many times at a given step in the horizontal and vertical directions, shifted, scaled and rotated by an arbitrary angle with respect to a predetermined point. Furthermore, during coping of elements one can also set the dose increment for the new elements in one of two ways: increasing by a predetermined value or sequential multiplication of a dose by a predetermined coefficient.

To perform the transformation, select elements and then, choosing the **Edit->Transform->Numeric...** menu item or by pressing the **Ctrl+Shift+N** key combination, open the **Numeric Transformation** dialog (see Fig. 12).

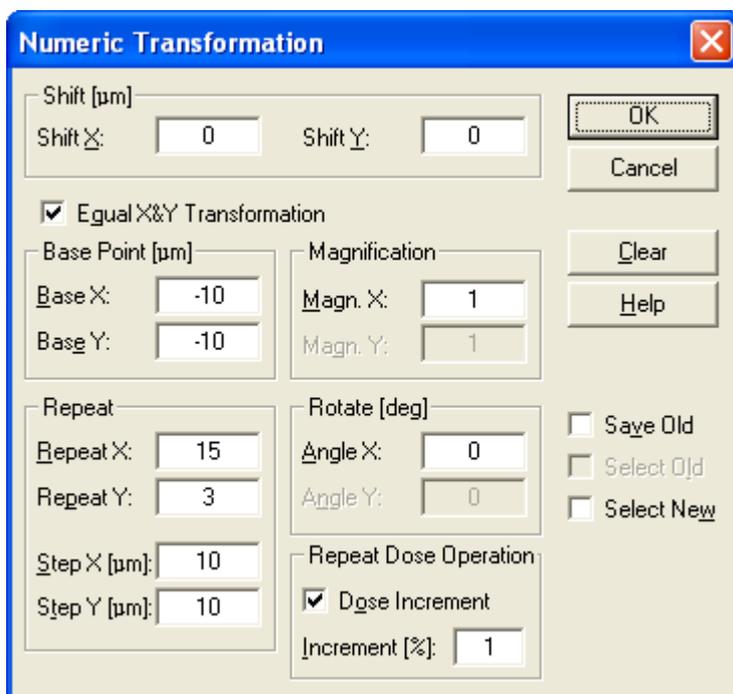


Fig. 12. Transformation of elements by using the **Numeric Transformation** dialog

Click **Clear** button to set transformation parameters to default values.

In order to displace the elements set shift values in the **Shift X** and **Shift Y** field, in microns.

Define a pivot point relative to the origin of the design in the **Base Point** fields. The elements rotate around and scale from this point.

Specify, if necessary, rotation angles in the **Rotate** fields, scaling coefficients in the **Magnification** fields, number of repeats and steps in fields of **Repeat** group and/or coefficient of scaling or increment for a dose in the fields of **Repeat Dose Operation** group.

Check the **Save Old** control to preserve the original elements in addition to newly created elements at transformation.

Check the **Select Old** control to leave the original elements selected after transformation.

Check the **Select New** control to select transformed elements after procedure.

Press **OK** to close the dialog box and perform the transformation.

Move&Rotate

In order to move and/or rotate elements on any distance or angle, select the elements and choose the **Edit->Transform->Move&Rotate** menu command or use the **Ctrl+Shift+M** shortcut keys.

Immediately after this transformation mode is activated: the mouse pointer is captured in the window, special cursor is appeared, and information panel is opened in the upper right corner of the window.

When mouse pointer is over the selection within an imaginary rectangular area that outlines the outstanding vertexes, the cursor takes the form of a pointer with a crosshair . If mouse pointer is outside an imaginary rectangular area, the cursor takes the form of a pointer with an open circle , symbolizing the rotation operation.

To move the elements to desired place of the structure, place cursor inside the imaginary rectangular area, grab them by pressing the left mouse button and holding it, drag to the right place. When moving, the elements images are drawn in dashed lines. The geometric center of the images (center of the circumscribed rectangle) is indicated by dashed crosshair.

