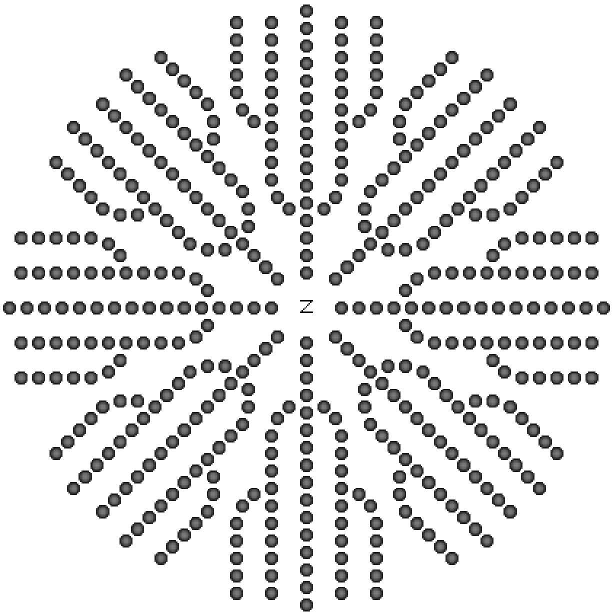

Figure 13. Snowflake-like navigation structure as a system of feature chains converging into an operational zone (designated as z).

are repeated (see pos. 4, 5) making the probe move to the right across the surface as far as one range of the fine manipulator and reach the point C. Finally, the probe moves to the desired point D drawn by the fine manipulator (pos. 6).

Movement errors and nonlinearities are more or less typical of any type of coarse manipulator. Usually their absolute values exceed the corresponding parameters of fine manipulators by orders. A distinctive feature of the suggested method [9, 15] is that the errors and nonlinearities of the coarse manipulator do not affect the allocation of the fine manipulator field within the coarse one. It is shown by analysis that the 'walking' type of positioners [16] best meets the requirements of the described method.

2.5.3. Automatic probe return into an operational zone. Let us consider one of the useful applications of the feature-oriented positioning algorithm: automatic return of the microscope probe into the operational zone [8, 9]. This function is required in SPM experiments where after the surface has been subjected to some kind of local probe action (mechanical indentation, scratching, oxidation, heating, electrical field evaporation, and so on), the sample is dismounted, exposed to a non-local treatment (film growing, etching, annealing, and so on), and mounted back again so as to watch the surface changes at the place affected.

To realize automatic movement to the point of modification, a ramified system of feature chains must be created on the initial sample surface which converges to the operational zone. In figure 13, an example of such a structure is presented. Now, it will suffice to catch any structure feature immediately after the probe approach, then to set up (approximately) an appropriate direction of movement towards the zone and to wait until the probe reaches the terminal chain element autonomously.

As the above is extended, an artificially manufactured substrate surface structure can be suggested to connect several technological zones to each other. Provided a feature size hierarchy exists in the structure, a more precise and quicker positioning can be realized. The latter is especially important when separate atoms or molecules are used as technology objects. Supplementing the described approach by the ability of carrying out accurate probe movements on a large coarse manipulator field (see previous section), a quite reliable way is obtained to transfer the nanolithograph end effector.

2.5.4. Automatic determination of the positional relationship between the probes in multiprobe instruments. With a real nanotechnology process, it is reasonable to apply an SPM lithograph equipped with probes of two types: analytical and technological ones. Analytical probes are intended for measurements and for check-ups while technological probes are used for surface modifications. The discrimination is necessary because the probe tip usually undergoes modifications in the course of a nanolithography process such as changes in radius, form, and physicochemical properties. Each of those types may be further specialized, e.g., one analytical probe serves as topography measurement tool and another for spectroscopy; one technological probe is used for local influence by electric field while another for indentation, etc.

The suggested feature-oriented technique provides for connecting the probes, i.e., accurately determining their mutual location as well as applying all kinds of probes to the same objects thus implementing a sequence of various technological operations with different tools. Automatic probe connection is also necessary in highly productive multiprobe microscopes for correctly assembling the whole image out of fragments obtained simultaneously while surface scanning with a probe array.

Suppose it is required to connect an analytical probe to a technological probe. By scanning with those two probes a certain surface area located within the reach of both probes, surface images are obtained and then subjected to recognition. After that, it is possible to determine (roughly) the shift value in the coordinate systems of the probes by revealing a surface feature on the image scanned with the technological probe and detecting the same feature on the image scanned with the analytical probe. Finally, in order to increase the precision of the measurement by eliminating the influence of drift and noise, a set number of skipping cycles of the probes should be carried out (here, instead of one probe and a pair of features we have one feature and a pair of probes).

The probes can be connected in a chain by moving from one probe to another probe adjacent to the first one, each time using a new feature within the overlap area of their scan fields. Otherwise, the probes can also be connected using the same feature by 'passing' that feature over from one pair of adjacent probes to another pair by means of the coarse positioner followed by ceaselessly repeated probe attachment (see section 2.5.2). Besides connection, the last trick provides for consecutively applying any number of analytical and technological probes to any surface feature and any point of that feature neighbourhood.

3. Experimental results

One of the problems that arose when practically realizing the real mode of the FOS concerned instabilities while scanning