Spatially-Resolved Imaging and Temperature Dependence of Single CdS Nanowire Photoluminescence

Thang B. Hoang[1], L. V. Titova[1], L. M. Smith[1] and H. E. Jackson[1]
J. M. Yarrison-Rice[2], J. L. Lensch[3] and L. J. Lauhon[3]

[1]*Department of Physics, University of Cincinnati, Cincinnati, OH 45221*
[2] *Department of Physics, Miami University, OH*
[3] *Department of Mat. Sci. and Engineering, Northwestern University, IL*

Sample growth:

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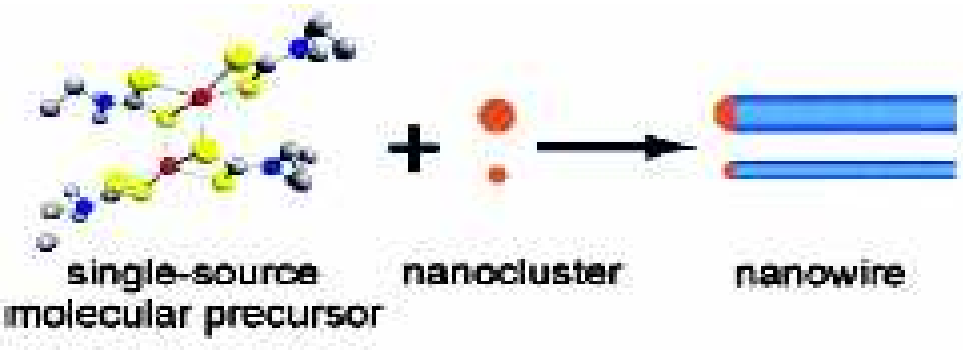
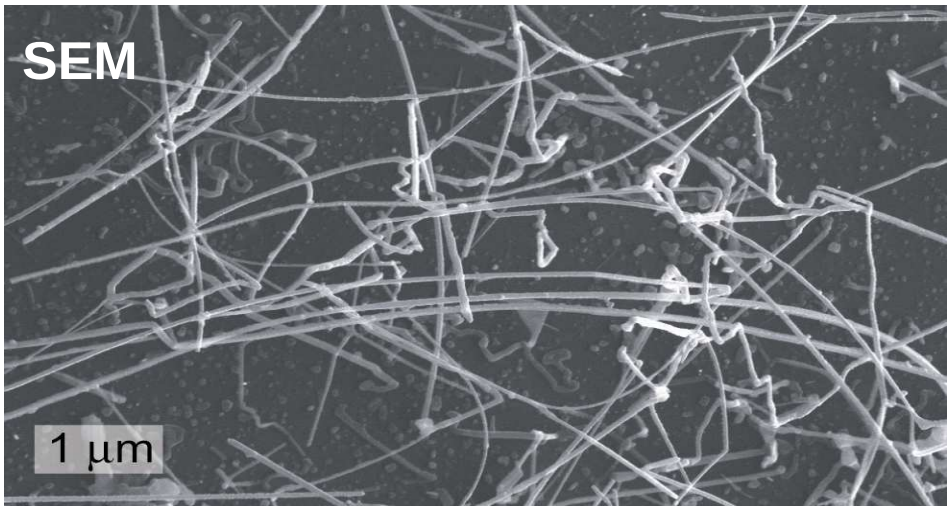
Vapor Liquid Solid (VLS) technique



C.J. Barrelet et al, J. Am. Chem. Soc. 125, 11498 (2003)



CdS nanowires grown with 10 nm catalyst

- majority of nanowires are straight and uniform
- few have significant irregularities
- nanowires were removed from the growth substrate into solution and deposited onto a silicon substrate
- individual nanowire:
  - ~ 50 – 200 nm in diameter
  - ~ 10 – 15 µm long

wire's diameter > Bohr exciton diameter (~6 nm)