If you want to rotate the elements, place cursor out of an imaginary rectangular area, grab them by pressing the left mouse button and holding it, move cursor along big arc, which outlines the elements, as long as the images will not receive the desired position.

Before dragging, move mouse pointer close to geometric center of the image at a distance less than half the cursor step. Now, when you press the left mouse button, the pointer will jump to the position of the geometric center. And thus, at the further dragging, it is easier to control position of the image. For more convenience and accuracy, use the arrow keys to move the image with cursor steps. If necessary, use the - and + keys to change the cursor step, as well as / and * keys (or mouse wheel) for scaling.

To place the elements in the right place press Enter key or double-click the left mouse button.

To cancel transformation, press the **Esc** key or double-click the right mouse button.

Rotate 180°

In order to rotate element by 180 degrees with respect to its geometrical center, select the element and choose the **Edit->Transform->Rotate 180°** menu command or use the **Ctrl+Shift+8** shortcut keys. If a group of elements are rotated, then rotation will be performed with respect to the total geometric center.

Rotate 90° CW

The command rotates element or group of elements by 90 degrees clockwise relative to the geometric center of the selected objects. To perform this operation, choose the **Edit->Transform->Rotate 90° CW** menu command or use the **Ctrl+Shift+9** shortcut keys.

Rotate 90° CCW

The command rotates element or group of elements by 90 degrees counterclockwise relative to the geometric center of the selected objects. To perform this operation, choose the **Edit->Transform->Rotate 90° CCW** menu command or use the **Ctrl+Shift+7** shortcut keys.

Flip Horizontal

The command flips a selected element or group of elements relative to an imaginary vertical axis passing through the geometric center of the selected objects. To perform this operation, choose the **Edit->Transform-> Flip Horizontal** menu command or use the **Ctrl+Shift+H** shortcut keys.

Flip Vertical

The command flips a selected element or group of elements relative to an imaginary horizontal axis passing through the geometric center of the selected objects. To perform this operation, choose the **Edit->Transform-> Flip Vertical** menu command or use the **Ctrl+Shift+V** keyboard shortcut keys.

3. Transformation of attributes and geometry of elements

Transformation by formula

Dimensions, spatial position and attributes of selected elements can be simultaneously changed by entering the appropriate mathematical expressions in **Transform By Formula** dialog.

In order to perform this transformation, select elements and open the dialog with the **Edit->Transform->By Formula...** menu command or by pressing the **Ctrl+Shift+F** shortcut keys. Further, in the dialog window, enter one or more mathematical equations characterizing conversion of the attributes and/or geometric parameters of all selected elements in accordance with certain rules. These rules are as follows:

- All expressions mostly are assignment operations to variable on the left of equal sign the result of calculations performed on the right side of the expression. For example, the expression might look like:

$coef = 100; d = coef * \log (d);$

The first statement declares a variable *coef*, which is assigned the number 100. In the second expression is evaluated the product obtained by multiplying variable *coef* and logarithm of variable *d*. The result is then assigned to *d*. As will be discussed below, the variable *d* is reserved to denote dose of an element. Thus, as a result of transformation with use of the above expressions, the dose of each of the elements will be redefined in accordance with the expression: $d = 100 * \log (d);$

- At the end of an expression should be semicolon;
- Expressions can be written in a line leaving spaces between them;
- To improve readability, you can insert spaces in expression.
- Mathematical expressions are case insensitive. Therefore, the expressions shown in the example below are equivalent expressions in the first example:

$Coef = 100 ; d = coef * \log (D);$

- Arguments of mathematical functions should be placed in parentheses, as in the example above.
- List of available mathematical functions extensive and listed in Help.
- The following mathematical operators are used in the expressions:
 - + - addition or plus sign;
 - - subtraction or minus sign;
 - * - multiplication;
 - / - division;
 - ^ or ** - exponentiation.
- Expressions can include logic operations and include the following logical operators:

> - greater than
 >= - greater than or equal
 < - less than
 <= - less than or equal
 <> - not equal
 && - and
 || - or
 TRUE - result of logic operation equals to 1
 FALSE - result of logic operation equals to 0

- The following symbols are not allowed in expressions: ~ ` % # @ & \$ { } [] " ' ? | \ !
- The appearance of any of these symbols in expressions will interrupt the transformation with the appropriate message.
- Circular constant $Pi = 3.14159\dots$ is the predefined variable.
- The following variables are reserved in expressions:

D for dose, *A* for 3D attribute, *L* - for layer;

Zx - scaling factor along X axis. Scaling is performed relatively to the geometric center. Center is calculated by the formula: $(Minx + Maxx) / 2$.

Zy - scaling factor along the Y axis. Center is calculated by the formula : $(Miny + Maxy) / 2$.

Rx - angle of pivoting movement around the geometric center with respect to the X axis, in degrees. Center is calculated by the formula: $(Minx + Maxx) / 2$.

Ry - angle of pivoting movement around the geometric center with respect to the Y axis, in degrees. Center is calculated by the formula: $(Miny + Maxy) / 2$.

Sx - shift of an element along the X axis, in μm , *Sy* - shift of an element along the Y axis.

Minx and *Maxx* - most outstanding coordinates of element along the X axis (in μm), which can be used for transformation as initial data.

Miny and *Maxy* - most outstanding coordinates of element along the Y axis (in μm), which can be used for transformation as initial data.

Entered expressions, for easy reuse, can be saved as a text file. To do this, press **Save FRM...** button and in the **Save Formula File** dialog, specify a file name and save it. Text file with formulas has FRM extension. To load previously created formulas, press **Load FRM...** and select the file.

Press **OK** to close the dialog and perform the transformation.

Ungroup

If you need to transform structure insertion (Structure reference, Dose map, Reference map) or Time&Date or Comments to the set of their constituent elements, selects the insertion / Time&Date / Comments and choose the **Edit->Ungroup** menu command (or press **U** hotkey). It may take some time in case of a large number of elements. In this case, a progress bar will appear in the status bar that displays the percentage of completion. It should be noted, this procedure would increase the size of the data file.

Designing with an image in background

Suppose, that on the surface of your substrate is formed some structure or there is some relief, and you want to design new elements that would fit into the existing pattern. In this case, using an image as a background can help you design. To begin the design, you need to take an image of the interested surface and save it in TIFF format (8 bit/pixel). If you acquire a picture with the NanoMaker, then you can essentially simplify the task of calibrating the resulting image.

Acquire image in a calibrated field (Scan Field) that will allow you to store in the tags of TIFF file the real sizes. It is convenient to use the **Microscope** dialog to capture the image. This will allow you to orient interested area and set the center position, which will be the anchor point of the image to the origin in the editor window.

Also, you can use a photo taken with any other device, but before using it in the editor as a background:

- convert it to a TIFF format (8bit/pixel);
- use the **Image Processing** dialog (**Video->Microscope->Processing...**) to set the real scale. For that, using your knowledge about actual size of the image, fulfill the **Rescale** operation, and define center of the image by pressing the **Set Origin** button;
- save the transformed image by pressing the **Save Image** button.

For the beginning open a new GDB file (**File->New Database**) and then load the desired image (**View->Redraw->Background**). Now you can start designing, using the background image as the basis for the newly created elements (see Fig. 13).

