Phosphorus Induced Faceting of Cu(755): Morphological Evolution and Possible Local Surface Chirality

Wissem GHARIANI[1], Cyril CHACON[1], Jérôme LAGOUTE[1],
Yves GARREAU[1,2], Alessandro COATI[2], Yann GIRARD[1]

[1]Université Paris Cité – UMR 7162, Laboratoire Matériaux et Phénomènes Quantiques, 75013 Paris, France

[2]Synchrotron SOLEIL–CNRS, L'Orme des Merisiers, Saint-Aubin, BP 48, 91192 Gif-sur-Yvette, France

wissem.ghariani@u-paris.fr

Abstract

Phosphorus growth on stepped copper surfaces provides an opportunity to investigate the interplay between adsorption, step restructuring, and surface morphology. Previous work on P/Cu(111) has revealed substantial structural transformations during phosphorus deposition [1]. Here, Scanning Tunnelling Microscopy (STM) reveals a pronounced morphological evolution of Cu(755) with increasing phosphorus exposure. The clean surface exhibits a regular stepped morphology, with step edges oriented along $[0\,1\,\bar{1}]$. After an exposure of 6 Langmuirs (L) at room temperature followed by an overnight 170 ℃ annealing, the initial structure undergoes substantial step reorganisation, resulting in small triangular terraces [Fig. 1(a)(b)]. Their edges are consistent with alignment along the directions [-1 2 -1] and [-1 -1 2], forming 120° angles. Furthermore, a striking modification of the surface morphology is obtained for the same 6 L exposure but at 260 ℃, see [Fig. 1(b)]. The resulting step segments have a characteristic length of 2.5 nm. After a longer 12 L exposure to the phosphorus flux at 260 ℃, extended faceted domains emerge [Fig. 1(d)]. Remarkably, phosphorus growth induced faceting develops transverse to the original step direction. This evolution suggests substantial substrate restructuring, rather than simple decoration of the pre-existing $6(111) \times (100)$ step structure. Within domains A and B [Fig. 1(c)(d)], smaller motifs are also observed, with quasi identical characteristic lateral dimensions of approximately 1.3×2.3 nm^2 on the B facets. These motifs may arise from local arrays of (111) microsteps.

Assuming the conservation of the projected surface area and the [755] perpendicular normal, possible facet orientations include (543) and (534), consistent with the directions $[\bar{1}\,2\,\bar{1}]$ and $[\bar{1}\,\bar{1}\,2]$, as seen on [Fig. 1(a)].

One possible scenario involves phosphorus adsorption modifying the orientation-dependent surface and step energies. At intermediate exposure, this modification could favour the segmentation of initially straight steps along several crystallographic directions, producing the triangular terraces observed at 6 L. At higher exposure, redistribution of Cu atoms, coupled with step bunching and lateral step reorganisation, could generate domains with different local step densities and orientations. Consequently, the resulting facets form two enantiomeric, mirror-image structures, meaning they are chiral. This mechanism could account for the emergence of transverse faceting with internal arrays of (111) microsteps, provided that phosphorus adsorption lowers the total energy of the resulting morphology.

These observations reveal an unexpected phosphorus-induced morphological instability whose microscopic mechanism remains to be elucidated. Nevertheless, this template could be highly useful for inducing anisotropic optical or magnetic properties in adsorbed materials.

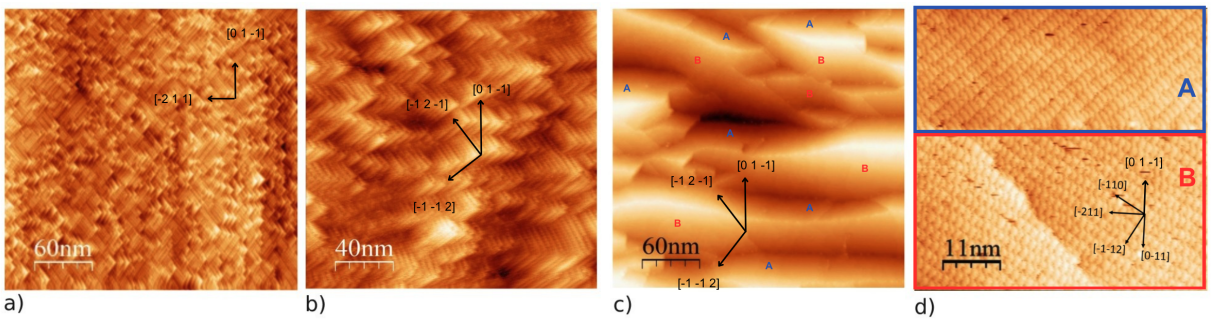

Figure 1: STM images illustrating the morphological evolution of Cu(755) upon phosphorus exposure: (a) 6 L deposited at room temperature, followed by annealing at $170\,^{\circ}\mathrm{C}$; (b) 6 L deposited at $260\,^{\circ}\mathrm{C}$; (c) 12 L deposited at $260\,^{\circ}\mathrm{C}$; and (d) a close-up of (c), showing the characteristic motifs. Two domains, A on top and B on bottom, showing symmetrical mirror facets.

References

[1] *Direct Observation of Structural Phase Transformations during Phosphorene Formation on Cu(111)*. ACS Nano (2025). doi:10.1021/acsnano.4c11802.

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