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DATE	24 March 2024
TO	Winston Potgieter, Phone: 210-286-2975, Email: axisdj@world-net.net
FROM	Charles R. Anderson, Ph.D.
SUBJ	Analysis of MS International, Inc. Cementino Gray Matte Porcelain Floor Tile Samples Described as Good (Lot 230710) and Bad (Lot 230709) using 3D Optical Microscopy, Profilometry, and Laser-Induced Breakdown Spectroscopy (LIBS)

Summary

The principal results of the optical microscopy, surface profilometry, and LIBS analysis of the MSI Cementino Gray Matte Porcelain Floor Tiles described by the home owner as Good and Bad are:

- The Good floor tile is more reflective. The Bad floor tile scatters light more. This causes them to appear differently.
- The composition of the glazes of the Good and Bad tiles appear to be very similar.
- The transluscent glaze particles were spread more evenly over the Good tile than over the Bad tile prior to partially melting them. The glaze particles on the Bad tile were less completely melted than were those on the Good tile. The colorant layer beneath the glaze is often obscured by those areas of deeper glaze on the Bad floor tile. This adds to the different appearance of the Bad floor tile compared to the Good floor tile.
- The surface roughness of the Bad floor tile is much greater than that of the Good floor tile. This was demonstrated by six measurements on each tile of surface roughness parameters. This difference in surface roughness is a major cause of the difference in light reflectivity. The increased surface roughness of the Bad floor tile will cause it to feel different when walked upon barefoot. It will also make it harder to clean.
- These differences show a lack of quality control on the part of the tile manufacturer.

If the buyer is shown Good tile, but Bad tile is delivered, then the buyer has a right to feel the victim of a bait and switch. MSI has responded to the homeowner by email on 8 March 2024 from Bhavesh Gandhi with a claim that they are not responsible for differences between different lots of tiles. Future buyers need to understand that MSI embraces low quality control standards.

Samples and Background

We received MSI Cementino Gray Matte Porcelain floor tile samples on 23 January 2024 from the homeowner so we could determine the differences in the tile samples with optical microscopy, surface profiling and roughness measurements, and Laser-Induced Breakdown Spectroscopy (LIBS) for elemental analysis. We received samples labeled Good (Lot 230710) and Bad (Lot 230709) by the homeowner. Judging by the lot numbers, the Bad tiles were made in the lot just prior to the good tile lot, so it is unlikely that these lots were manufactured with a long interval of time between them. The homeowner believed the Good tile lot looked better and cleaned more easily than did the Bad tile lot. These samples are shown in Figure 1.

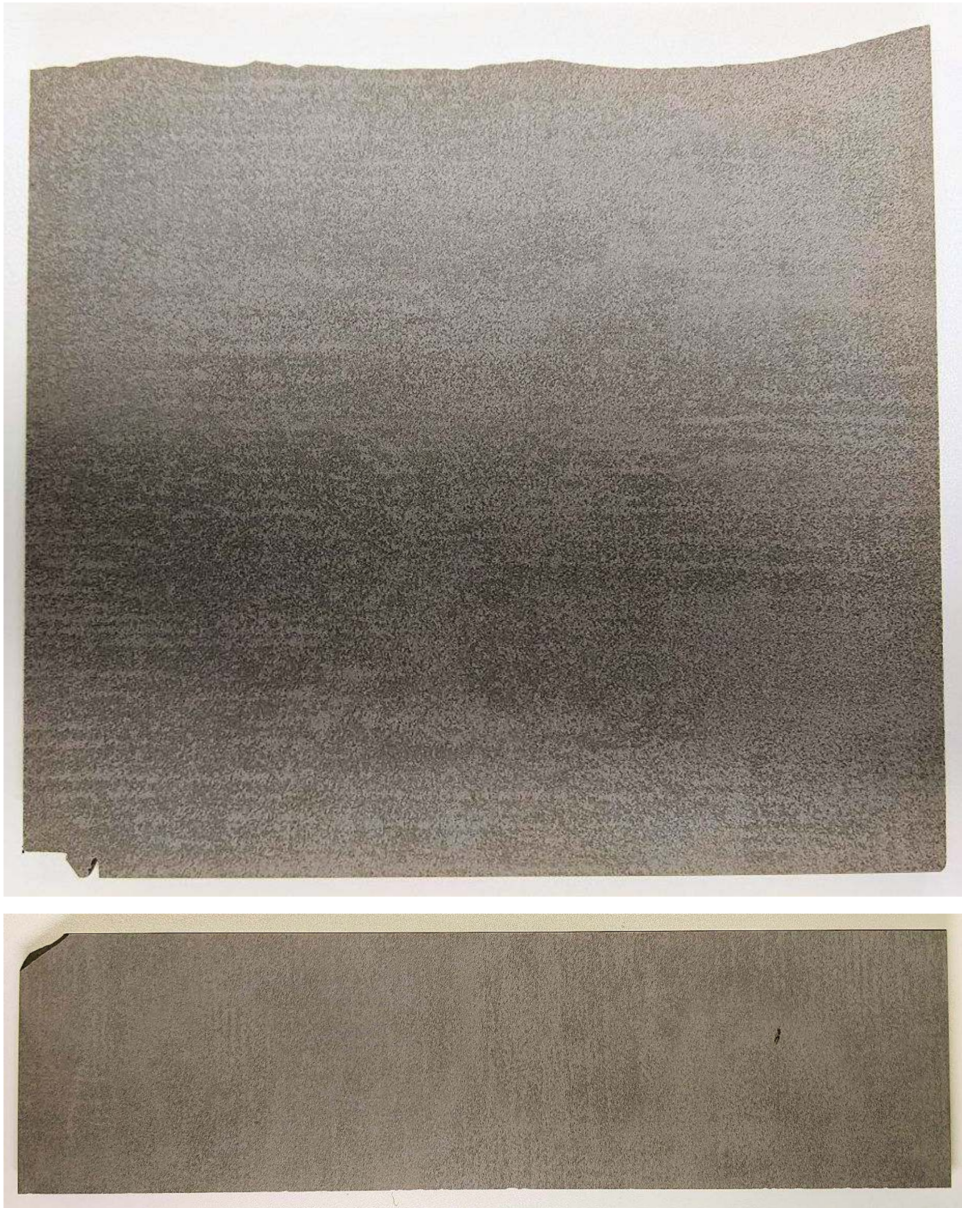


Figure 1. The Bad tile is shown above and the Good tile is shown below.

Optical Microscopy and LIBS Analysis

The samples were examined with a Keyence VHX-7000N Digital Optical Microscope, equipped with an EA-300 Laser-Induced Breakdown Spectroscopy (LIBS) unit.

This digital microscope has lenses providing zoom magnification from 20 to 2000 times with a 4K CMOS image sensor. The sample stage and the lens are motorized. It has the ability to acquire images many distances above the sample and reconstruct an image from the in-focus areas from each of the many images. The resulting images are capable of showing features at higher magnification that one could otherwise only see with an SEM, which has a much greater depth-of-field than does an optical microscope. It can image very large areas by automatically making multiple adjacent images and then stitching them together. The microscope has axial through the lens and ring lighting. It can also provide lighting from various angles. Both 2-dimensional and 3-dimensional distance measurements can be made. The instrument can make particle size analyses and grain-size analyses using advanced automatic image analysis. Surface topography profiles can be acquired. Surface roughness measurements can also be made.

The EA-300 LIBS elemental analyzer focuses pulses from a 355 nm laser beam on a surface. Depending upon the power chosen, a crater of either about 10 or 20 micrometers in diameter is formed in the material surface as ionized material is ejected from the surface. The depth of the crater is commonly about 5 to 7 micrometers. The de-excitation of the resulting plasma emits characteristic radiation in the deep ultraviolet, visible, and near infrared range (185 - 960 nm wavelength). The emitted light is analyzed through the lens by a 1 by 1.8 inch 3.19-megapixel CMOS image sensor. Each pixel is analyzed over a 16-bit intensity range for the RGB color. The elements in the plasma are identified semi-quantitatively from this intensity and color data. Small areas in a larger sample and small particles of contamination can be elementally analyzed for all the elements, including H, Li, Be, B, C, N, O, F, Na, Mg, Al, Si, P, S, and heavier all the way to U.

Linear and surface roughness parameters can be measured for a surface along a line or for a surface area. The 3-dimensionally focused surface can be referenced to a fitted plane for tilt correction or to fitted spheres or cylinders. The measured surface parameters are:

Sa, Arithmetic mean deviation
Sq, Root mean square deviation
Ssk, Skewness
Sku, Kurtosis
Sp, Maximum peak height
Sv, Maximum valley depth
Sz = Sp + Sv