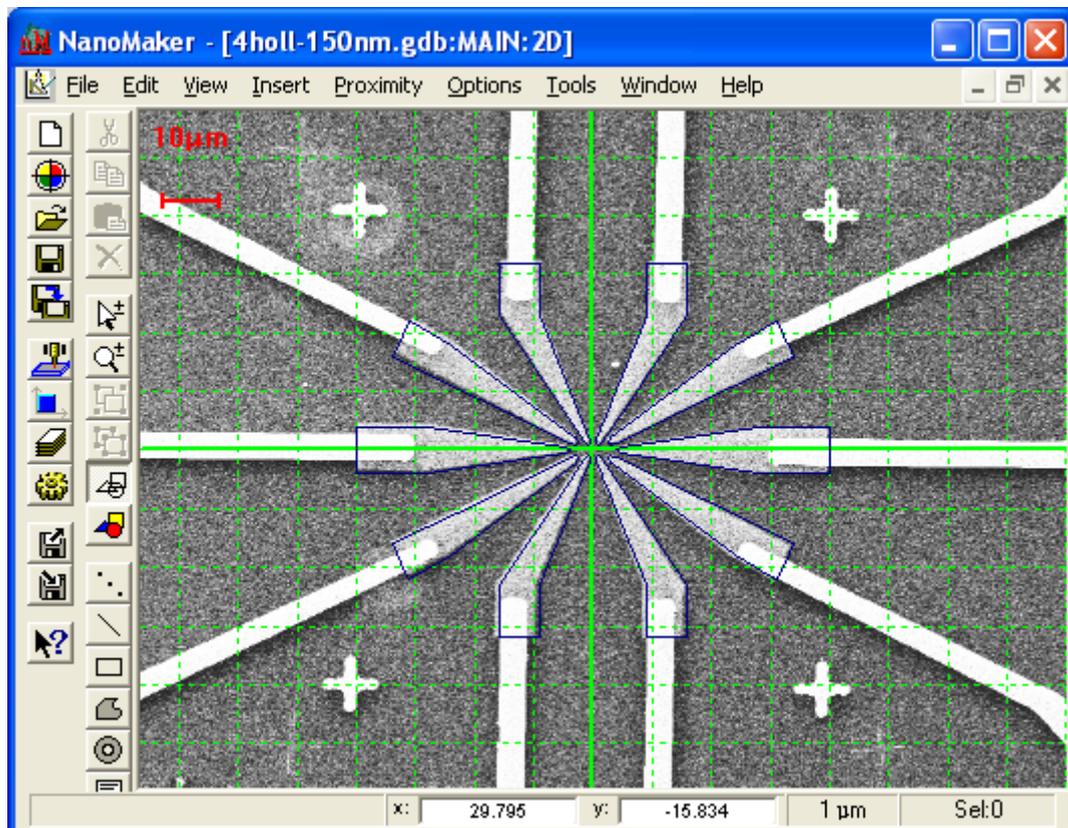


Fig 13. Structure design using background image

Brightness of the background image can be changed for the convenience of the design. To do this, open the **Image** tab of the **View Options** dialog (**Options-**

>**View->Image** tab) and adjust in the **Tone** group the cropping of the brightest pixels in **Auto** or **Manual** modes. After closing the **View Options** dialog, in the editor window press the **Alt+C** shortcut keys to redraw the view.

Saving

Upon completion of the work, the results of patterns design have to be saved in GDB file. If a new structure was designed or you made minimal changes to the existing structure, then select the **File->Save** menu command to save the data in an existing file. If the changes are substantial, with many deleted and newly created elements, then it is recommended to use the **File->Save As** menu command and save the design in a new GDB file, which in some cases will significantly minimize the file size.

DESIGNING LITHOGRAPHIC STRUCTURES

Designing of a dose wedge structure

This section describes an example of designing a dose wedge structure. This structure can be used to determine contrast of a resist (the development rate as a function of the exposure dose) and its sensitivity. Description of the method for determining a contrast is given in the article published at site [1].

To design this structure a few editing techniques are used including transformation of elements by formulas and numerical form transformation (corresponding menu commands are - **Edit->Transform->By Formula** and **Edit->Transform->Numeric**).

For the beginning, create a new GDB file by using **File-> New Database** command. While determining parameters in the **New Data Base File** dialogue do not define database grid and leave the default resolution of 1 nm (see Fig. 1). Press OK button to close the dialogue and open an editor window for MAIN structure.

