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Atomic resolution NC-AFM imaging on Au(111) at room temperature

Application Note

Atomic resolution non-contact atomic force microscopy (NC-AFM) imaging on metal single crystal surfaces is extremely challenging due to the small atomic corrugation and the small lattice constant inherent to metallic surfaces. Consequently only very few atomic-resolution cantilever-based NC-AFM studies have been reported yet. Even more challenging compared to other metal surfaces is imaging on the Au(111) surface since in this case the typically observed herringbone reconstruction additionally modulates the surface topography by a small modulation height of several 10 pm.

Within this note we present

- Topographic NC-AFM imaging of the Au(111) surface revealing atomic steps and the herringbone reconstruction with high resolution
- Highest quality atomic resolution NC-AFM imaging of the Au(111) surface at short range attractive and repulsive forces at small oscillation amplitudes
- Acquisition of a two-dimensional force map F(x,z) on Au(111)

All data was recorded without external dampers on the UHV system at the SPECS laboratory.

Displayed images represent raw data with no filtering or smoothing applied.

Measurement: S. Torbrügge, SPECS GmbH

SPECS

Topography of Au(111) imaged by NC-AFM

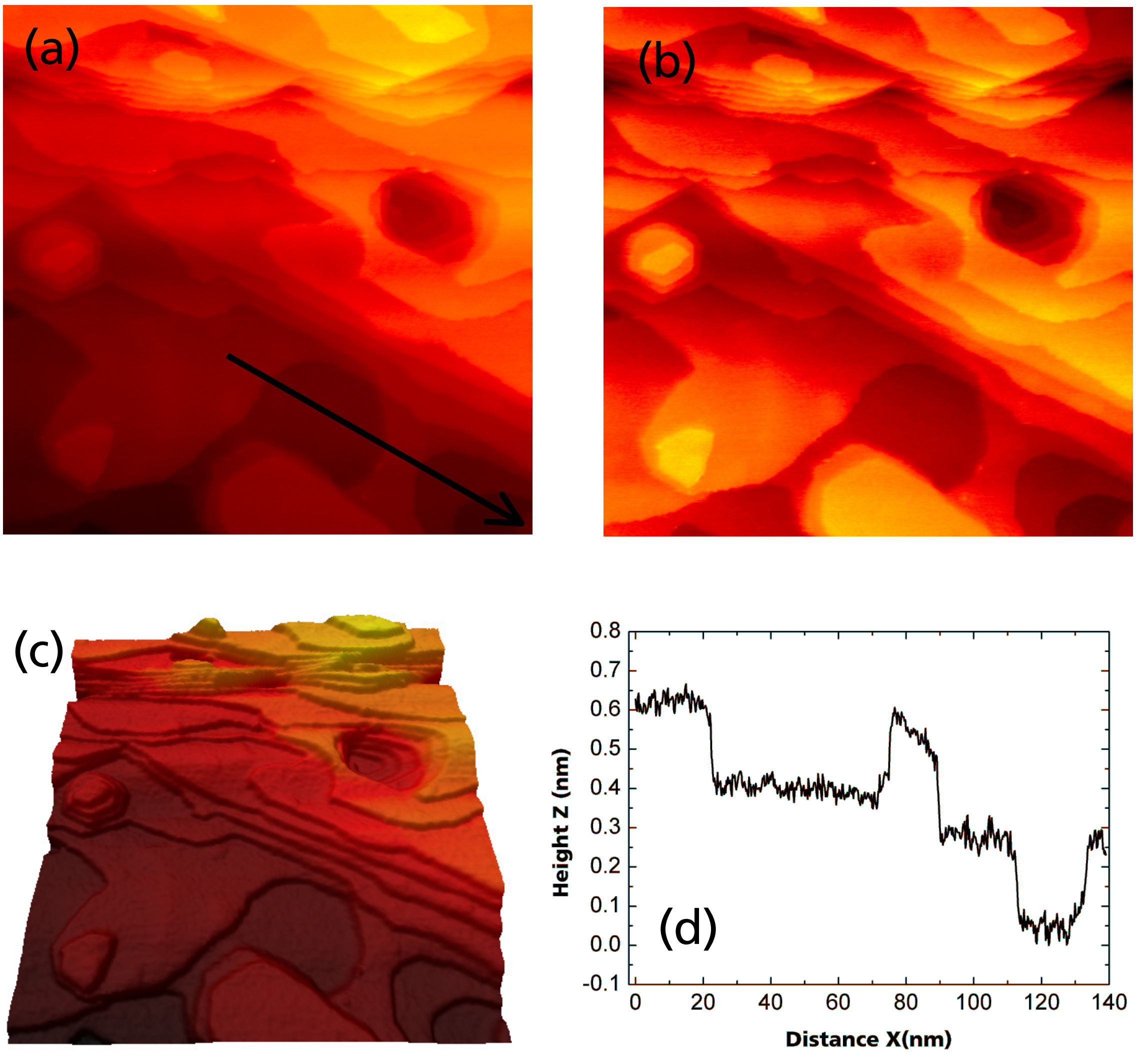

Figure 1: Large scale NC-AFM image of the Au(111) surface

(a) Large scale overview scan, (b) same image as in (a) but with plane subtraction to enhace step contrast, (c) 3D image representation of (a), (d) line profile along the line indicated in (a). Atomic steps of 0.24 nm height are observed.

Imaging parameters: f_{res} = 999,114 Hz, A = 400 pm Δf_{set} = -0.2 Hz, Q= 28,900, U_{CPD} = + 1.53 V
Image size: 200 nm x 200 nm, (1024 x 1024) pixels, imaging speed: 1.3 lines/s

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Herringbone reconstruction imaged by NC-AFM