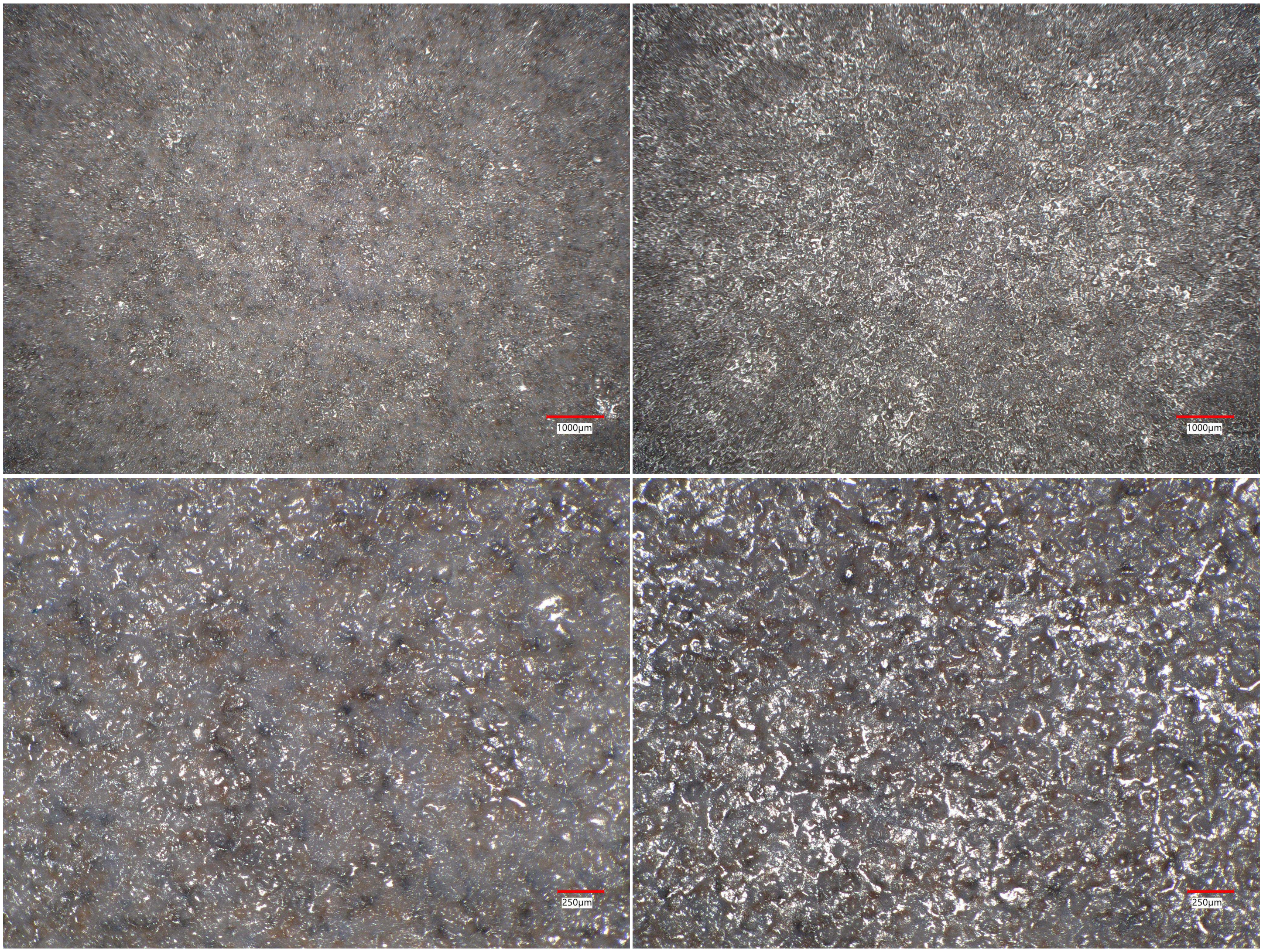


Figure 2. The two images on the left are of the Bad tile sample and those on the right are of the Good tile sample. These images were made with coaxial (through the lens) illumination. The far greater amount of white appearing areas in the right side images shows that the Good tile sample is much more reflective than is the Bad tile sample on the left. Those reflective areas on the left side tend more often to be individually much smaller areas than those on the right side.

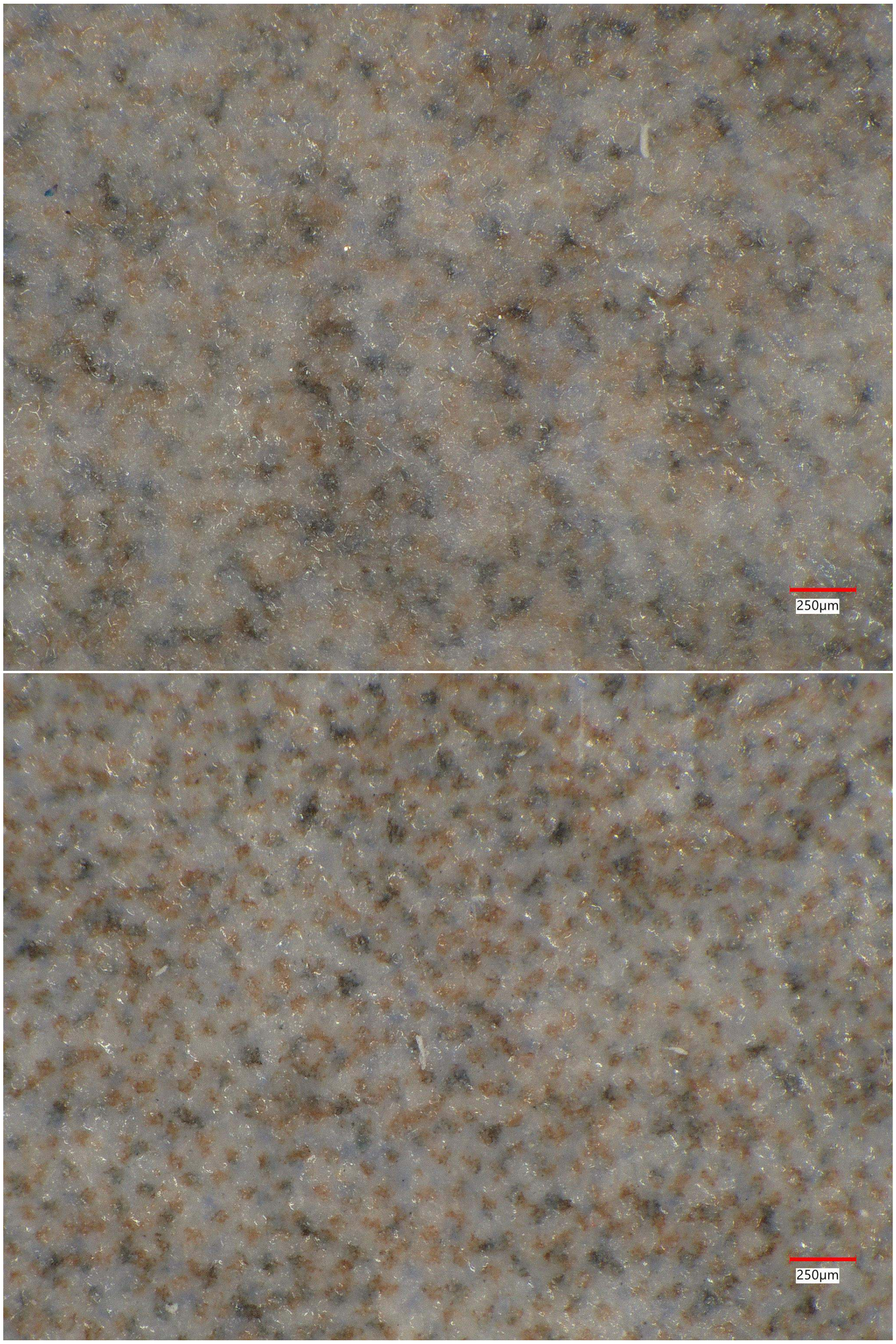


Figure 3. The upper image is of the Bad tile and the lower image is of the Good tile. Both are shown using ring illumination. The translucent glaze on the Good tile appears to be smoother than that on the Bad tile. Notice that the underlying colorant spots are more uniformly seen in the Good tile than in the Bad Tile. This is because the translucent glaze over the colorant is so thick in some areas that its obscures the colorant layer in those thicker glaze areas.