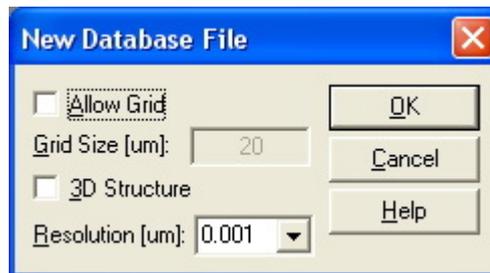


Fig. 1 Set parameters for a new database file in **New Database File** dialogue

Then, open the **Attributes** dialogue by using **Insert->Attributes...** command. Use this dialog to define attributes for the elements that will be created, particularly set dose (**Dose [%]**) equal to 100% (see Fig. 2). Close the dialog.

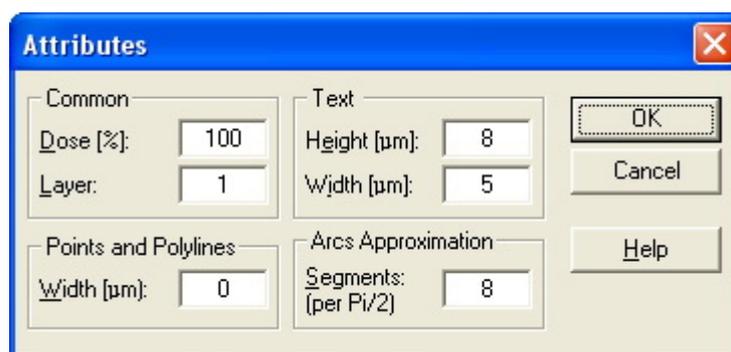


Fig. 2 Define attributes for new elements in **Attributes** dialogue

In just created window for the **Main** structure introduce rectangular element with coordinates of left-bottom vertex – (0, 0) μm and right-top vertex (2, 50) μm , respectively (see Fig. 3).