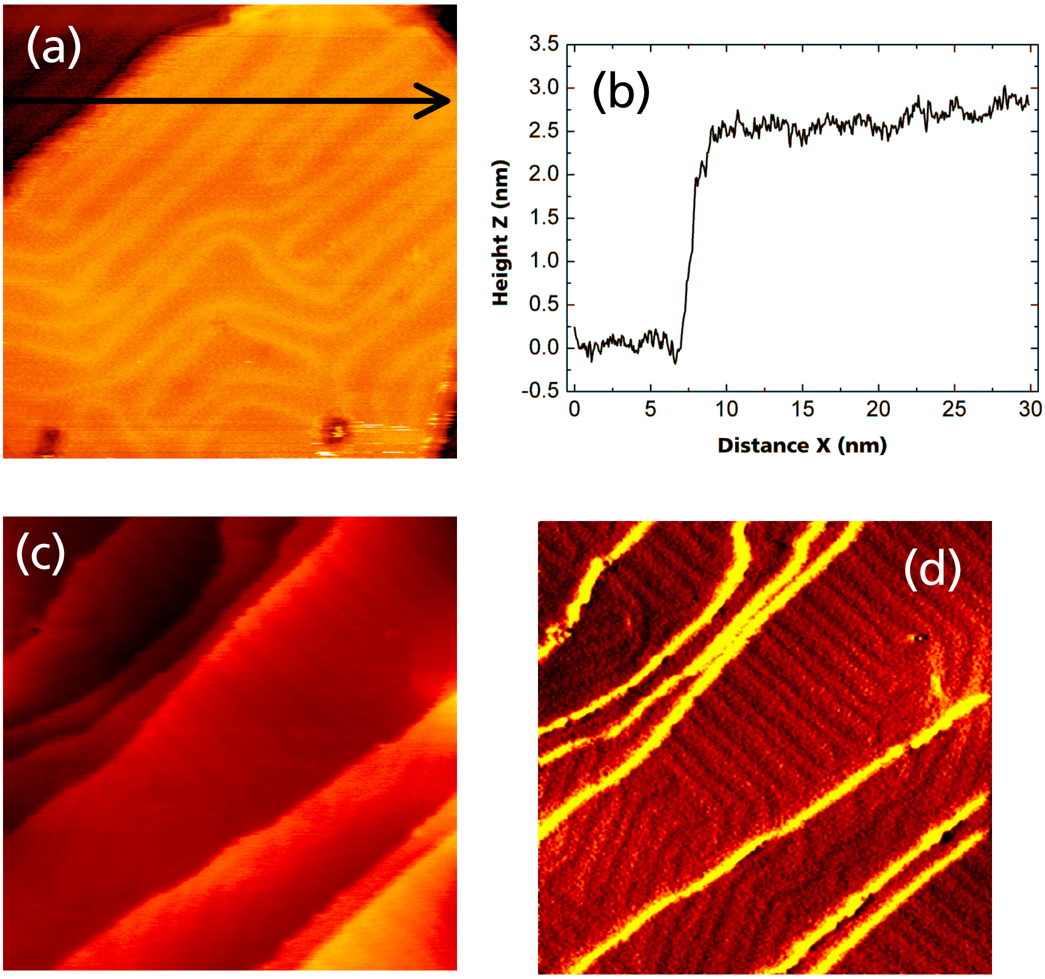

Figure 2: Herringbone reconstruction

The herringbone reconstruction observed for the Au(111) surface in NC-AFM images exhibits typically a corrugation of several 10 pm. In image (a) the herringbone reconstruction is confined by the shape of the Au island, in (c) by the stepped surface structure. (b) shows a line profile along the line in (a). (d) shows the derivative image of (c) to enhance the contrast.

Image (a)
Imaging parameters: f_{res} = 999,114 Hz, A = 400 pm Δf_{set} = +0.75 Hz, Q= 28,900, U_{CPD} = + 1.03 V