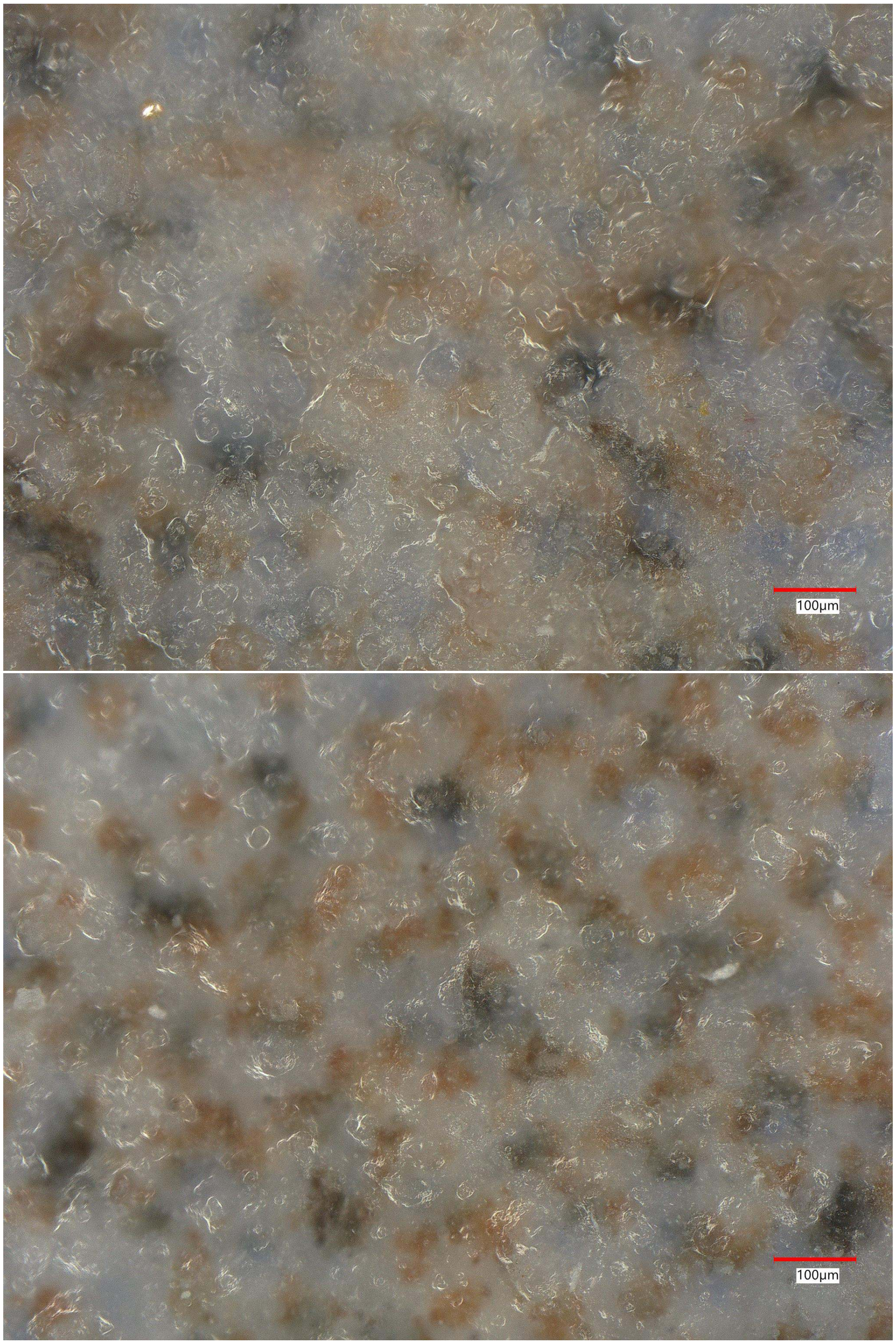
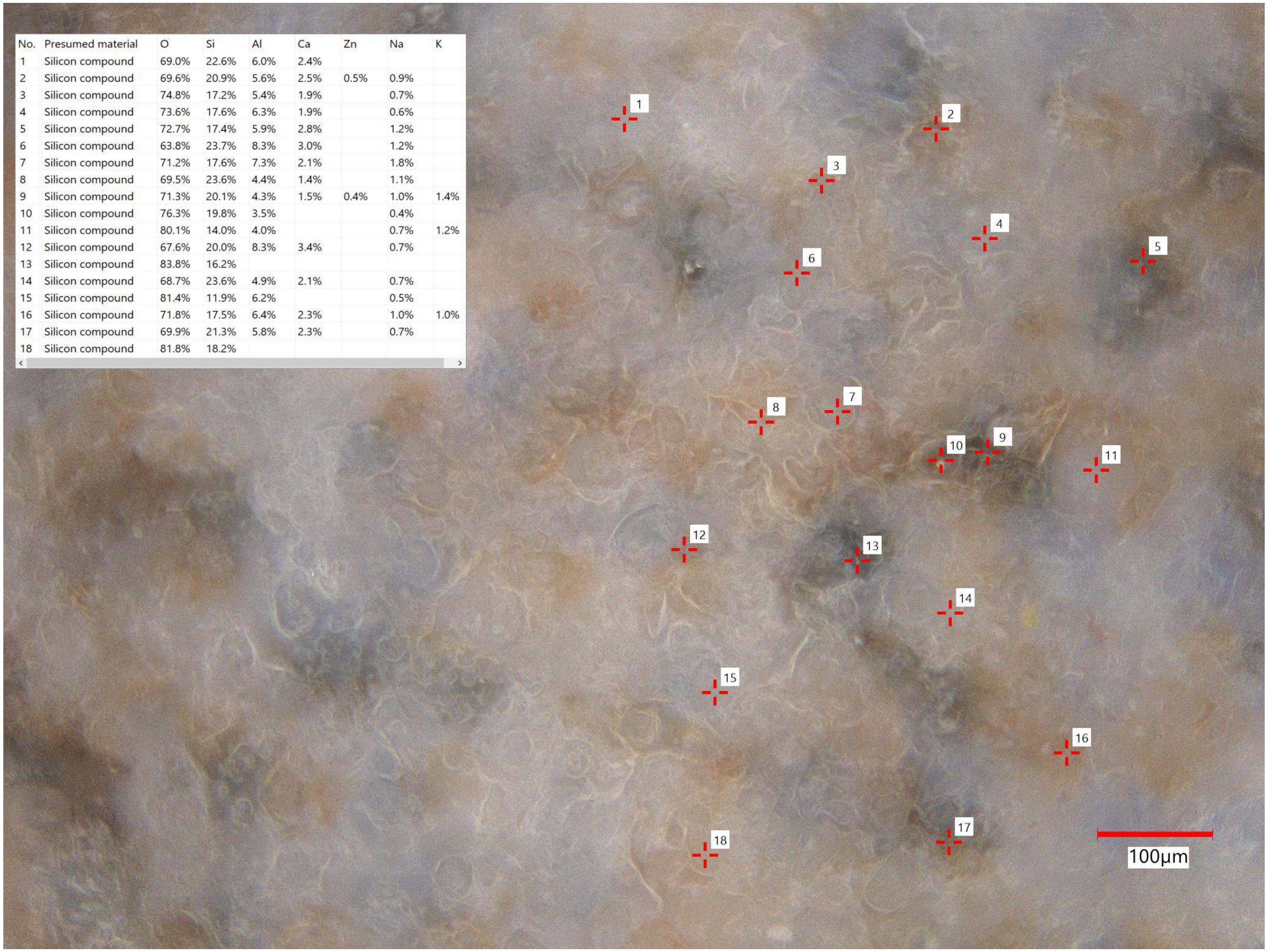
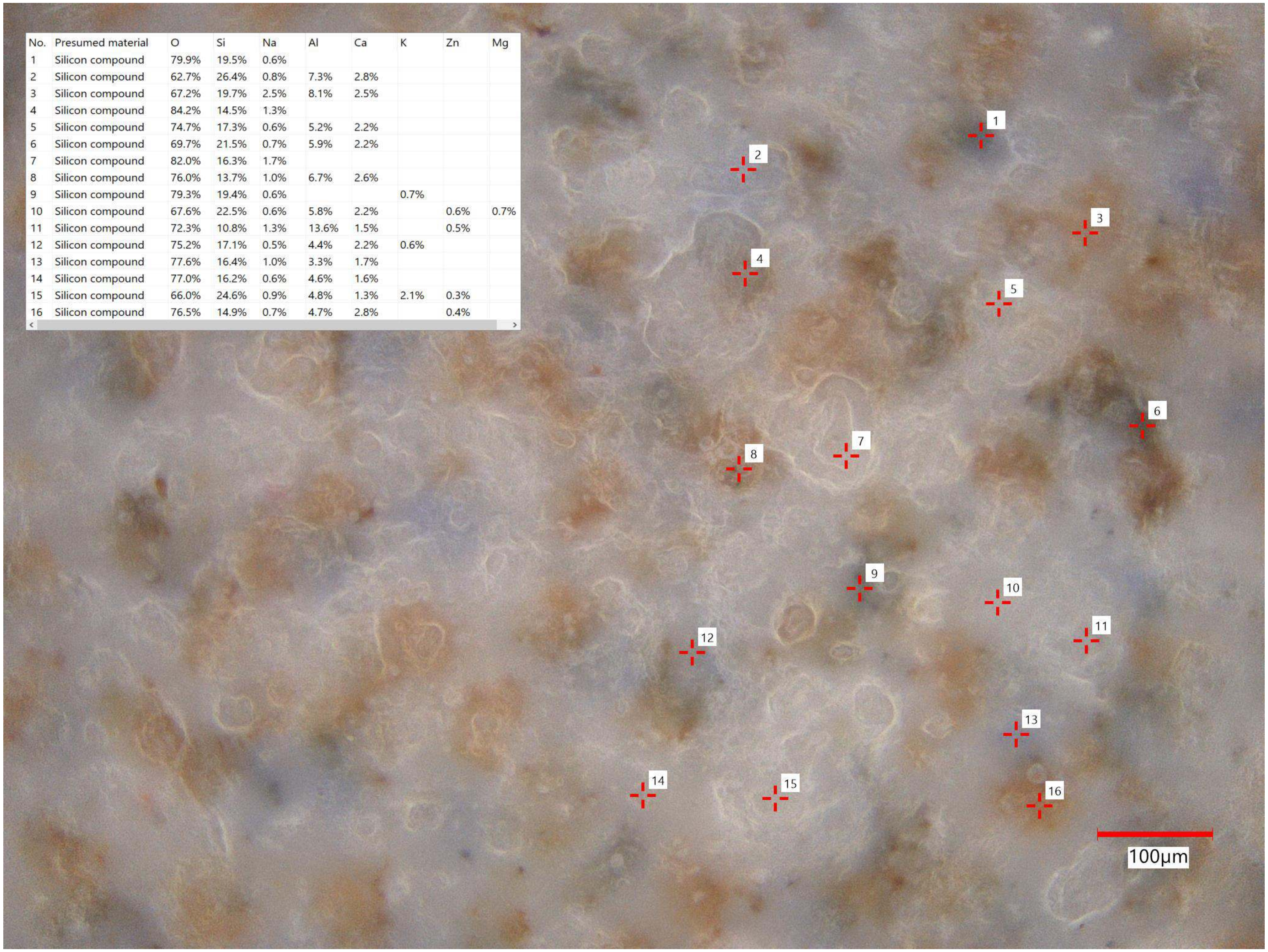


Figure 4. These ring illuminated images of the Bad tile (above) and the Good tile (below) show that the translucent glaze is more evenly applied across the surface of the tile on the Good tile than on the Bad tile. This is indicated by the more uniform visibility of the colorant layer. Note also that there are more featureless areas of the glaze in the Good tile compared to the Bad tile. This indicates a more thorough melting of the glassy powder material that was spread over the surface to form the glaze. The particles before partially melting were spread more uniformly over the Good tile than they were over the Bad tile.



No.	Presumed material	O	Si	Al	Ca	Zn	Na	K
1	Silicon compound	69.0%	22.6%	6.0%	2.4%			
2	Silicon compound	69.6%	20.9%	5.6%	2.5%	0.5%	0.9%	
3	Silicon compound	74.8%	17.2%	5.4%	1.9%		0.7%	
4	Silicon compound	73.6%	17.6%	6.3%	1.9%		0.6%	
5	Silicon compound	72.7%	17.4%	5.9%	2.8%		1.2%	
6	Silicon compound	63.8%	23.7%	8.3%	3.0%		1.2%	
7	Silicon compound	71.2%	17.6%	7.3%	2.1%		1.8%	
8	Silicon compound	69.5%	23.6%	4.4%	1.4%		1.1%	
9	Silicon compound	71.3%	20.1%	4.3%	1.5%	0.4%	1.0%	1.4%
10	Silicon compound	76.3%	19.8%	3.5%			0.4%	
11	Silicon compound	80.1%	14.0%	4.0%			0.7%	1.2%
12	Silicon compound	67.6%	20.0%	8.3%	3.4%		0.7%	
13	Silicon compound	83.8%	16.2%					
14	Silicon compound	68.7%	23.6%	4.9%	2.1%		0.7%	
15	Silicon compound	81.4%	11.9%	6.2%			0.5%	
16	Silicon compound	71.8%	17.5%	6.4%	2.3%		1.0%	1.0%
17	Silicon compound	69.9%	21.3%	5.8%	2.3%		0.7%	
18	Silicon compound	81.8%	18.2%					

Figure 5. The LIBS analysis of 18 sites on the tile surface are given in atomic percents in the embedded table for the Bad tile. The glaze is mostly an aluminosilicate with calcium, sodium, potassium, and zinc at lower concentrations.