=> expect no quantum confinement

Motivation: nanowire morphology and optical properties

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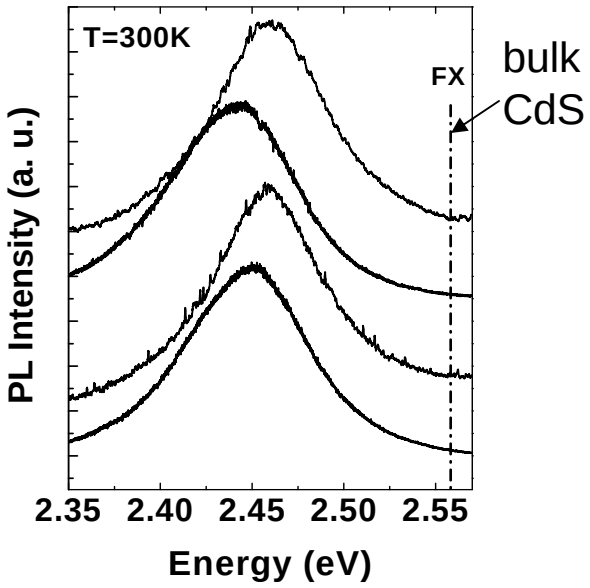
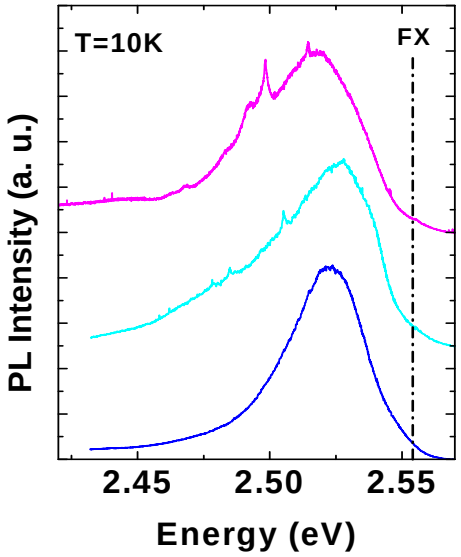
Room temperature



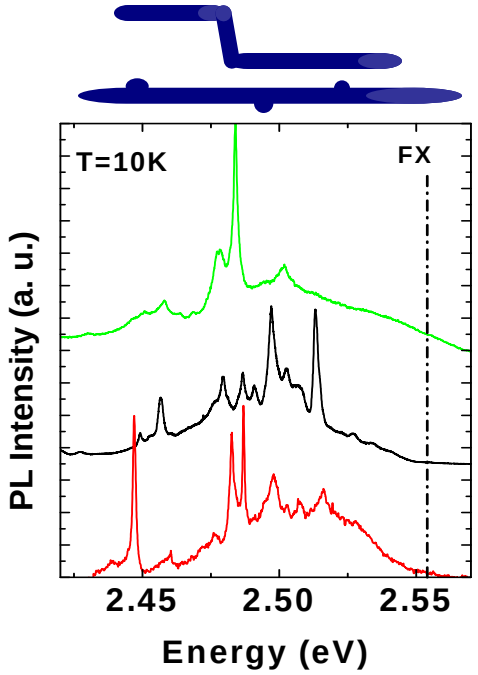
room temperature emission is similar regardless of wire morphology

