Growth of Single-Crystalline $B_{12}As_2$ on m-plane (1-100) 15R-SiC

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Research Achievement

Icosahedral boron arsenide $B_{12}As_2$ (IBA) is a wide band gap semiconductor (3.47eV) with the extraordinary ability to “self-heal” radiation damage. This makes it an attractive choice for devices exposed to radiation levels which can severely degrade the electrical properties of conventional semiconductors, causing devices to cease functioning. Among the particularly intriguing possible applications for IBA are Beta Cells, devices capable of producing electrical energy by coupling a radioactive beta emitter to a semiconductor junction, another space electronics [1-4]. IBA is based on twelve-boron-atom icosahedra, which reside at the corners of an α-rhombohedral unit cell, and two-atom As-As chains lying along the rhombohedral [111] axis [1]. In the absence of native substrates, IBA has been heteroepitaxially grown on substrates with compatible structural parameters. To date, this has been attempted on substrates with higher symmetry than IBA such as Si and 6H-SiC. Unfortunately, growth of a lower symmetry epilayer on a higher symmetry substrate often produces structural variants, a phenomenon known as degenerate epitaxy [5, 6]. These variants, which comprise both the rotational and translational variety, are expected to have a detrimental effect on device performance, and have severely hindered progress of this new material to date.

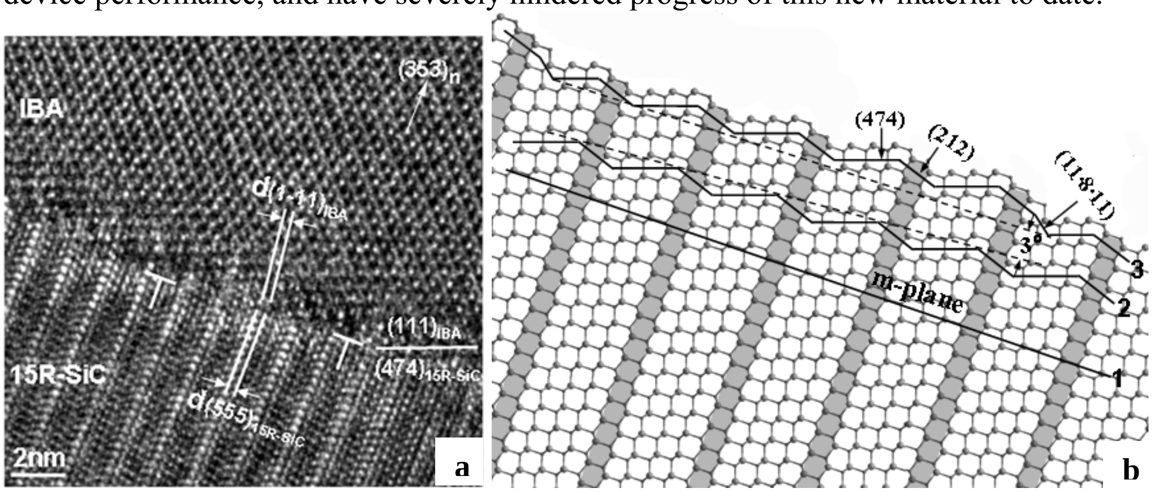

Fig. 1. (a) HRTEM image recorded along the [10-1] zone axis (equivalent to [11-20] in the hexagonal system) showing a sharp IBA/15R-SiC interface and the (353) surface orientation of IBA. The symbol ⊥ marks the location of interfacial dislocations with extra half-planes in the 15R-SiC substrate. (b) Cross-sectional visualization along [10-1] of the 15R-SiC structure. The uppermost black line indicates the on-axis, facet configuration comprising closed-packed (474) atomic terraces and coupled (212) and (11·8·11) step risers. The middle black line indicates the surface comprising only (474) and (212) facets which results in a 3° misorientation from m-plane and the lower line indicates the m-plane itself (unfaceted). Note the lamellar nano-domains of 3C-SiC structure bounded by the (474) facets and the shaded domain boundaries parallel to the (111) plane ((0001) in hexagonal system).

In this work, heteroepitaxial growth of untwinned single crystal IBA on m-plane 15R-SiC is demonstrated. Synchrotron white beam x-ray topography (SWBXT), Raman spectroscopy and high resolution transmission electron microscopy (HRTEM) confirm the high quality of the films (see Fig 1(a). High quality growth is shown to be mediated by ordered nucleation of IBA on close packed (474) facets which dominate the m-plane surface. Such nucleation is shown to be possible for untwinned but not for twinned IBA (see Figs. 1(b) and 2). This work demonstrates that m-plane 15R-SiC is a good substrate choice for the growth of high-quality, untwinned IBA epilayers for future device applications.

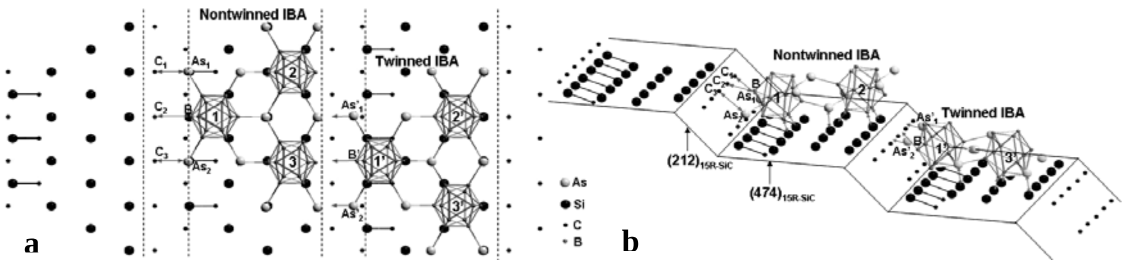

Fig. 2. Plan view ((a)) and 3-D perspective view ((b)) of nontwinned and twinned (353) IBA nucleated on m-plane 15R-SiC surface facets. For the non-twinned IBA, the triangular configuration of B atoms at the bottoms of icosahedra 1, 2 and 3 bond to the similarly oriented triangular configurations of Si atoms exposed on the (474) terrace (see (a) and (b)). In addition, atoms As1, B, and As2 can be well bonded to atoms C1, C2, and C3, respectively, on the neighboring (212)15R-SiC step riser. In contrast, while the triangular configuration of B atoms at the bottoms of icosahedra 1', 2' and 3' can similarly bond to the (474) terrace, atoms As'1, B', As'2 are not able to reasonably bond to the corresponding C atoms on the neighboring (212)15R-SiC step riser.

Future Work

Work is underway to grow IBA films on large area m-plane SiC substrates. Once completed, simple devices will be fabricated and tested to confirm improved performance.

Publications

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