No.	Presumed material	O	Si	Na	Al	Ca	K	Zn	Mg
1	Silicon compound	79.9%	19.5%	0.6%					
2	Silicon compound	62.7%	26.4%	0.8%	7.3%	2.8%			
3	Silicon compound	67.2%	19.7%	2.5%	8.1%	2.5%			
4	Silicon compound	84.2%	14.5%	1.3%					
5	Silicon compound	74.7%	17.3%	0.6%	5.2%	2.2%			
6	Silicon compound	69.7%	21.5%	0.7%	5.9%	2.2%			
7	Silicon compound	82.0%	16.3%	1.7%					
8	Silicon compound	76.0%	13.7%	1.0%	6.7%	2.6%			
9	Silicon compound	79.3%	19.4%	0.6%			0.7%		
10	Silicon compound	67.6%	22.5%	0.6%	5.8%	2.2%		0.6%	0.7%
11	Silicon compound	72.3%	10.8%	1.3%	13.6%	1.5%		0.5%	
12	Silicon compound	75.2%	17.1%	0.5%	4.4%	2.2%	0.6%		
13	Silicon compound	77.6%	16.4%	1.0%	3.3%	1.7%			
14	Silicon compound	77.0%	16.2%	0.6%	4.6%	1.6%			
15	Silicon compound	66.0%	24.6%	0.9%	4.8%	1.3%	2.1%	0.3%	
16	Silicon compound	76.5%	14.9%	0.7%	4.7%	2.8%		0.4%	

Figure 6. The LIBS analysis of the Good floor tile sample shows that its glaze elemental composition is essentially the same as that on the Bad floor tile. The glaze composition does not seem to be very different between the Good and the Bad floor tiles. The issues seem to be due to its application and the heating to partially melt the powder particles of the silicates.

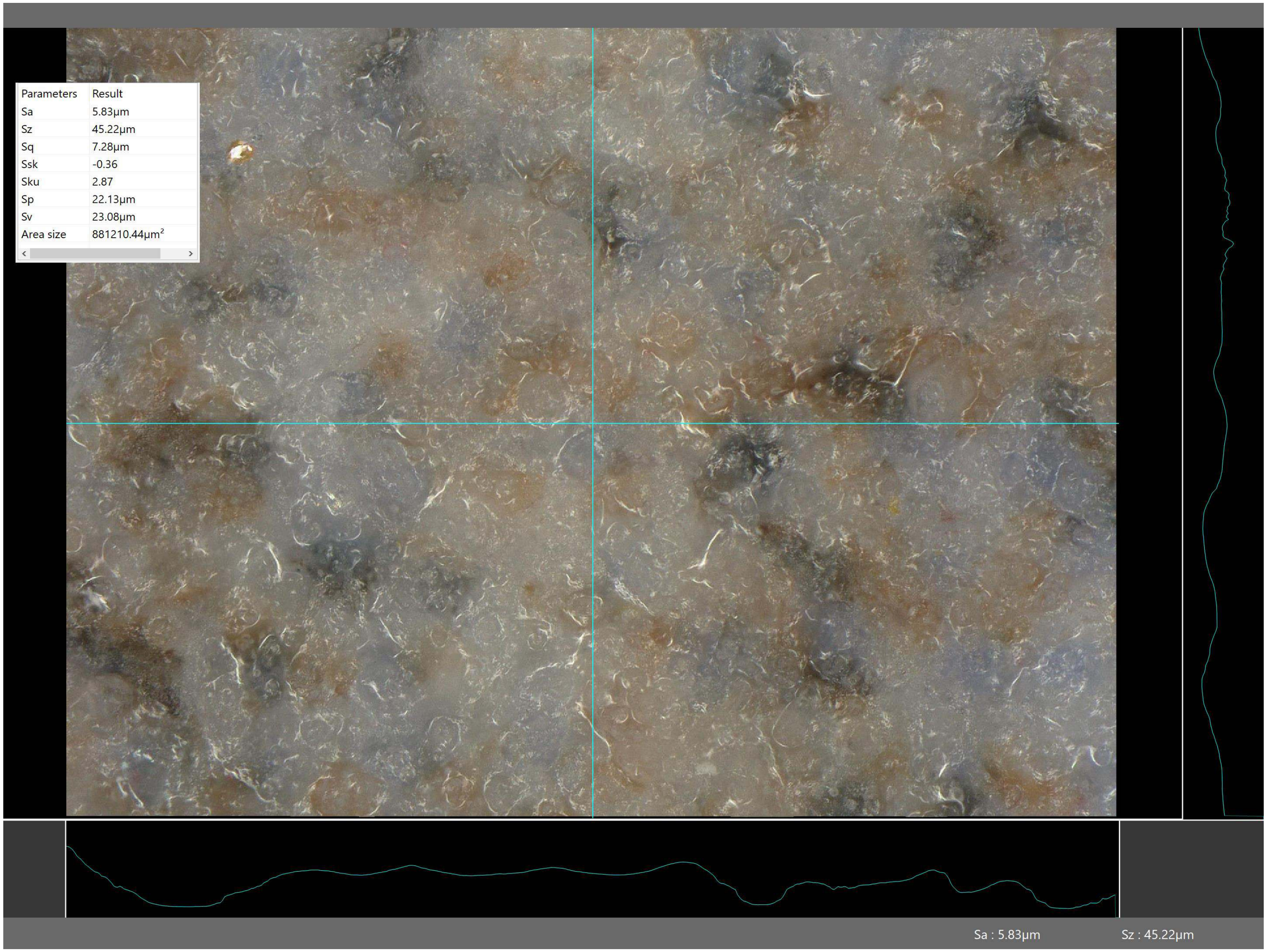


Figure 7. The surface roughness parameters for this area of the Bad tile are shown in the embedded table. The profile along the vertical center line is shown on the right side and the profile along the horizontal cener line is shown at the bottom.

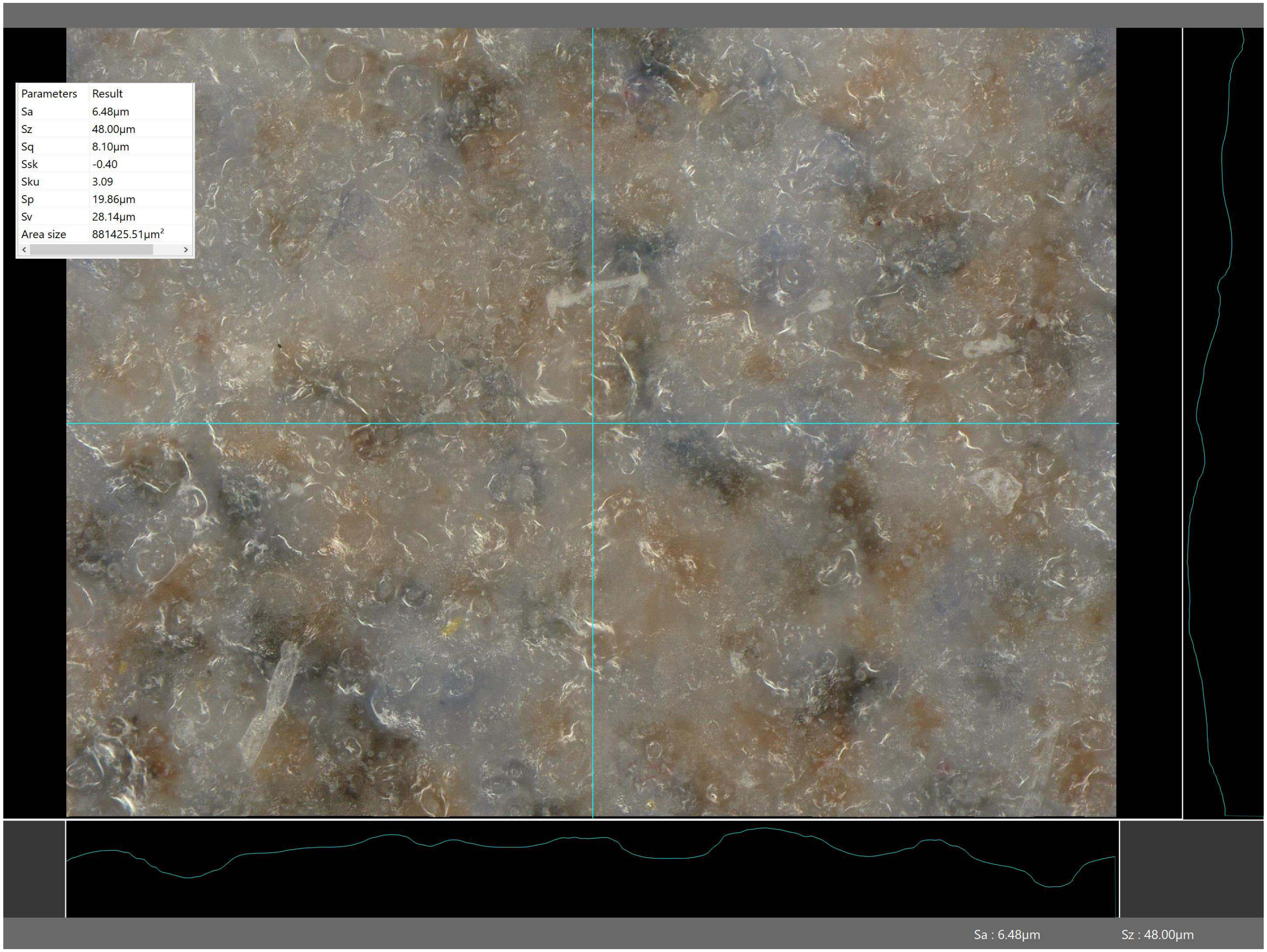


Figure 8. The surface roughness parameters are given in the embedded table for this second area of the Bad floor tile.