Low temperature

Uniform wires



Irregular-shaped wires

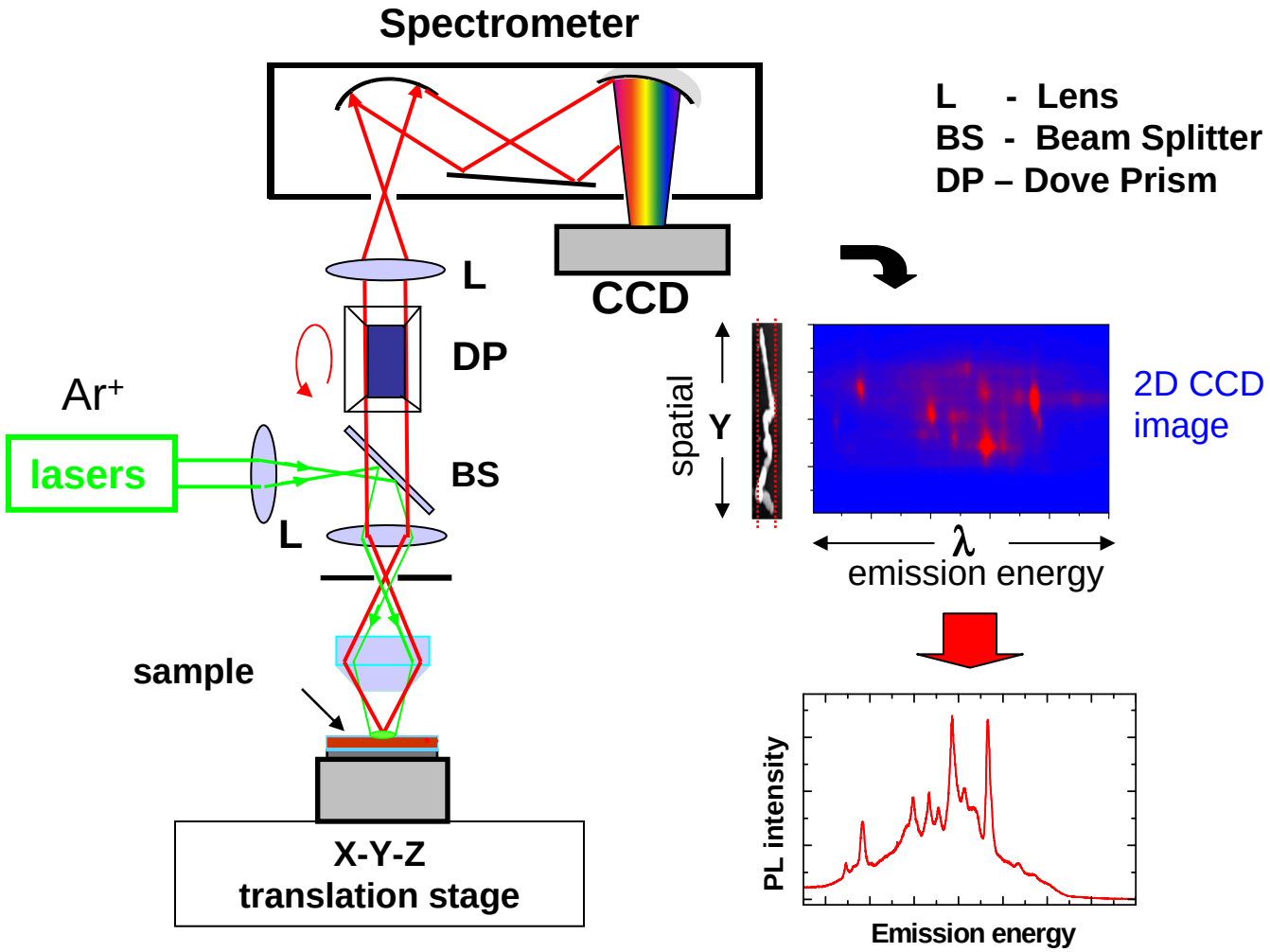


low temperature PL differs significantly

we study:

- spatially-resolved PL imaging
- temperature-dependent PL spectroscopy
- time-resolved PL spectroscopy *(L. V. Titova- previous talk)*

Experimental setup



A Dove Prism (DP) is used to rotate image of a nanowire along slit of the spectrometer.

Single nanowire studies

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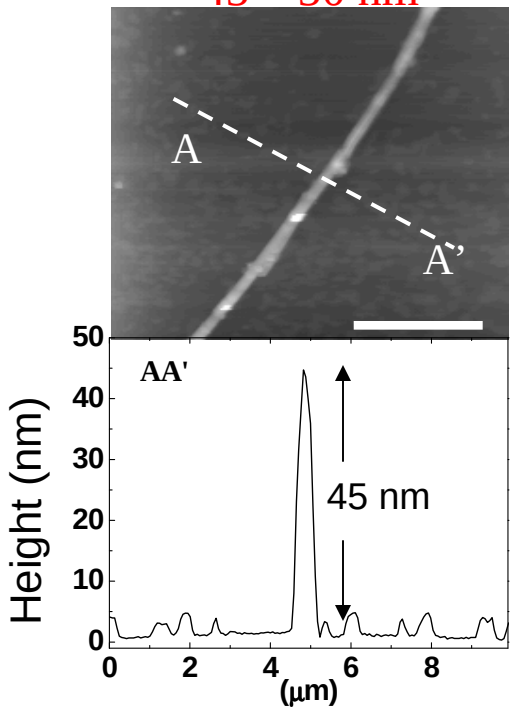
We investigated 10 different single nanowires:

AFM images of the two nanowires:

uniform wire

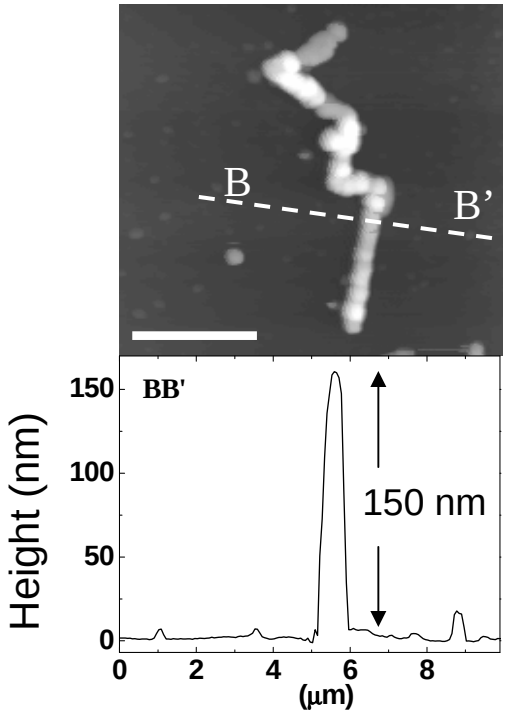
~45 – 50 nm



straight and uniform

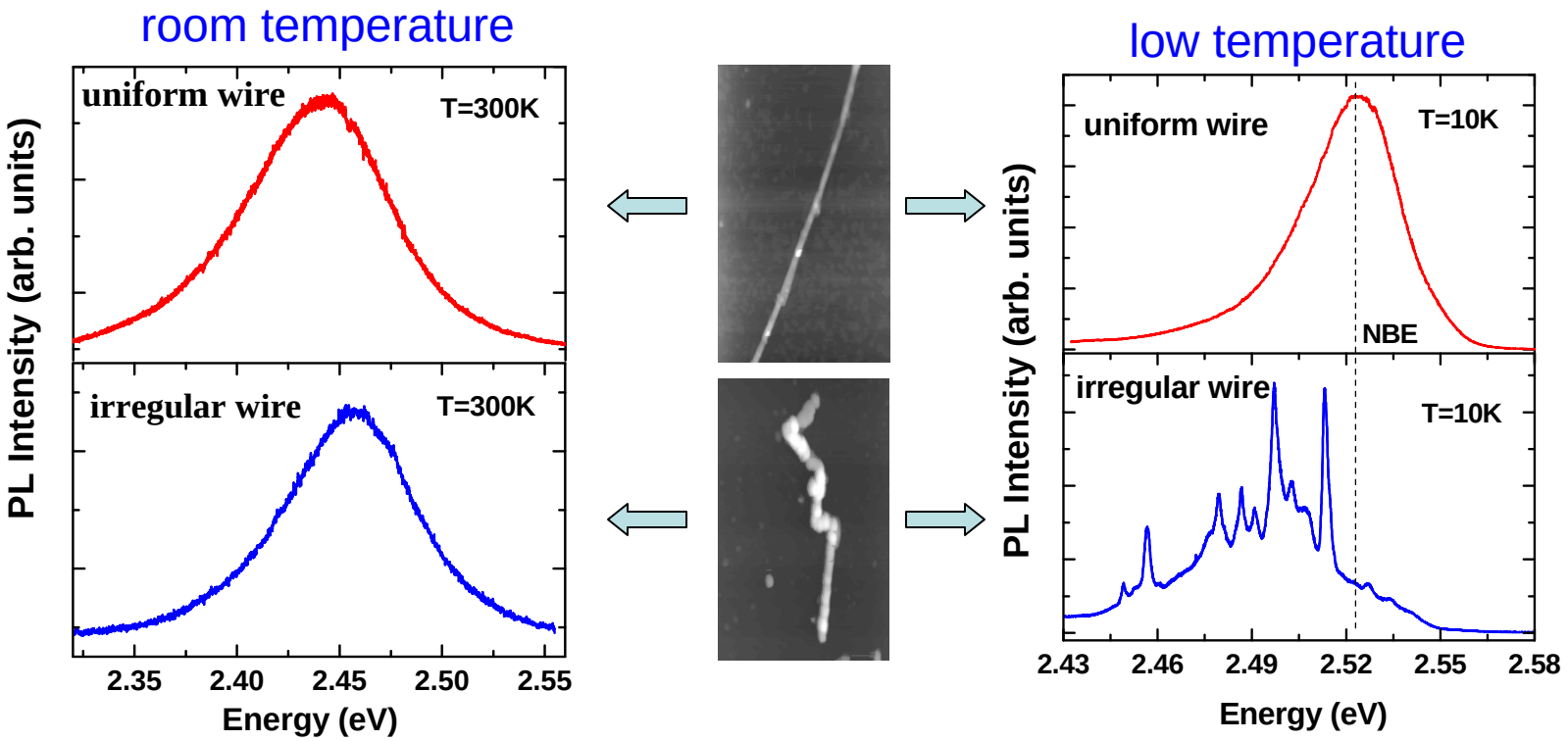
irregular wire

~100 – 200 nm



with morphological irregularities

Room-T PL vs. Low-T PL



room temperature: the PL spectra of the 2 wires are alike and consist of a single line - NBE (Near Band Edge) emission

low temperature: the PL properties of the 2 wires differ significantly