Image size: 30 nm x 30 nm, (512 x 512) pixels, imaging speed: 3.3 lines/s

Image (c)
Imaging parameters: f_{res} = 999,114 Hz, A = 400 pm Δf_{set} = -0.20 Hz, Q= 28,900, U_{CPD} = + 0.95 V
Image size: 70 nm x 70 nm, (512 x 512) pixels, imaging speed: 1.0 line/s

Herringbone reconstruction imaged by NC-AFM

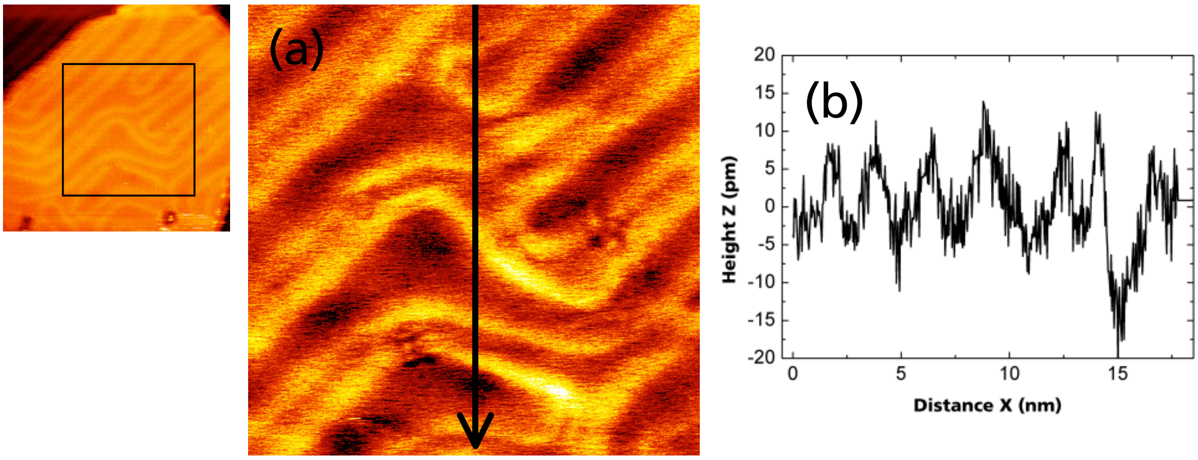

Figure 3: Herringbone reconstruction

(a) High resolution NC-AFM image of the herringbone reconstruction. (b) A corrugation of about 10 pm is registered for the reconstruction.