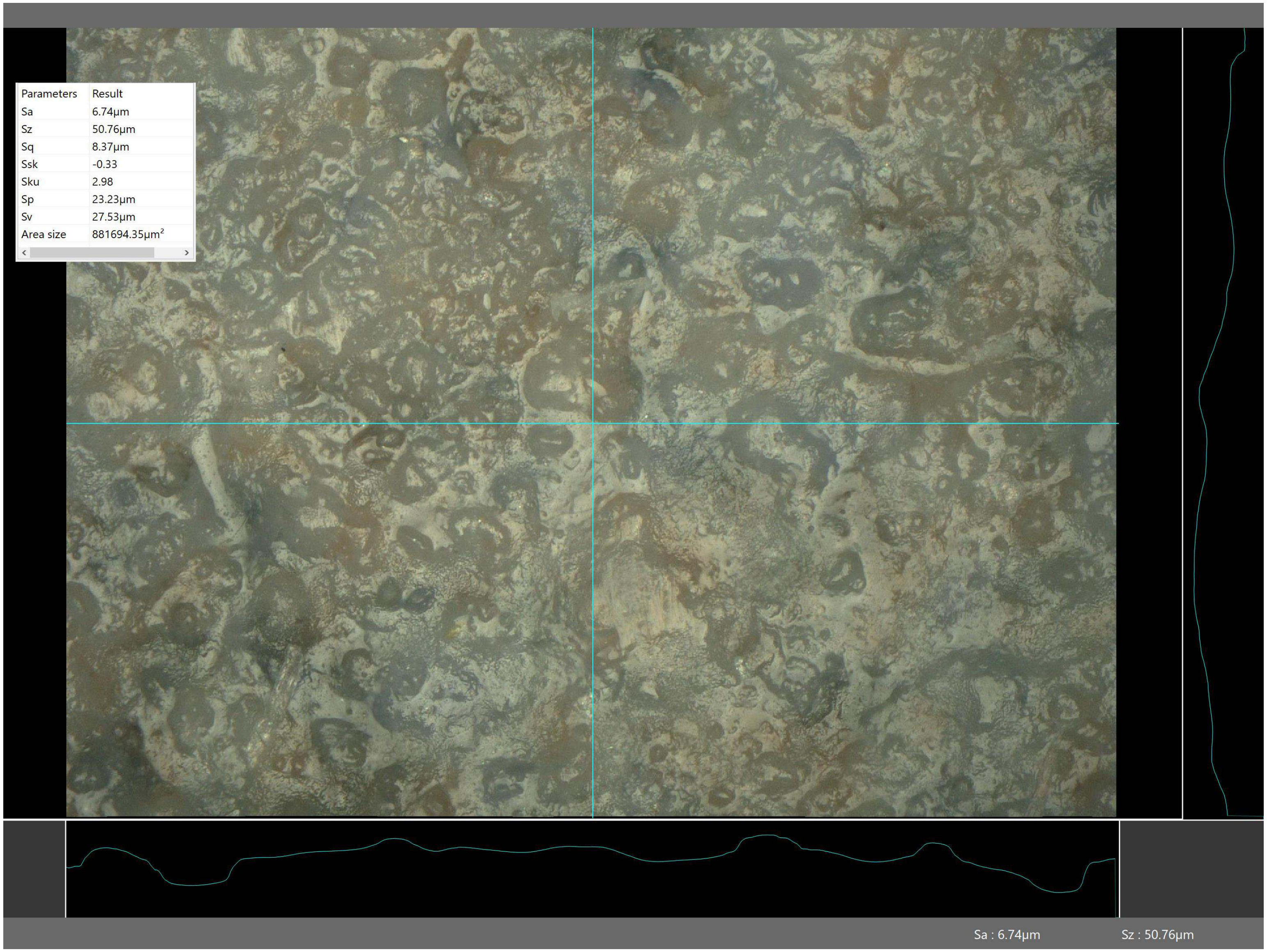


Figure 9. The surface roughness parameters are given for a third area of the Bad floor tile. The illumination is coaxial light, so the reflection off the surface of the glaze is enhanced and the underlying colorants are less visible.

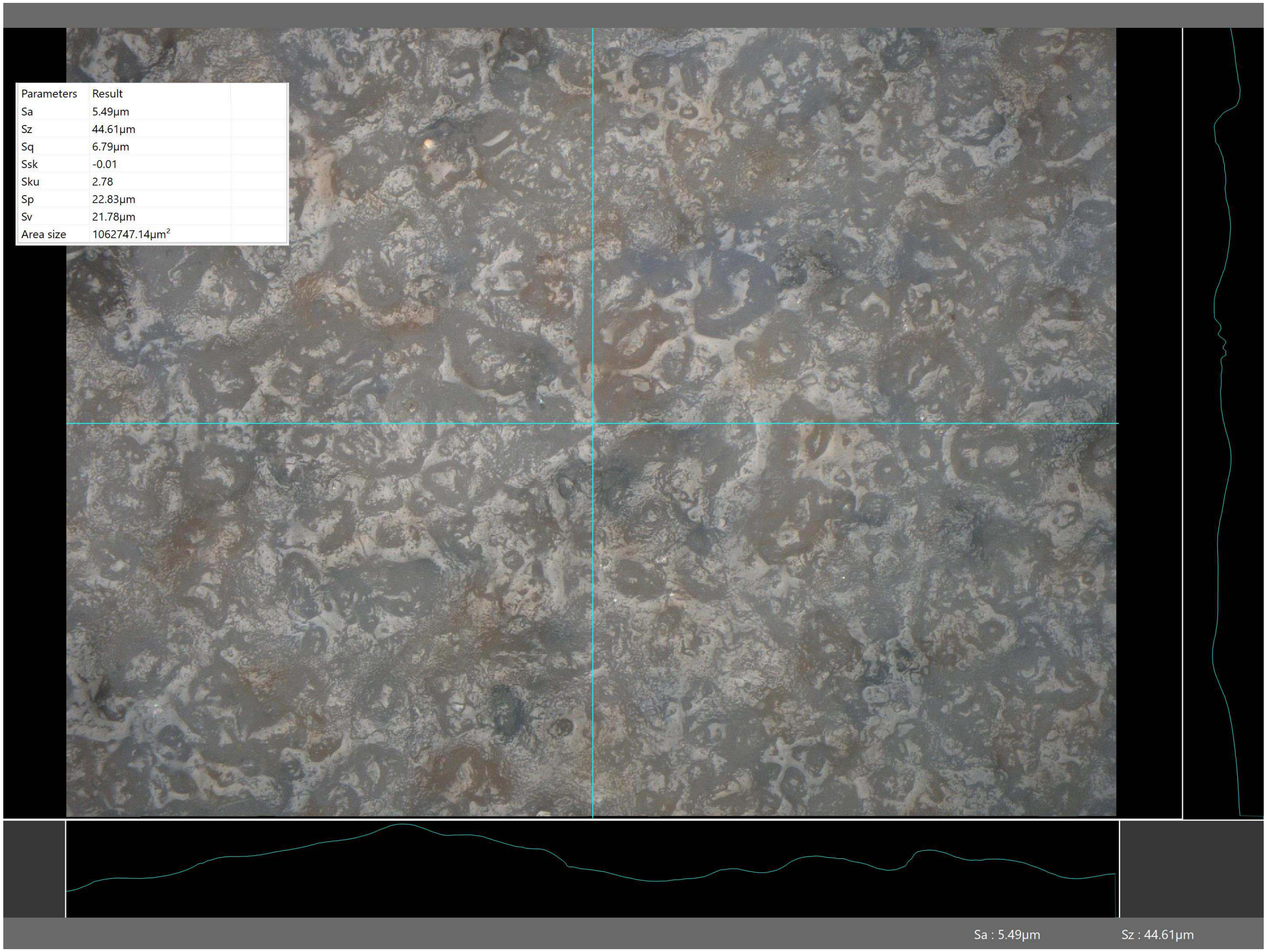


Figure 10. The fourth area examined for the surface roughness parameters for the Bad floor tile is shown above using coaxial illumination.