sharp lines are attributed to defect or surface state related emission

Low-T PL imaging

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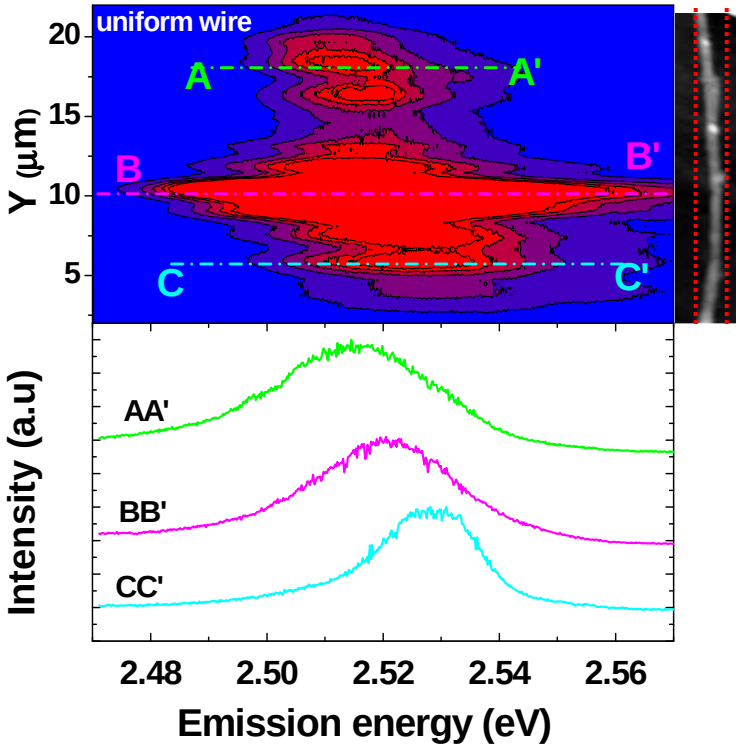
a Dove Prism is used to rotate image of a nanowire: (so it parallels to the slit of spectrometer)



only NBE emission with occasional small energy variation

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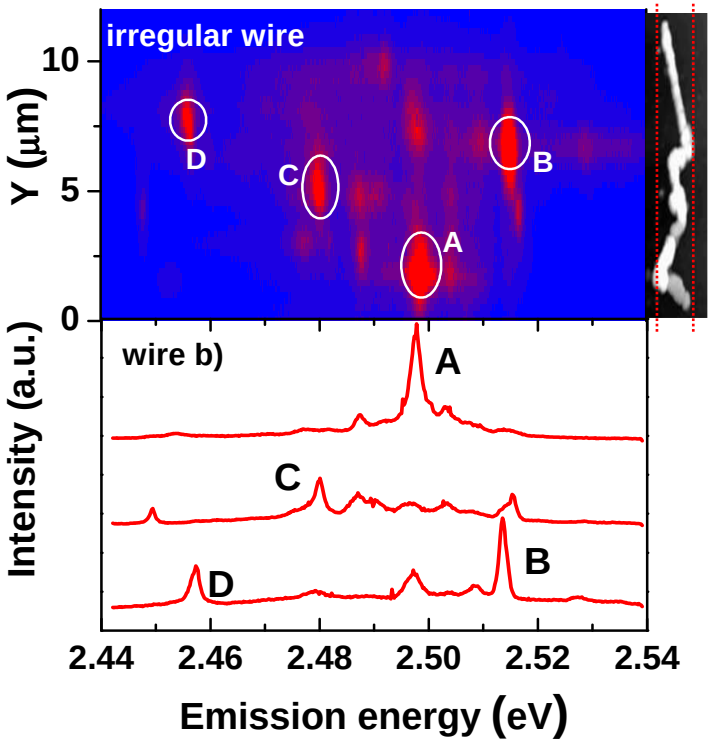
compositional/strain fluctuation