Imaging parameters: f_{res} = 999,114 Hz, A = 400 pm Δf_{set} = +0.75 Hz, Q= 28,900, U_{CPD} = + 1.03 V
Image size: 25 nm x 25 nm, (512 x 512) pixels, imaging speed: 3.3 lines/s

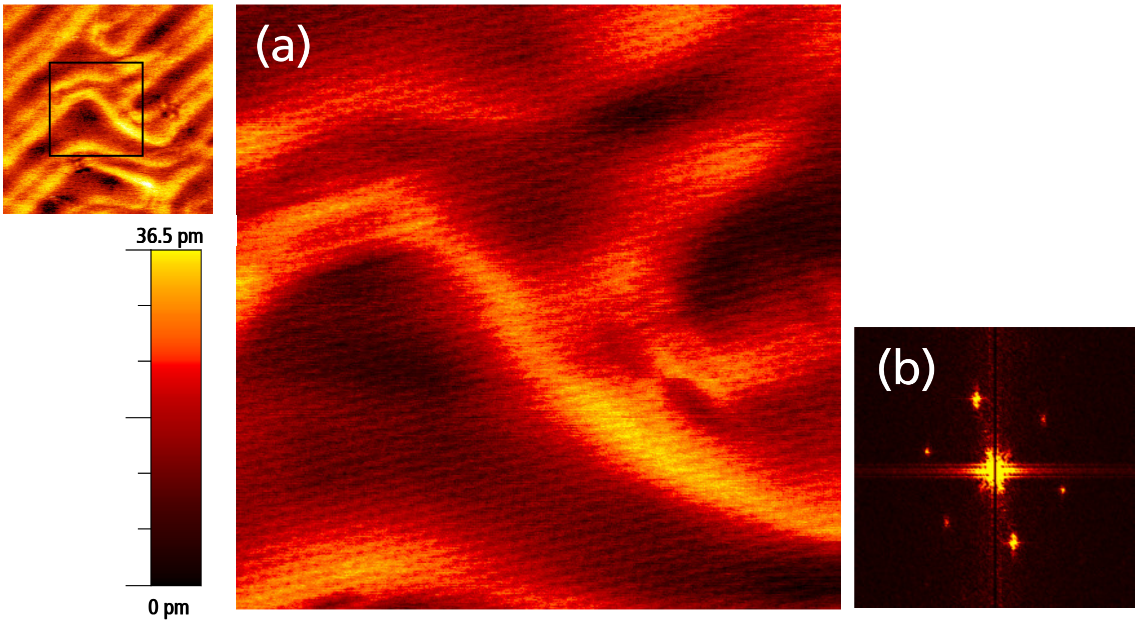

Figure 4: Atomic details of the herringbone reconstruction imaged by NC-AFM

(a) High resolution NC-AFM image showing the atomic details of the herringbone reconstruction. (b) Fast fourier transformation of image (a) revealing the hexagonal ordering of the Au(111) surface.

Imaging parameters: f_{res} = 999,114 Hz, A = 400 pm Δf_{set} = +0.75 Hz, Q= 28,900, U_{CPD} = + 1.03 V
Image size: 11 nm x 11 nm, (1024 x 1024) pixels, imaging speed: 2.5 lines/s

Atomic-resolution NC-AFM imaging on Au(111)