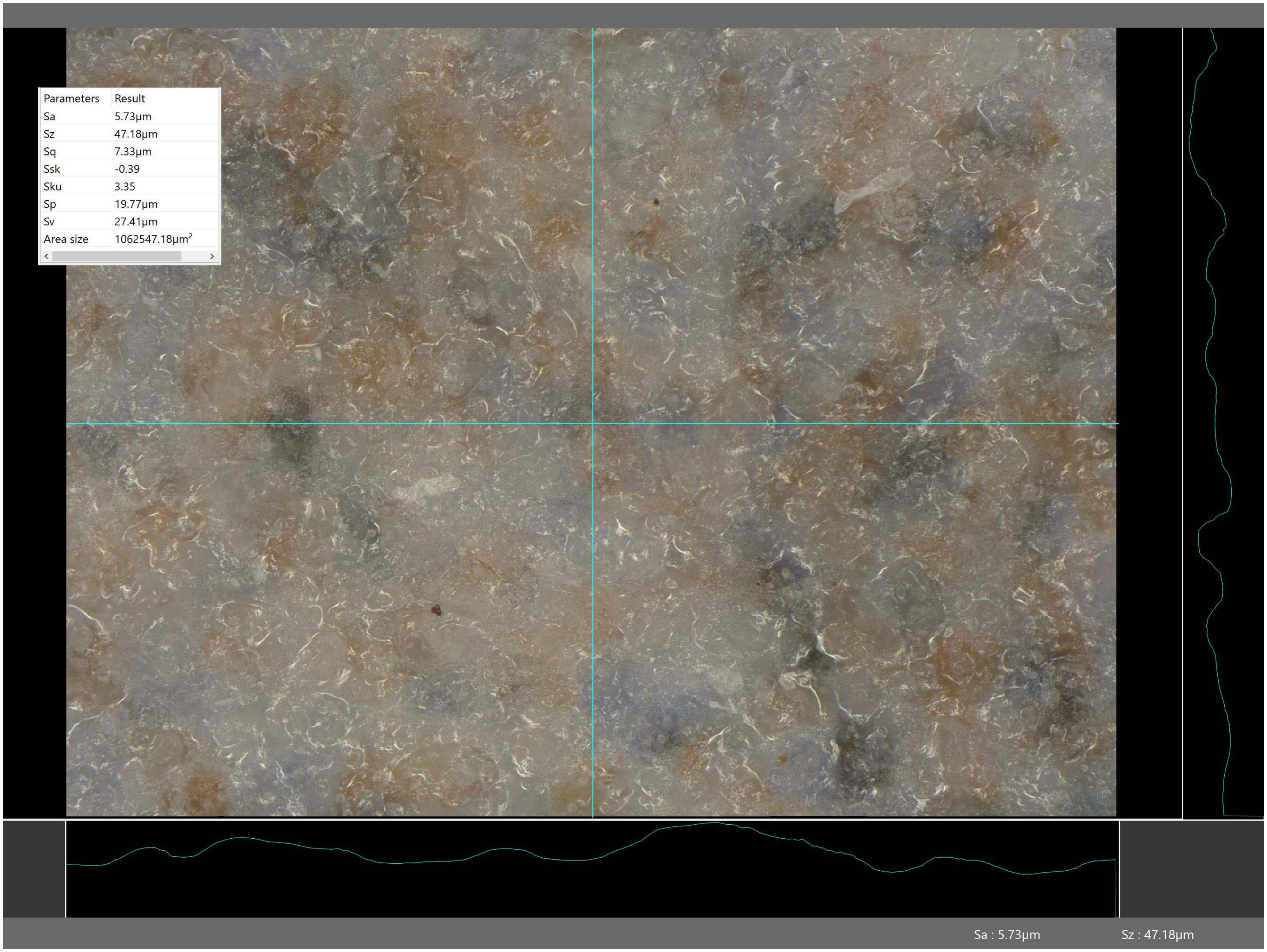


Figure 11. The surface roughness parameters for the fifth area of the Bad tile are given in the embedded table. This image as illuminated by ring lighting.

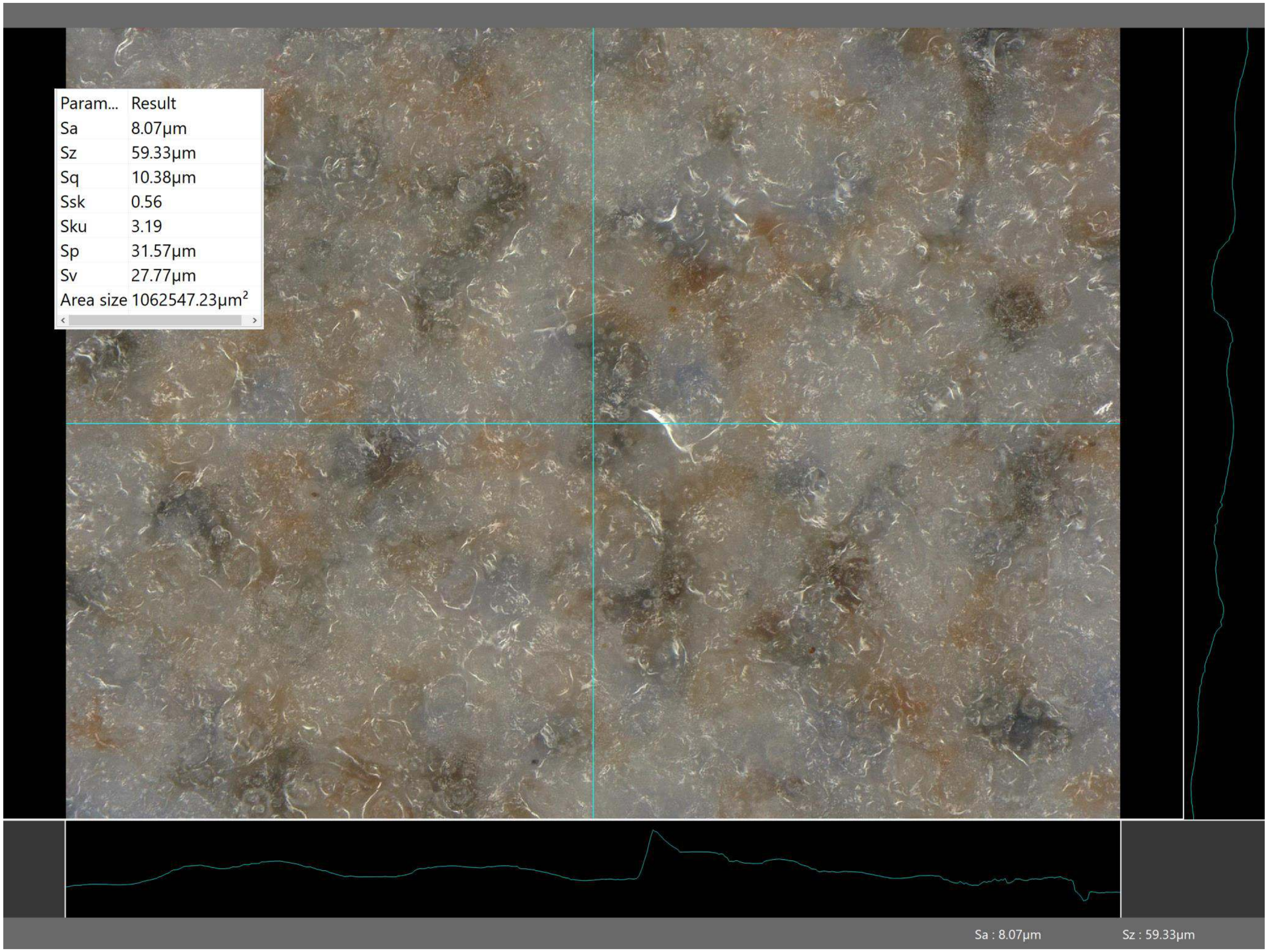


Figure 12. The sixth region of the Bad floor tile for which the surface roughness parameters have been determined.

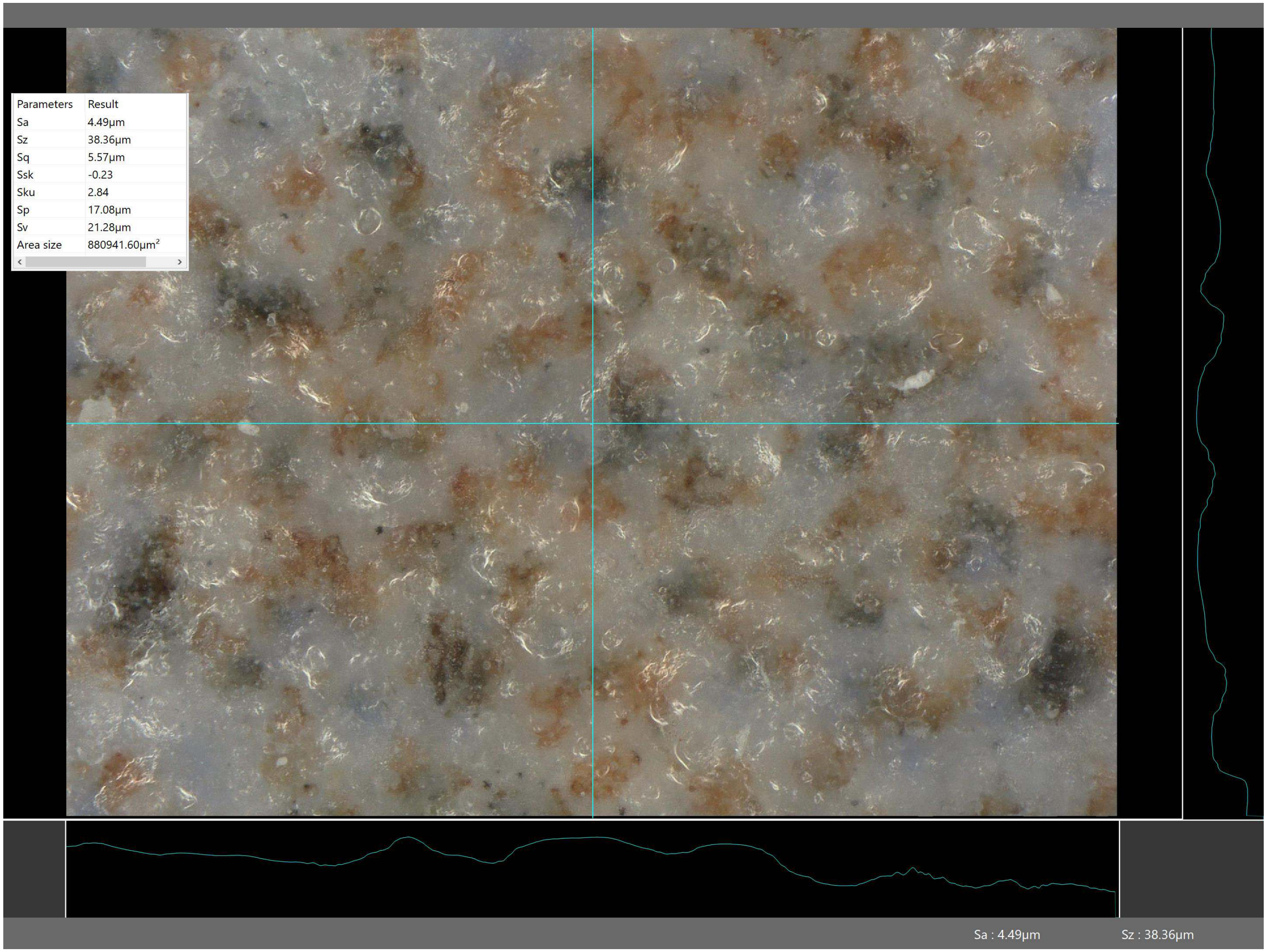


Figure 13. The surface roughness parameters were determined for this area of the Good floor tile.