narrow lines occur at specific localized positions along the wires

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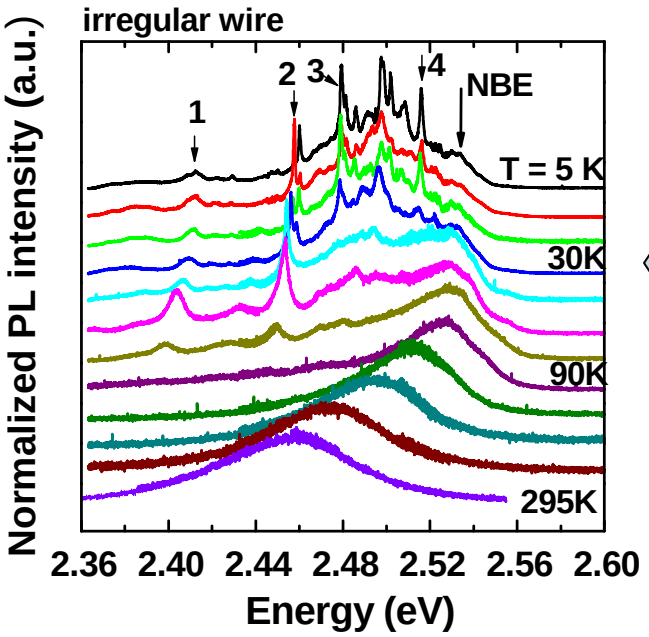
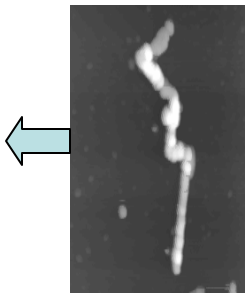
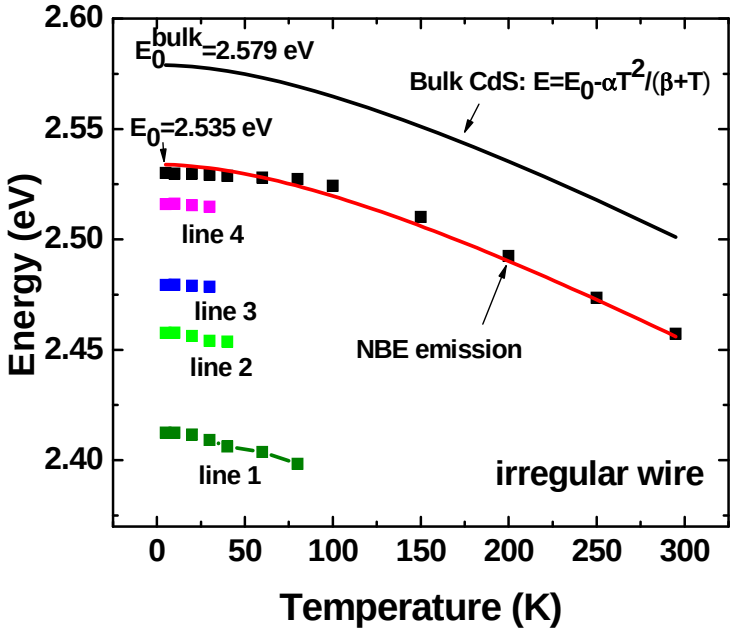
excitons localized to particular positions along the wire

Temperature dependence







- narrow lines start decreasing in intensity at 30 K and disappear by 90 K.
- NBE emission becomes the only peak as the temperature increases

- energies of the NBE emission and the localized states follow the band edge as temperature increases.
- indicates that localized states are not deep levels but are excitonic: consistence with time-resolved PL measuring of lifetime

Conclusions

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- **we investigated the optical properties of single CdS nanowires:**
  - **room temperature nanowire PL not sensitive to morphological irregularities or defects.**
  - **low temperature (< 20 K) extremely sensitive to such defects.**
  - **sharp line (localized state) emissions appear to be excitonic and related to surface states or traps.**
  - **time-resolved PL shows quantum efficiency can be increased by removing such defects or surface states**
  - **low-T PL provides quick and non-destructive method for rapidly characterizing QW growth**