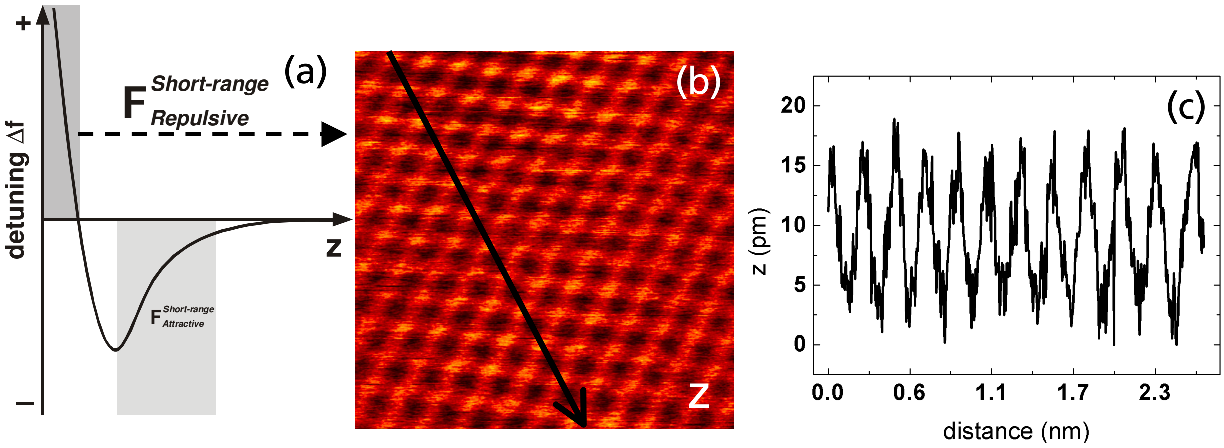

Figure 5: Atomic-resolution NC-AFM imaging on Au(111) in the repulsive regime

(b) Atomic-resolution topographic NC-AFM image of the Au(111) surface. (c) Line profile along the solid line in (b). An atomic corrugation of about 15 pm is observed. The image was obtained at **positive** detuning Δf which results in imaging at short-range repulsive forces as schematically illustrated in (a).

Imaging parameters: f_{res} = 999,114 Hz, A = 100 pm Δf_{set} = +2.21 Hz, Q= 28,900, U_{CPD} = + 0.96 V
Image size: 3 nm x 3 nm, (512 x 512) pixels, imaging speed: 10.0 lines/s

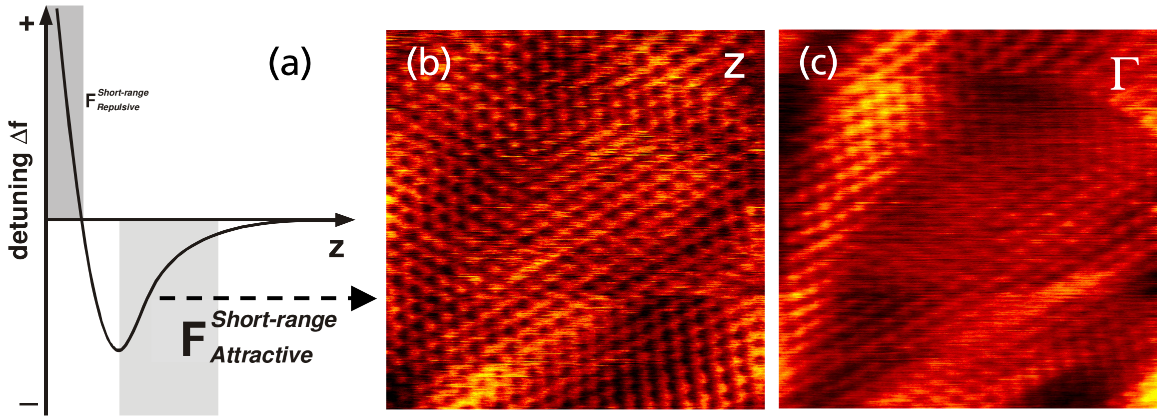

Figure 6: Atomic-resolution NC-AFM imaging on Au(111) in the attractive regime

Atomic resolution imaging in the attractive regime: (b) topography and (c) dissipation Γ are recorded simultaneously. The images were obtained at **negative** detuning Δf which results in imaging at short-range attractive forces as schematically illustrated in (a).

Imaging parameters: f_{res} = 999,114 Hz, A = 300 pm Δf_{set} = -0.5 Hz, Q= 28,900, U_{CPD} = + 0.16 V
Image size: 5 nm x 5 nm, (1024 x 1024) pixels, imaging speed: 4.5 lines/s

Force Mapping on Au(111)