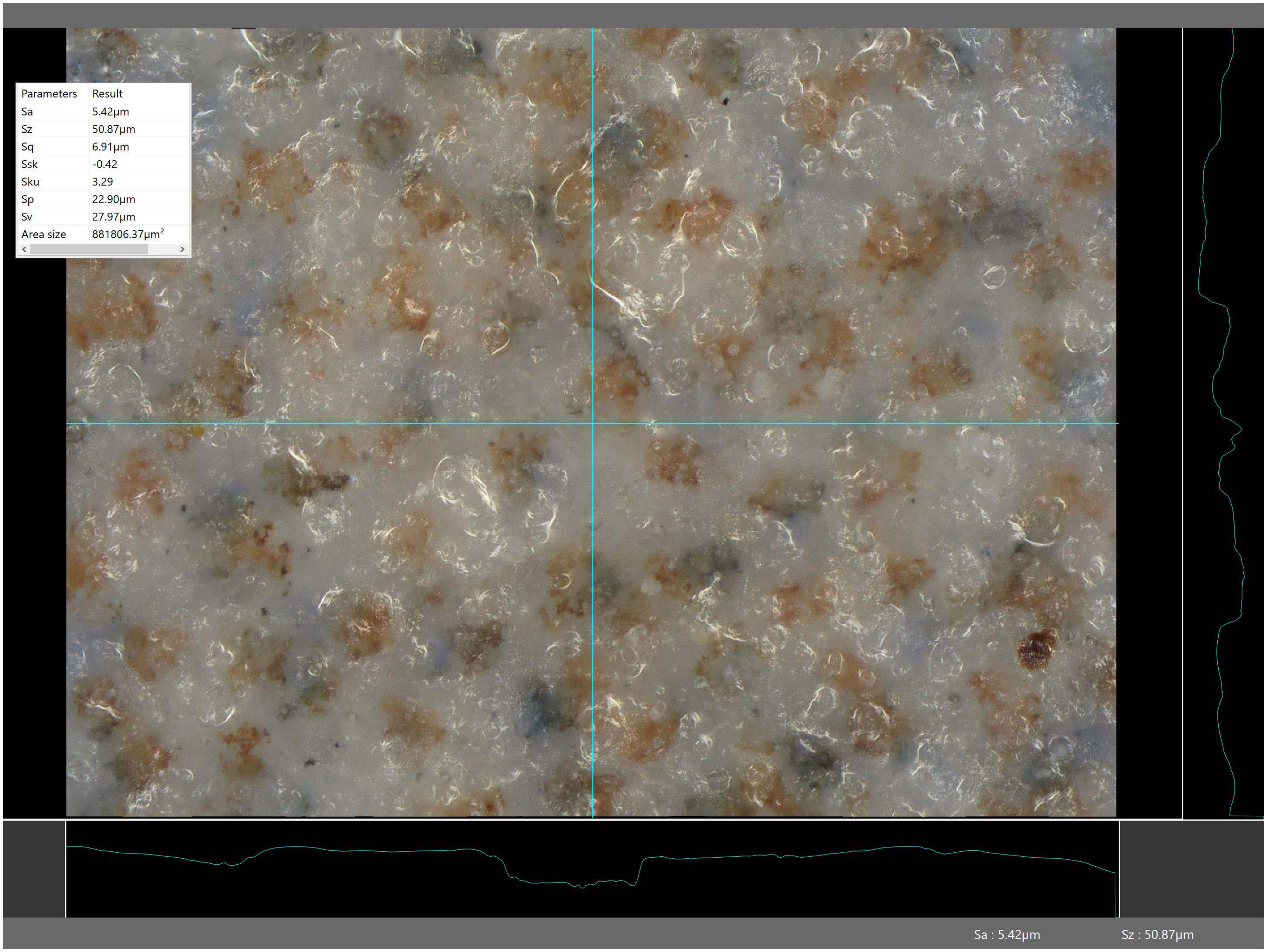


Figure 14. The surface roughness measurements were determined for this second area of the Good floor tile.

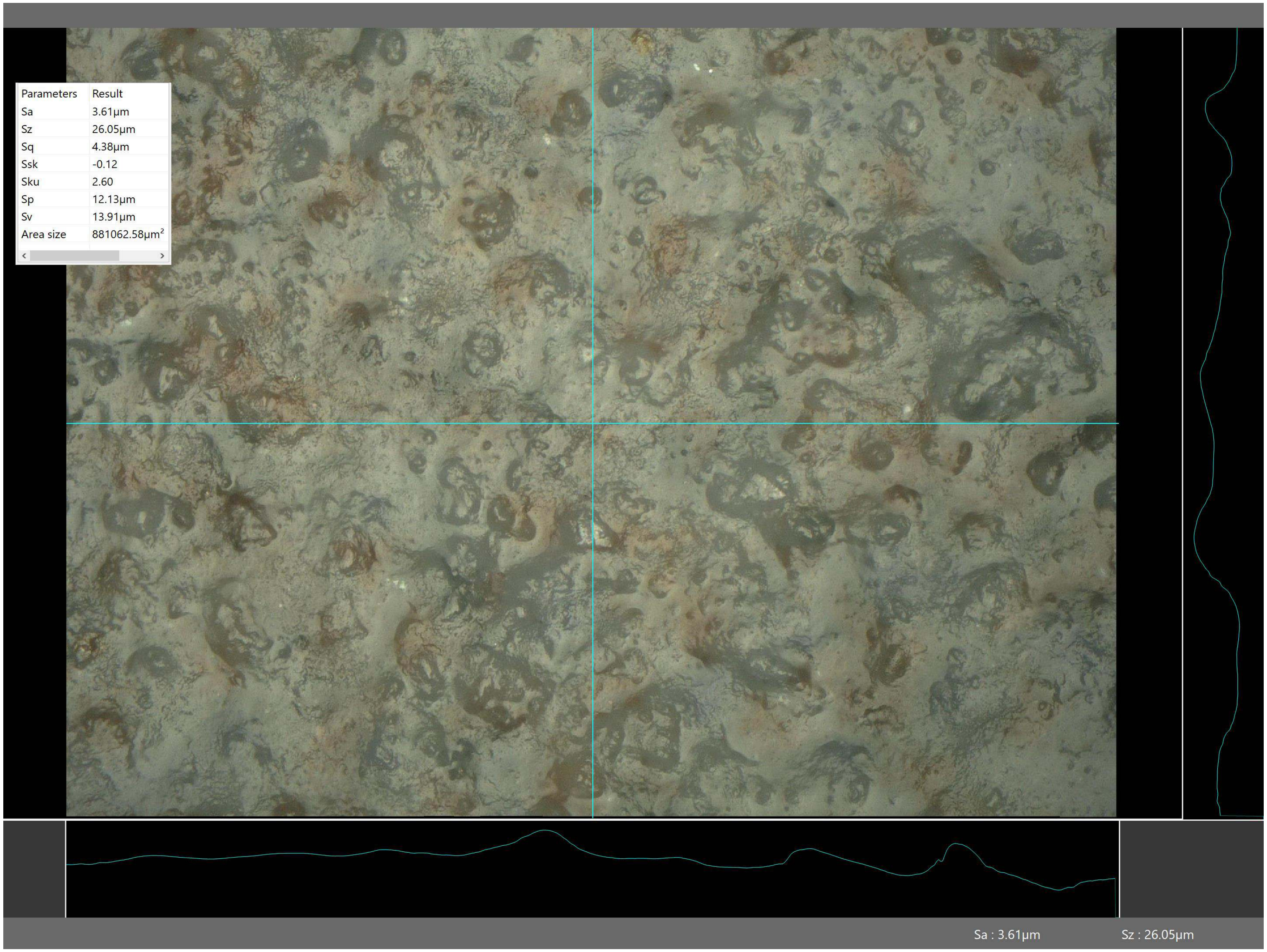


Figure 15. This coaxially illuminated third area of the Good floor tile has the much lower surface roughness parameters given in the embedded table.

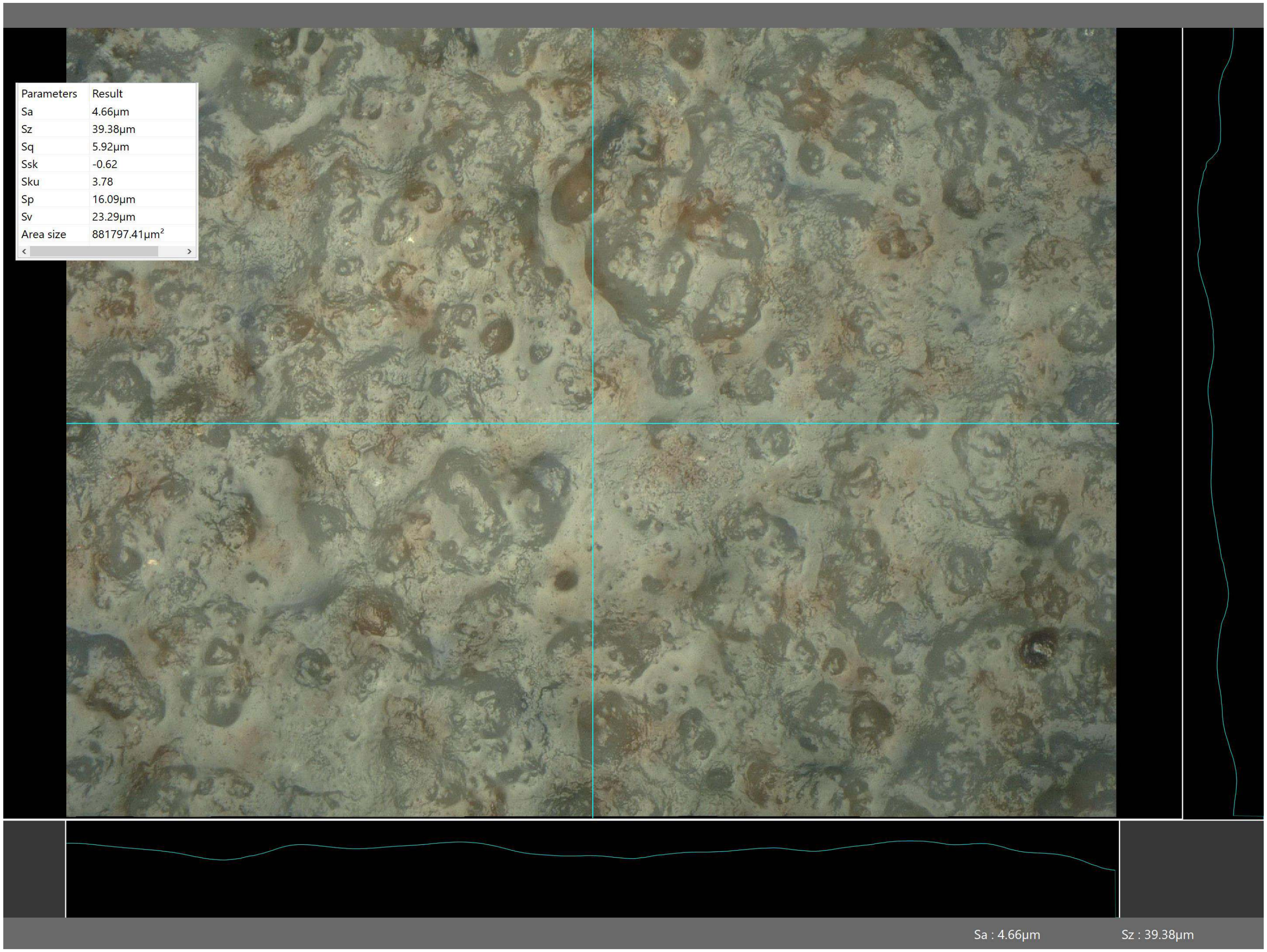


Figure 16. This illumination here is again coaxial. This fourth area of the Good floor tile has the surface roughness measurements given in the embedded table.

