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Electronic Structure of Intentionally Disordered AIAs/GaAs

ASuperlattice

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dimensional systems retain, in fact, a three-dimensional
character, and the states need not be localized by disorder.
We will show that the localization in the d-SL originates
mostly from the formation of impuritylike, localized
bound states due to insertion of 6' layers into the o-SL.
In Fig. 1(a) we show the planar wave function average
lPz(z)l = f d r~lPz(r)l of a few occupied and unoccu-pied band-edge states of a d-SL with a 1000-monolayer unit cell. We see that these band-edge wave functions are sharply localized. We can quantify the effective localiza-tion length (in monolayer units) for the wave function Pz at energy F. as [5]

Luff(&) = —„pl(t I't/E&l')

0.04

50

Position {nm)
100 150 200 250

{a) d-SL,
0.02.
0.01.
0.00

G2 c3 cl
Leff = 14
y= 0.21

-0.01.

g -0.02-

g

-0.03
-0.04

0
0.04
O

g 0.03 y) G
0.02.
0.01.
0.00
-0.01
-0.02.
-0.03.

250

U2

Leff = 12
y= 0.23

750

Leff = 11 (C) A3
y

=0.

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2.100— CBM of o-SL
2.075—

2.050—

CBM of periodic 5-layers

2.025—

2.000—

1.975—

+ -.

-.. + po-SL

1.950—

0.125—
0.100—
0.075—

o.o5o-.+

/

0.025—
0.000

po-SL

VBM of periodic 5-layers
VBM of o-SL

0.00
ordered

0.25 0.50 0.75 1.00
max. disorder

length of the band-edge states in a d-SL is decided already by the chemical, impuritylike binding of a single 6 layer [Figs. 1(b) and 1(c)]. Furthermore, the energy position of the gap levels at small to intermediate degrees of disorder R is also determined by the properties of noninteracting, periodically arranged 6 layers (Fig. 2). For higher values of R, disorder shifts and broadens the gap

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of intermedia5ET BT /.02 48Tf 192.2illustr44 302.67 Td (degrT BT /XiET B.02 48 109.78 336.11 Td (band-ed /Xi2 8 /Xi2247.8 Tf 27depen.56c 336.11 Td (bandT BT /Xi21866 Tf 48 109. 303 Td (the)Tj ET BT /Xi20i2 6. 48 109.78 336.11 Td (band-ed2 BT /Xi2 9.247.8 Tf 279.8-15.67270.11 Td (shifts)Tj ET22 8.99 48 109.45.44 270 Td (and)Tj ees)Tj ET8Tf 48 109. 9 314 Td (of)Tj ETBT /Xi2 8.92237192.256 291.56 Td (propertT /Xi7 Tf8 /Xi2 9.53a22.cula292 Td (R)Tj ET BTET BT /12 Tf 237192.2f states

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0.3

0.2-

(a)

75

So Q

2S 9

0.0

T=300 K

I

-0.2 -0.1 0.0 0.1 0.2 0.3

Energy (eV)

0.4

FIG. 4. (a) Density of states p(E) (solid line) and L,«(E)
(dashed line) averaged over 100 realizations of N = 2000
ML d-SL's, calculated with the Kronig-Penney model. Dots
indicate L,ff(E) obtained for an N = 128 ML pseudopotential
calculation. (b) The product g(E, T) = kTp(E)L,ft(E).

states tj2 and c3 in Fig. 1(a)]. The localization along g relaxes the kii-selection rule, thus further enhancing
the oscillator strength. The enhanced oscillator strength
is refiected by short radiative lifetimes 7". we calculate r = 1 ns for the Ij2 c3 transition at energy 1.96 eV [Fig. 1(a)]. These radiative lifetimes are 1000X faster compared to those measured in indirect-gap o-SL's (r = 5.5 p,s at T = 2 K) [16].
To understand why the PL intensity in a d-SL has a
weaker temperature dependence than in an o-SL, con-
sider vertical transport to nonradiative recombination cen-ters. This channel will be inhibited, unless there are strongly overlapping

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