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One-dimensional phosphorus chain and two-dimensional blue phosphorene grown on Au(111) by molecular-beam epitaxy

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Single layer (SL) phosphorus (phosphorene) has drawn considerable research attention recently. It is a semiconductor showing superior transport and optical properties. In the past several years, few-layer or SL black phosphorus has been successfully isolated by exfoliation and extensively studied. Recently, an allotrope of black phosphorus, blue phosphorus (blueP), is predicted to stabilize in SL form on several substrates. In this work, we report a unique growth sequence of blueP by molecular-beam epitaxy during its growth on Au(111) substrate. One-dimensional (1D) atomic chains of phosphorus are observed at low coverage, which develop into more compact patches of the $(\sqrt{3} \times \sqrt{3})R30^\circ$ structure and finally blueP with increasing coverage. In particular, over a large coverage range, a composite surface consisted of locally high-P coverage blueP islands and locally low-coverage 1D chains or loose $(\sqrt{3} \times \sqrt{3})R30^\circ$ patches prevails owing to the minimization of the overall system energy. First-principle calculations are carried out to explain this growth phenomenon.

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