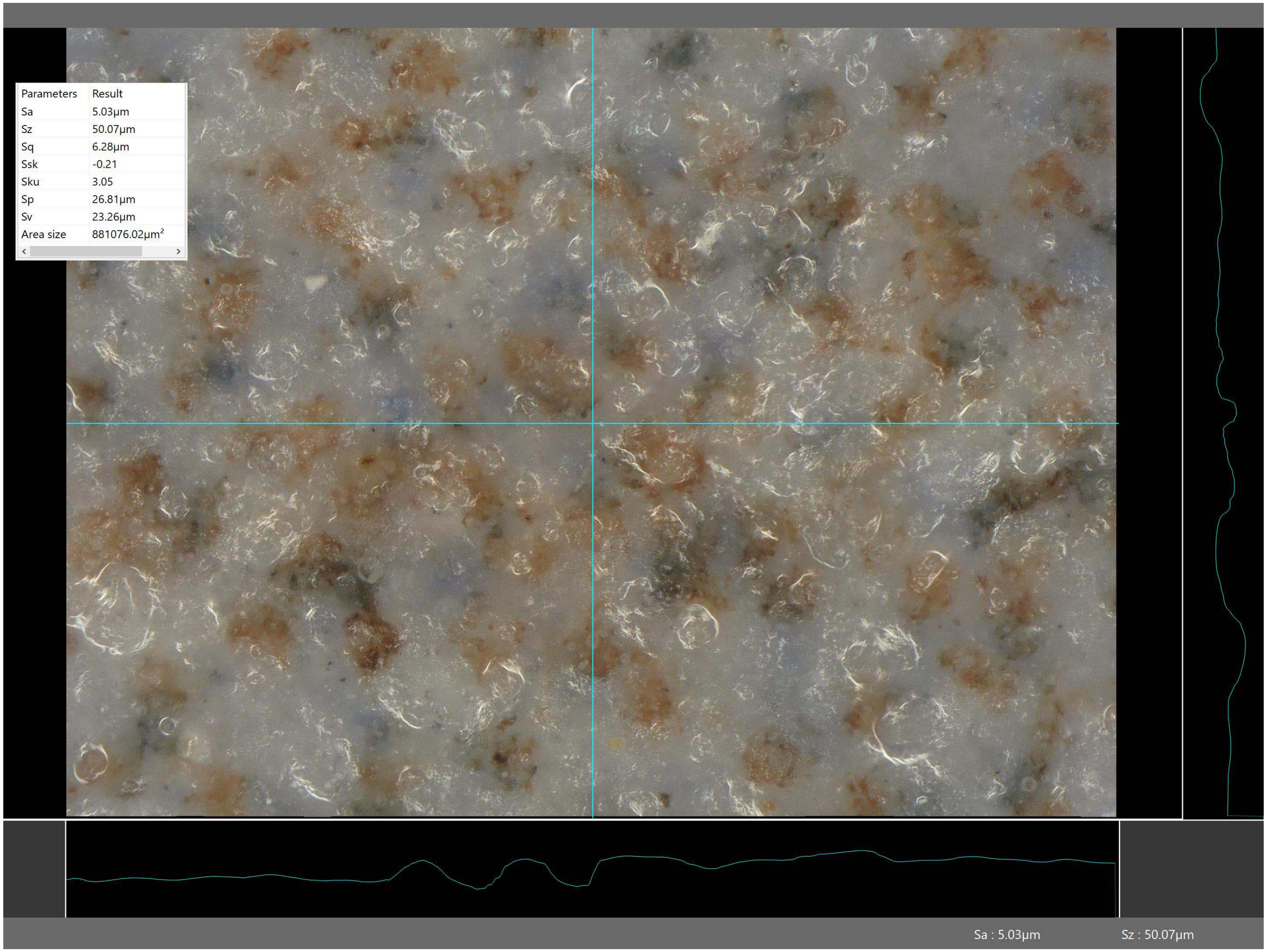


Figure 17. This is the fifth area of the Good tile with its surface roughness parameters.

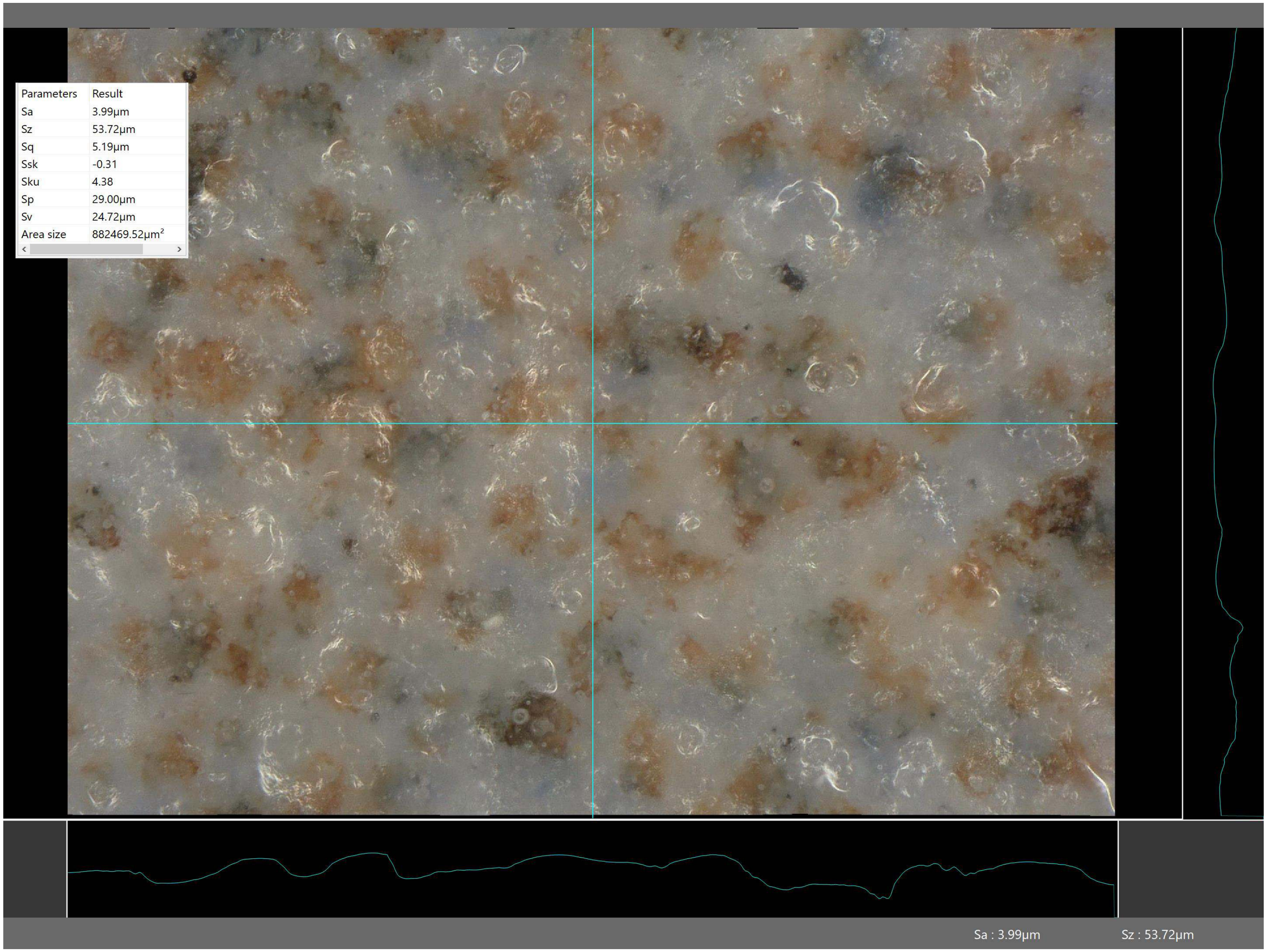


Figure 18. This sixth area of the Good tile has the surface roughness parameters given in the embedded table.

Table 1. The surface roughness parameter S_a for the Bad and the Good floor tiles in micrometers.		
	Bad Tile	**Good Tile**
Area 1	5.83	4.49
Area 2	6.48	5.42
Area 3	6.74	3.61
Area 4	5.49	4.66
Area 5	5.73	5.03
Area 6	8.07	3.99
Average	**6.39**	**4.53**

Table 1 summarizes the surface roughness measurement of the parameter S_a. The Bad tile values range from a low value of 5.49 microns to a high value of 8.07 microns. The Good tile values range from 3.61 to 5.42 microns. Every measured value on the Good floor tile is less than that on the Bad floor tile. The average Good tile value is much lower than the average value for the Bad tile.

Table 2. The surface roughness parameter S_q for the Bad and the Good floor tiles in micrometers.		
	Bad Tile	**Good Tile**
Area 1	7.28	5.57
Area 2	8.10	6.91
Area 3	8.37	4.38
Area 4	6.79	5.92
Area 5	7.33	6.28
Area 6	10.38	5.19
Average	**8.14**	**5.71**

The measured values of the roughness parameter S_q are given in Table 2. The Bad tile values range from 6.79 to 10.38 microns and the Good tile values range from 4.38 to 6.91 microns. All but one of the six Good tile measurements is lower than any of the six Bad tile measurements and the exception is barely higher than the lowest of the Bad tile measurements.