Atomic removal via mechanochemical reactions

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Ultra-precision of nanomanufacturing process down to the atomic level is of paramount importance for new development of nanoelectronics with unique functionalities. The ultimate precision that can be achieved for the crystalline materials would be the topographic control down to atomic level. Achieving such an ultimate precision requires physical means or processes to reliably and reproducibly remove atoms at a specific location with an arbitrary shape without causing subsurface damages or disorders. Here, a mask-less and chemical-free nanolithography process is demonstrated for regio-specific removal of atoms on crystalline materials (such as silicon, graphene) via shear-induced mechanochemical reactions. Since the chemical reactions involve the topmost atoms exposed at the interface, removal of the atomic layer is possible and the crystalline lattice beneath the processed area remains intact, keeping perfect crystalline order without subsurface structural damage for crystalline silicon or controlling the atomic structures of the fabricated graphene step edges. Molecular scale simulations explain the atom-by-atom removal process, where the atoms are removed preferentially through the formation and dissociation of interfacial bridge bonds. Based on the parametric thresholds needed for the atoms removal, the critical energy barrier for stress-assisted chemical dissociation of Si-Si bonds and C-C bonds is determined respectively. The mechanochemical nanolithography method demonstrated here could be extended to nanofabrication of other crystalline materials.

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