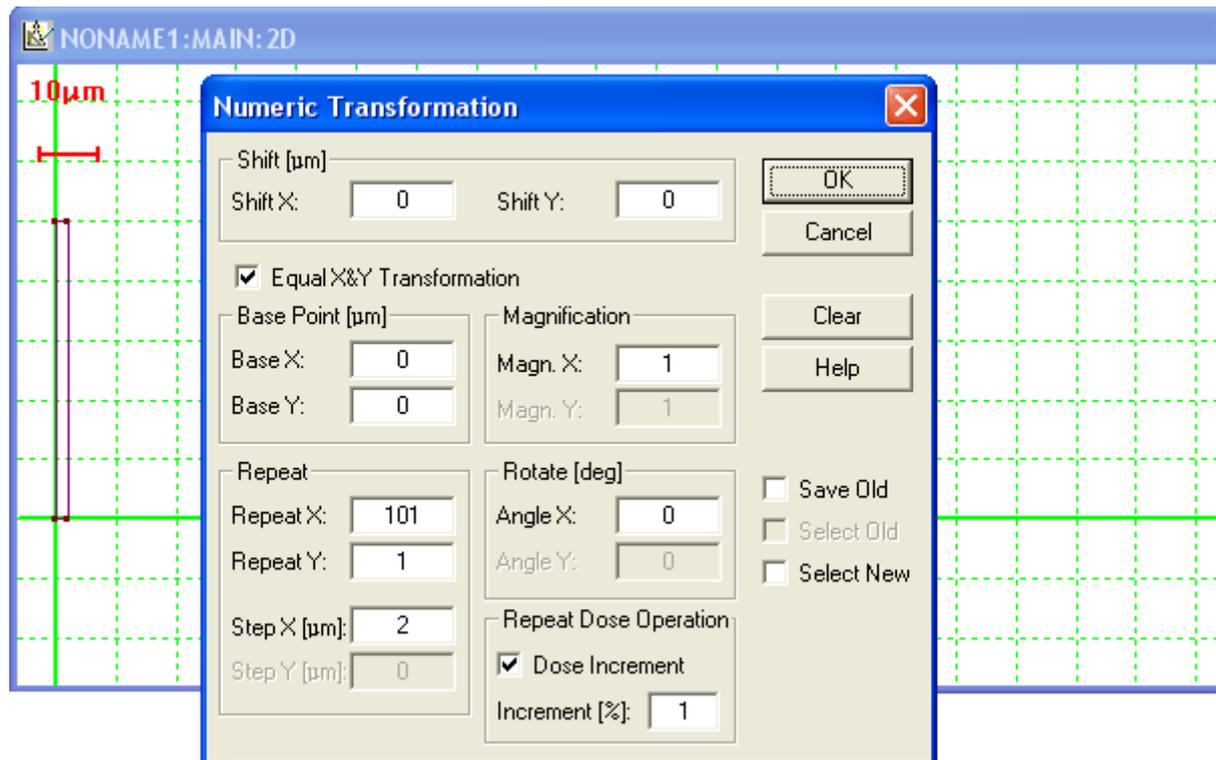


Fig. 3 Parameters for transformation using **Numeric Transformation** dialogue

By numeric transformation, propagate the rectangular element 101 times along the X axis with incrementing dose for each subsequent element by 1%. To do this:

- Select element with **Alt+A** shortcut keys;
- Open the **Numeric Transformation** dialogue by choosing the menu command **Edit->Transform->Numeric...** (or **Ctrl+Shif+N** shortcut keys);
- In the dialogue specify number of repetitions along X axis (**Repeat X**) equal to 101 with steps (**Step X**) equal to 2 μm. Set dose increment (**Dose Increment**) to 1 % (see Fig. 3);
- Press **OK** button, to close the dialog and perform the transformation.

The transformation will create an array of 101 contiguous rectangular elements in which the dose d_0 (Dose attribute) increases linearly from left to right from 100% at the far left to 200% at the far right.

To implement the method for determining contrast in accordance with [1] one need to define such exposure dose distribution in a wedge, that after development, the resist thickness decreases linearly from its left edge to right one. Such nonlinear dose distribution is given by a transformation formula. Since the development rate of the positive resist v is proportional to d^γ , where γ is the resist contrast (according to formula 1 in [1], then transformation of the element's dose according to the formula

$$d = 100 * \left(\frac{d_0}{100} - 1 \right)^{\frac{1}{\gamma}}$$

will create a dose distribution in wedge from 0 to 100%. Here d_0 - initial dose of the element.

And, if a real resist contrast will correspond to the used value γ , then perfectly linear wedge will be formed after development.

To transform dose of rectangular elements by formula:

- Selects all elements in structure by **Alt+A** shortcut keys;
- Open **Transform by Formula** dialogue, by selecting the **Edit->Transform->By Formula...** menu command (or **Ctrl+Shif+F** shortcut keys);

