Claims

1. A method of determining 3D crystallographic orientation on a crystalline surface of a sample, the method comprising

directing a beam of collimated light to strike a spot on the crystalline surface at a predetermined angle of incidence, wherein reflections from the crystalline surface at said spot are projected onto an image sensing unit positioned in a path of reflected light, thereby generating an image of a reflectance pattern based on angle-dependent-reflectance of the crystalline surface sensed by the image sensing unit;

obtaining a directional reflectance profile from the image of the reflectance pattern by pixelising the reflectance pattern into a pixelated-image with a center coinciding with an intersection of a specularly reflected light beam and the image sensing unit, wherein the pixelated-image is divided into equal radial-pixels-segments about the center and each radial-pixels-segment is divided into pixels in respective radial direction; and

processing the directional reflectance profile based on analyzing reflection intensity data in the pixelated-image of the directional reflectance profile to determine the crystallographic orientation of the crystalline surface at said spot of the crystalline surface.

2. The method according to claim 1, wherein obtaining the directional reflection profile from the image of the reflectance pattern comprises extracting an annular portion of the reflectance pattern and pixelising the annular portion of the reflectance pattern into the pixelated image with the center coinciding with the intersection of the specularly reflected light beam and the image sensing unit, wherein the pixelated image is a pixelated-annular-image and the center is an annulus-center of the pixelated-annular-image.

3. The method according to claim 1 or 2, wherein the predetermined angle of incidence is from 0° to 80° as measured from a surface normal of the crystalline surface.

4. The method according to any one of claims 1 to 3, wherein processing the directional reflectance profile comprises transforming local-reflection-intensity-data of the pixels of the pixelated-image of the directional reflectance profile to integrated-reflection-intensity-data along great circles of the directional reflectance profile, each great circle parameterized by

an azimuth angle of the great circle and an elevation angle of a respective plane containing the great circle.

5. The method according to claim 4, wherein transforming comprises applying a Funk-Radon transform to the local-reflection-intensity-data of the directional reflectance profile.

6. The method according to claim 5, wherein processing the directional reflectance profile comprises determining the great circle with a highest value of the integrated-reflection-intensity-data and using the azimuth angle and the elevation angle of the great circle to determine the crystallographic orientation at said spot of the crystalline surface.

7. A method of determining 3D crystallographic orientation on a crystalline surface of a sample, the method comprising

directing a beam of collimated light to strike a spot on the crystalline surface at a predetermined angle of incidence, wherein reflections from the crystalline surface at said spot are projected onto a detector screen positioned in a path of reflected light, thereby displaying a reflectance pattern on the detector screen;

capturing an image of the reflectance pattern on the detector screen;

obtaining a directional reflectance profile from the captured image of the reflectance pattern by pixelising the reflectance pattern into a pixelated-image with a center coinciding with an intersection of a specularly reflected light beam and the detector screen, wherein the pixelated-image is divided into equal radial-pixels-segments about the center and each radial-pixels-segment is divided into pixels in respective radial direction; and

processing the directional reflectance profile based on analyzing reflection intensity data in the pixelated-image of the directional reflectance profile to determine the crystallographic orientation of the crystalline surface at said spot of the crystalline surface.

8. The method according to claim 7, wherein obtaining the directional reflectance profile from the captured image of the reflectance pattern comprises extracting an annular portion of the reflectance pattern and pixelising the annular portion of the reflectance pattern into the pixelated-image with the center coinciding with the intersection of the specularly reflected light beam and the detector screen, wherein the pixelated image is a pixelated-annular-image and the center is an annulus-center of the pixelated-annular-image.

9. The method according to claim 7 or 8, wherein the predetermined angle of incidence is from 0° to 80° as measured from a surface normal of the crystalline surface.

10. The method according to any one of claims 7 to 9, wherein the detector screen is a light diffusing white screen.

11. The method according to any one of claims 7 to 10, wherein processing the directional reflectance profile comprises transforming local-reflection-intensity-data of the pixels of the pixelated- image of the directional reflectance profile to integrated-reflection-intensity-data along great circles of the directional reflectance profile, each great circle parameterized by an azimuth angle of the great circle and an elevation angle of a respective plane containing the great circle.

