

## Lateral Calibration of AFM at 100-nm Scale

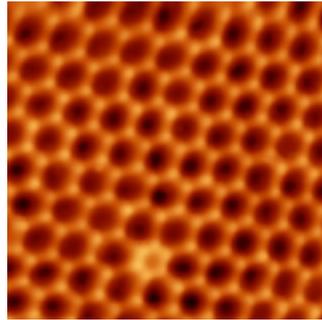


Fig.1. Tapping mode AFM image of Scalped Aluminium Grating SAG-102. Scan size 900x900 nm. One can see difference in X and Y calibration, creep is also visualized in the upper half of the image. Image courtesy of V. Dremov, ISPP RAS.

Scalped Aluminium Gratings (SAG) are high-precision hexagonal surface structures that can be used as AFM reference and calibration standards in XY plane. Unlike expensive submicron calibration gratings manufactured by lithography methods, SAG has repeatable and reproducible self-organized ordered structure with periodicity determined by the conditions of a simple electrochemical processing. There are two options for the pitch of SAG that provide the formation of large honeycomb domains<sup>1,2</sup>; the average periodicity within the domains is  $102.5 \pm 0.5$  nm (SAG-102) or  $65.0 \pm 0.3$  nm (SAG-65), which is statistically derived over large areas of a number of domains.

## Tip Quality Check

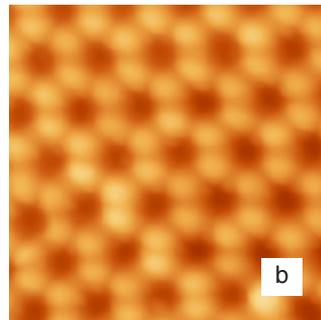
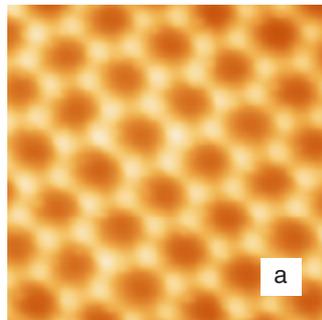


Fig.2. AFM images of SAG-102 made using a tip with 10-nm (a) and 15-nm (b) radius. Each scan size 500x500 nm. Images courtesy of V. Dremov, ISPP RAS

Scalped Aluminium Grating (SAG) can be used as an express method of AFM tip quality check<sup>3</sup>. The hexagonal pattern of SAG consists of concaves and spikes, each concave is surrounded by six spikes. The shape of the spikes can be approximated by triangular pyramids with a height of about 30 nm and an apex radius of about 5 nm. Though the in-plane orientation of the pyramids may be different, no distinguishable difference in height or apex radius of the Al spikes situated on various defect-free domains can be observed<sup>2</sup>. Because of the extremely sharp apexes of the pyramids, their experimentally observed radii on AFM scans exhibit the sharpness of the AFM tip.

Tapping mode is preferable when doing AFM tests to avoid damage to the tip or the grating.

1. K.S. Napolskii et al. Long-range ordering in anodic alumina films: a microradian X-ray diffraction study. *J. Appl. Cryst.*, 2010, v. 43, pp. 531–538.
2. K.S. Napolskii et al. Origin of long-range orientational pore ordering in anodic films on aluminium. *J. Mater. Chem.*, 2012, v. 22, pp. 11922–11926.
3. V. Dremov et al. Simple and reliable method of conductive SPM probe fabrication using carbon nanotubes. arXiv:1406.5117 [cond-mat.mes-hall].

## Scalloped Aluminium Grating

Scalloped Aluminium Grating (SAG) is a hexagonal structure formed by electrochemical processing of high-purity Al. Two-dimensional hexagonal packaging can be observed within surface domains containing 1500 concaves in average (see Fig. 3). There are two options for the pitch of the grating, each providing accuracy (HWHM of interconcave distance) of about 6 nm (see Table 1).

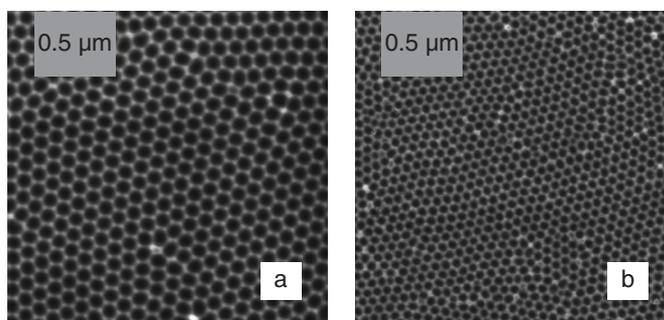


Fig.3. SEM image of SAG-102 (a) and SAG-65 (b) presenting a number of domains with hexagonal packaging of concaves. Images courtesy of I.V. Roslyakov and K.S. Napolskii, MSU.

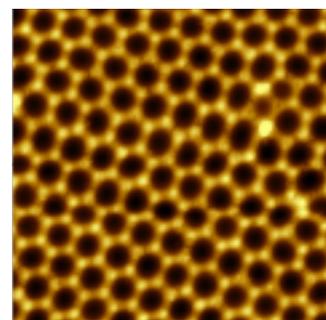


Fig.4. Application example of SAG-102 for acoustic AFM. Scan size 1x1 µm, height 45 nm. Image courtesy of A. Temiriazhev, IRE RAS.

Table 1. Structural parameters of Scalloped Aluminium Gratings.

	SAG-102	SAG-65
Pitch average	102.5	65.0
Accuracy of the pitch average*	0.5 nm	0.3 nm
HWHM of pitch distribution	6.5 nm	6 nm
Average profile height	38 nm	24 nm
Domain structure	Polydomain	
Domain size**	4 µm	2.4 µm
Pattern	Dense hexagonal package within a single domain	
Material	Aluminium	
Substrate	Al dice 7 mm diameter	
Active area	4 mm diameter	

\* Pitch accuracy is specified as the standard deviation of the average value obtained from statistical analysis of SEM images. More than  $10^5$  concaves are analyzed.

\*\* Weighted mean value over more than 500 domains is given.

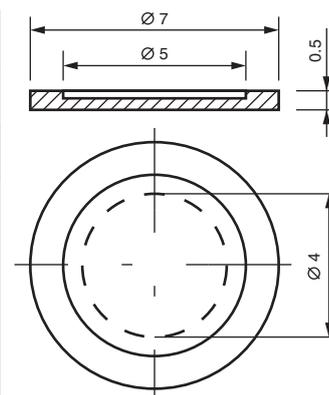


Fig.5. Schematic drawing of SAG active area etched in an Al dice.

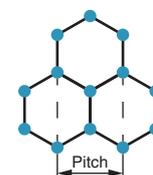


Fig.6. Hexagonal lattice pitch

SAG are non-traceable samples provided with manufacturer's statement for the hexagonal pitch, which is derived from the batch measurements. The pitch can be confirmed by measurements on traceable AFM, SEM, Auger or FIB equipment.

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