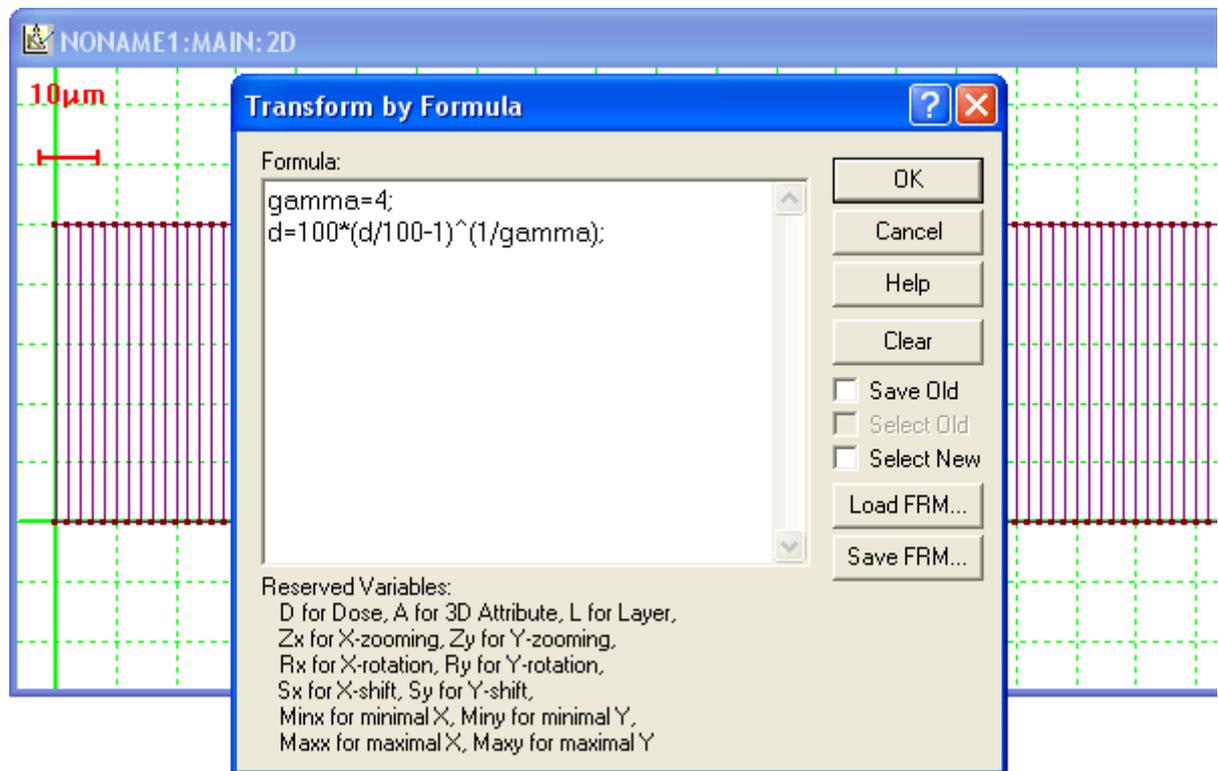


Fig. 4. The transformation formula in **Transform by Formula** dialogue. Selected rectangular elements are seen in the background.

- Enter the following formula in dialogue window: $\gamma = 4; d = 100 * (d/100-1)^{(1/\gamma)}$;, where the supposed value for contrast γ equals to 4 (see Fig. 4);
- Press **OK** to close the dialogue and perform the transformation.

The resulting dose wedge structure design is shown on Fig. 5 (in dose displaying mode).

Do not forget to save the newly created structure.

In the above-mentioned article [1], to determine contrast, the seven dose wedges were designed for seven supposed contrast values. After exposure and development it was found that a linear profile of the wedge is achieved for contrast value equal to 3 (on Fig. 6 the values to the right of the wedges). The constancy of the distance between the interference fringes shows the linearity of the wedge profile.