12. The method according to claim 11, wherein transforming comprises applying a Funk-Radon transform to the local-reflection-intensity-data of the directional reflectance profile.

13. The method according to claim 12, wherein processing the directional reflectance profile comprises determining the great circle with a highest value of the integrated-reflection-intensity-data and using the azimuth angle and the elevation angle of the great circle to determine the crystallographic orientation at said spot of the crystalline surface.

14. An apparatus configured to perform a method of determining 3D crystallographic orientation on a crystalline surface of a sample, the apparatus comprising:

a collimated light source configured to be disposed above the crystalline surface and to direct a beam of collimated light at a predetermined angle of incidence to strike a spot on the crystalline surface;

a detector screen disposed in a path of reflected light so as to display a reflectance pattern on the detector screen, wherein the detector screen is a light diffusing white screen;

an image capturing device disposed relative to the detector screen in a manner so as to capture an image of the reflectance pattern on the detector screen; and

a processor in communication with the image capturing device to receive the image of the reflectance pattern captured by the image capturing device,

wherein the processor is configured to obtain a directional reflectance profile from the image of the reflectance pattern by extracting an annular portion of the reflectance pattern and pixelising the annular portion of the reflectance pattern into a pixelated-image with a center coinciding with an intersection of a specularly reflected light beam and the detector screen, wherein the pixelated-image is divided into equal radial-pixels-segments about the center and each radial-pixels-segment is divided into pixels in respective radial direction, and

wherein the processor is configured to process the directional reflectance profile based on analyzing reflection intensity data in the pixelated-image of the directional reflectance profile to determine the crystallographic orientation of the crystalline surface at the spot which the beam of collimated light is directed.

15. The apparatus according to claim 14, wherein the processor is configured to obtain the directional reflectance profile from the image of the reflectance pattern by extracting an annular portion of the reflectance pattern and pixelising the annular portion of the reflectance pattern into the pixelated-image with the center coinciding with the intersection of the specularly reflected light beam and the detector screen, wherein the pixelated image is a pixelated-annular-image and the center is an annulus-center of the pixelated-annular-image.

16. The apparatus according to claim 14 or 15, wherein the processor is configured to transform local-reflection-intensity-data of the pixels of the pixelated-image of the directional reflectance profile to integrated-reflection-intensity-data along great circles of the directional reflectance profile, each great circle parameterized by an azimuth angle of the great circle and an elevation angle of a respective plane containing the great circle.

17. The apparatus according to claim 16, wherein the processor is configured to apply a Funk-Radon transform to transform the local-reflection-intensity-data of the directional reflectance profile.

18. The apparatus according to claim 17, wherein the processor is configured to determine the great circle with a highest value of the integrated-reflection-intensity-data and use the azimuth angle and the elevation angle of the great circle to determine the crystallographic orientation of the crystalline surface.

19. The apparatus according to any one of claims 14 to 18, further comprising a movable stage on which the sample with the crystalline surface is placed.

20. The apparatus according to claim 19, wherein the movable stage is actuated, wherein the processor is in communication with the movable stage so as to control an actuation of the movable stage to position the sample relative to the collimated light source such that the beam of collimated light strikes on the spot of the crystalline surface of the sample.

21. The apparatus according to any one of claims 14 to 20, further comprising a pair of movable arms, a first of the movable arms coupled to the collimated light source and a second of the movable arms coupled to the detector screen.

22. The apparatus according to claim 21, wherein the pair of movable arms is actuated, wherein the processor is in communication with the pair of movable arms so as to control an actuation of the pair of movable arms to position the collimated light source and the detector screen such that the beam of collimated light strikes on a desired spot of the crystalline surface of the sample and the detector screen is positioned to display the reflectance pattern obtained by the reflections from the spot of the crystalline surface which the beam of collimated light is directed.