Lifetime and polarization of the radiative decay of excitons, biexcitons, and trions in CdSe nanocrystal quantum dots

M   C   ,[1,2] A   F   ,[2]   A   ,   [2]

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M   ,   ,   -   ,   '   ʒ -
(X),   (X⁺   X),   (XX)
C S   ,   ,   .   ,   ,   -
-                                ,   -   -
.O,   ,   -   ,   ʒ   -
,   .
. ( )   ʒ   *bright*   ,
c   ,   ʒ   *dark*   ,   c
,   . ( ) T   -
(X): (XX)   ~1:1   (R=19.2   ). T   ʒ ,   -
2   (R=10.3   ). ( ) T   ,   (X⁺): (X)
2   ʒ   .

I. INTRODUCTION

O   ,   ,
(NQD)   ,   X (,
,   *e-h*),   X⁺ (*e-2h*)   X (2*e-h*),
XX (2*e-2h*),   . (F   . 1). P   ,   -
,   XX   C S   NQD
,   ,   , , -100-   ,   *non-*
radiative A,   ,   ~20
                radiative   X. F   A,
[2]   X⁺, X ,   XX   C S   NQD .

(*XX*)   (*X*$^+$ *X*).

II. METHOD

C S , ꞁ

R = 10.3, 14.6,   19.2 ,

.[7] T   - i

i R   .[8]   [9].

T   '   -   -

(LDA)   '   '

LDA   . T   -

S   '   '   -

'   -   '   . T

(i) -

'   '   S v,c '

-          ' (c)

$$\left(\frac{1}{\tau}\right)_{i,j} = \frac{4nF\,\omega_{ij}^{3}}{3c^{2}}|\boldsymbol{M}_{i,j}|^{2},\qquad\qquad (2)$$

n

$,\ F=3\ /(\ _{NQD}+2\ )$

$(\quad,\ =n^{2}$
$_{NQD}$

$NQD),$

$,\ \hbar\ \omega_{ij}$

c

-460.8   -460.8   -4   6460.8   T   6460 -60.110   T   6460 -60.110   08302655.14.0132T   T /F21T

$$\tau^{(SP+C)} = \left(\frac{E_g^{(SP)}}{E_g^{(SP+C)}} \right)^3 \tau^{(SP)}, \tag{5}$$

τ^{SP} τ^{SP+C} (LMT 1)
+C , (LMT 2), . T , ,

ъ *along* z [F . 4( )]. T '
[$N_V=3$ $N_C=1$ E . (1)]
' ,
' *X*. T 12

,

'
, .[19] T , , , -

,

' - '

' 75% (R . 19). I -
, [9,14] C S NQD ,
- *dark*,
( ) *bright* (F . 1( )).
T , (25 30
) 28 /F41. - 0.3 .56TD - 17. /-

,19 83TD62095414001 9T 0001 0.50010TD,T 001 0.250TD0.0001T 14T 9.9701 0.5011T 0.00014T001 0.250TD0.000

F. Trions

I   '   ,

,   '

. T X^+ [$N=3$

F . 1( )]   , $(e_1^1 h_1^2)$,

$(e_1^1 h_1^1 h_3^1)$,

$(e_1^1 h_1^1 h_4^1)$,

$(e_1^1 h_1^1 h_2^1)$. R X^+ ($N=3$)   ,

$N=1, \ldots,$, h_i.

T   - X [$N=3$

F . 1( )]   ,   , $(e_1^2 h_1^1)$,

$(e_1^2 h_2^1)$. T $(e_1^2 h_3^1)$]