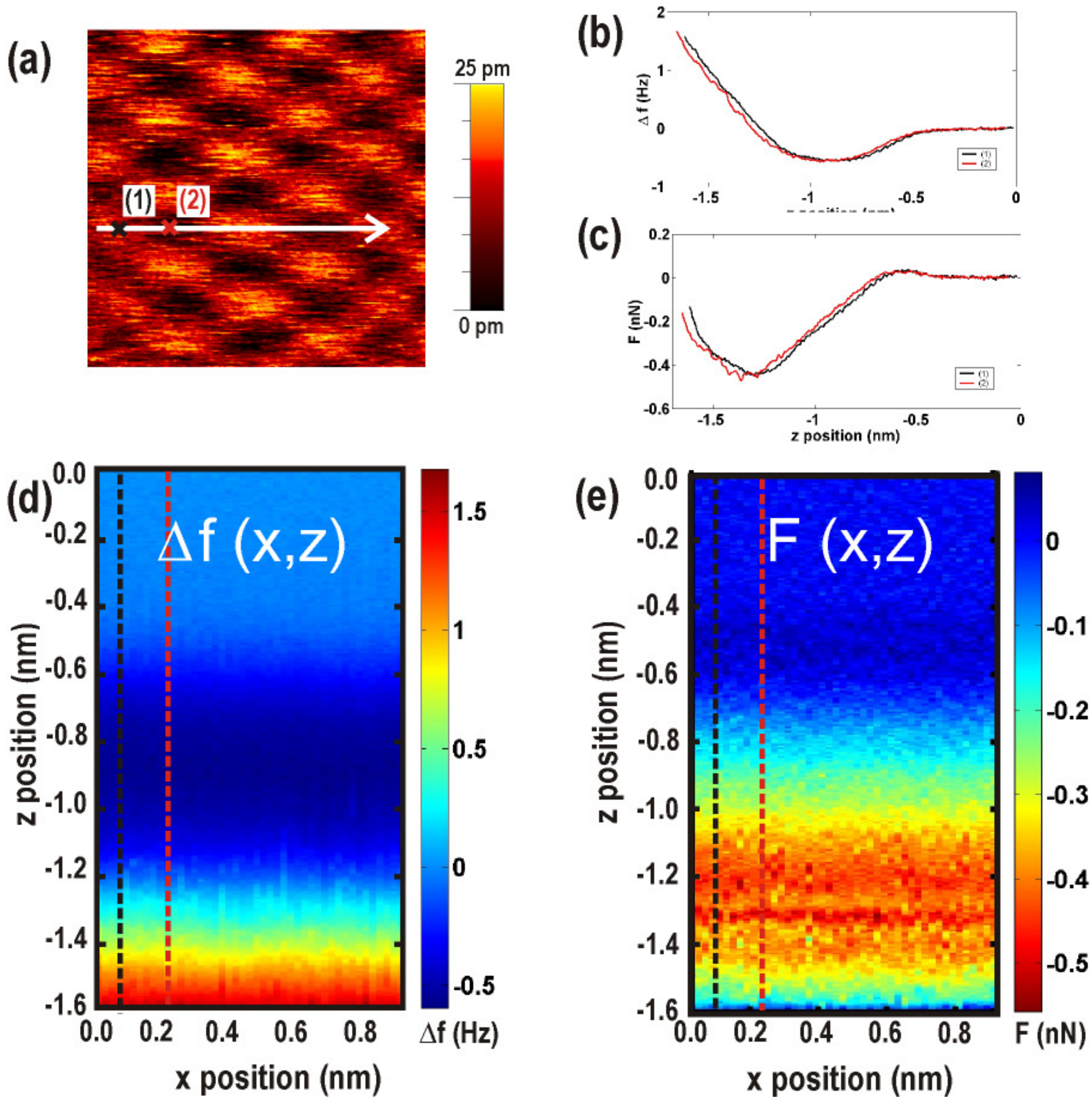

Figure 7: Force Mapping on Au(111)

(a) Topographic NC-AFM image of the Au(111) surface. A corrugation of about 15 pm was registered between maximum and minimum positions in the image. Two Δf(z) curves and derived force distance curves F(z) recorded atop a maximum (1) and minimum (2) position in (a) are presented in (b) and (c), respectively. (d) and (e) show Δf(x,z) and derived F(x,z) maps consisting of 46 curves recorded along the line in (a). Remarkably, no tunneling current was detected throughout the spectroscopic experiment.

Imaging parameters in (a): f_{res} = 999,114 Hz, A = 400 pm Δf_{set} = +1.24 Hz, Q= 28,900, U_{CPD} = + 0.6 V
Image size: 1.1 nm x 1.1 nm, (256 x 256) pixels, imaging speed: 6.6 lines/s

Spectroscopy parameters: 1.6 nm z-sweep distance, 256 points/curve,1.3 s/curve

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