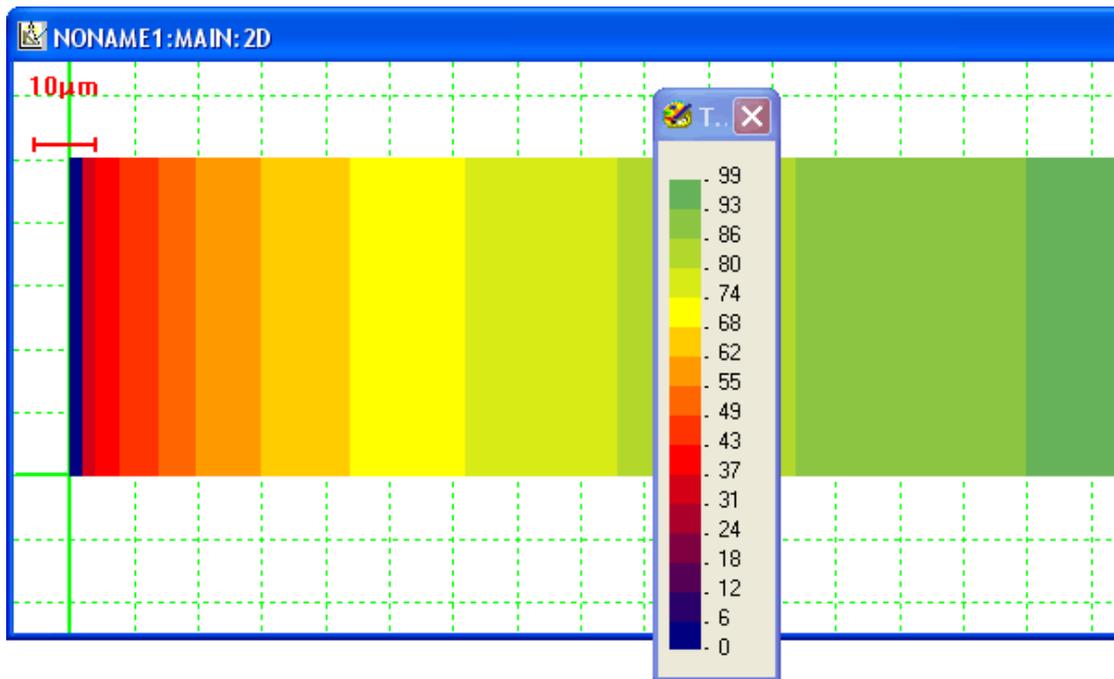


Fig. 5. Resulting dose wedge structure design in dose display mode.

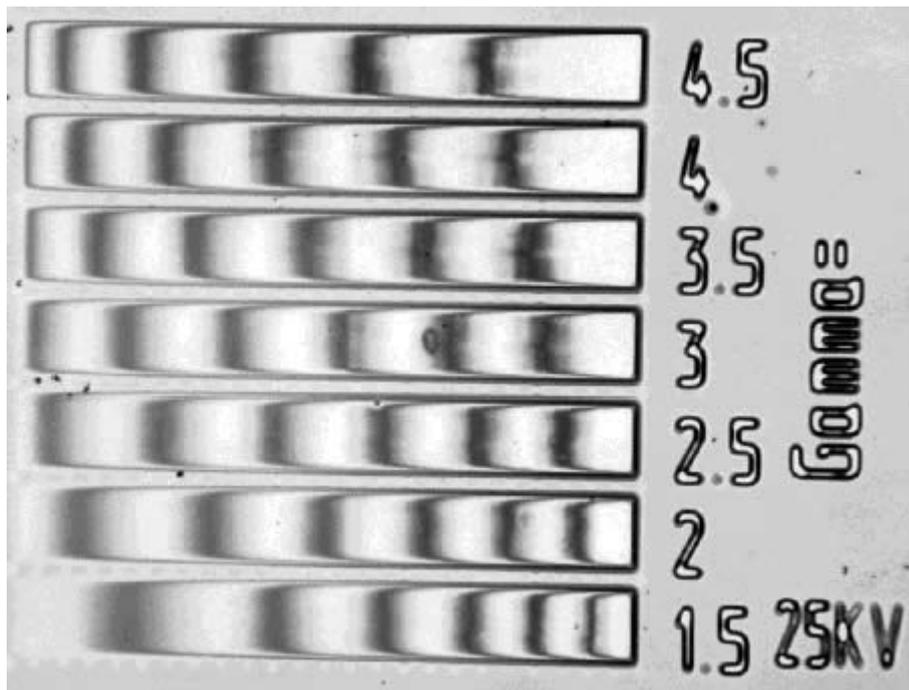


Fig. 6 The photo of produced structure to determine the resist contrast. An equal distance between the interference fringes shows the linearity of the resulting profile. Closest to this is the middle wedge corresponding to contrast value equal to 3.

[1] www.nanomaker.com/nav.php?go=paper8.