Slow-positron beam studies of ZnSe and ZnTe compounds

(*preliminary data*)

- G. P. Karwasz, A. Karbowski

University Nicolaus Copernicus, Didactics of Physics Division, Toruń

- A. Marasek, K. Strzałkowski, F. Firszt

University Nicolaus Copernicus, Semiconductors and Carbon Compounds Division, Toruń, Poland

- R.S. Brusa, L. Toniuzzi, S. Mariazzi

Universita' Degli Studi di Trento, Dipartimento do Fisica, Trento, Italy

II-VI ternary compounds

- Wide gap: 1.5 eV (CdTe) ÷ 5.5 eV (BeSe):
- ligth emmiters
- photodetectors
- UV detectors in VIS and IR environment – astronomy, flame detectors, medical equipment
- scintillators
- heterojunction lasers
- Mn chalcogenides $Zn_{1-x-y}Be_xMn_ySe$ - magnetoelectronics
- …

Blue-green laser

GaN: blue-violet laser, but hardly > 450 nm

Green-blue laser (>450 nm)

II- VI compounds
* 1991 (M.A. Haase, APL 59, 1272)
but τ<400 h

Stress accumulation
→ macroscopic defects
in optically active zone

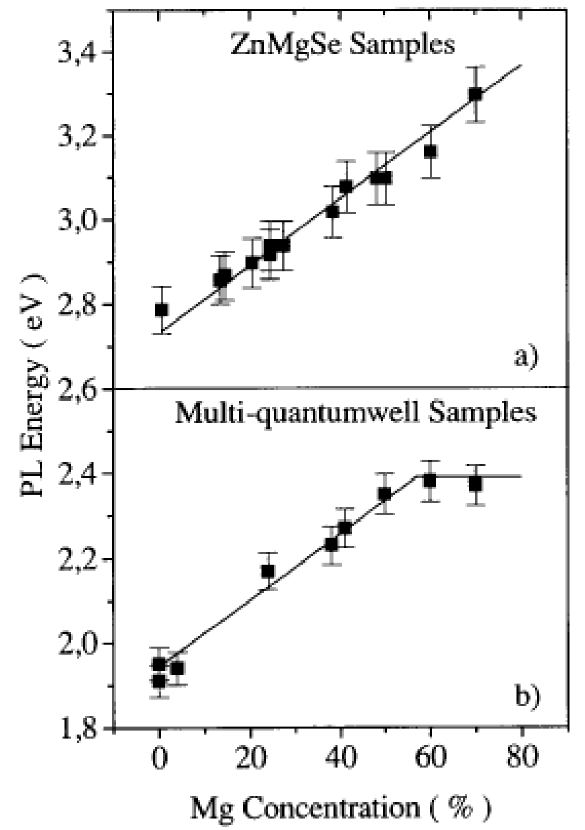

Fig. 2. (a) Energy of the near band edge PL data for the $Zn_{1-x}Mg_xSe$ samples as a function of x. The solid line is a linear fit to the data that gives an energy gap variation of 7.8 meV per percent Mg content change. (b) PL peak energy for the ZnMgSe/ZnTe multi-quantum-well samples as a function of Mg content in the ZnMgSe layer. The fit gives the same energy dependence versus Mg content as in (a). The measurements were taken at 4.2 K, using an Ar laser line at 363.8 nm for excitation.

Type I–type II band offset transition of the ZnMgSe---ZnTe system
S. O. Ferreira, H. Sitter, W. Faschinger, R. Krump and G. Brunthaler Journal of Crystal Growth Volume 146, Issues 1-4, **1995, Pages 418-421**

ZnSe ↔ZnTe↔MgSe vs. GaN

Manufacturing Industry

Blue-green semiconductor laser with 488 nm wavelength developed.(Optoelectronics)

New Materials Asia, March, 2008

E-MAIL PRINT LINK

PREMIUM

Content provided in partnership with HighBeam RESEARCH

Nichia Corp, Japan, has developed a blue-green light-emitting semiconductor laser element whose centre wavelength is 488 nm in a continuous oscillation. It aims to start sample shipments of the laser in March 2008.

The luminous wavelength of the laser is the longest of all the products with a gallium nitride (GaN) semiconductor laser element.

dopants

- **Beryllium:**

- increase the lattice rigidity (covalent bonding)
- better controlling the band gap and lattice constant to get matching with III-V etc.
- UV detectors with 3 orders rejection rate vs VIS

- **Magnesium:**

- tayloring band gap

- **Manganese:**

- opto-magnetic applications

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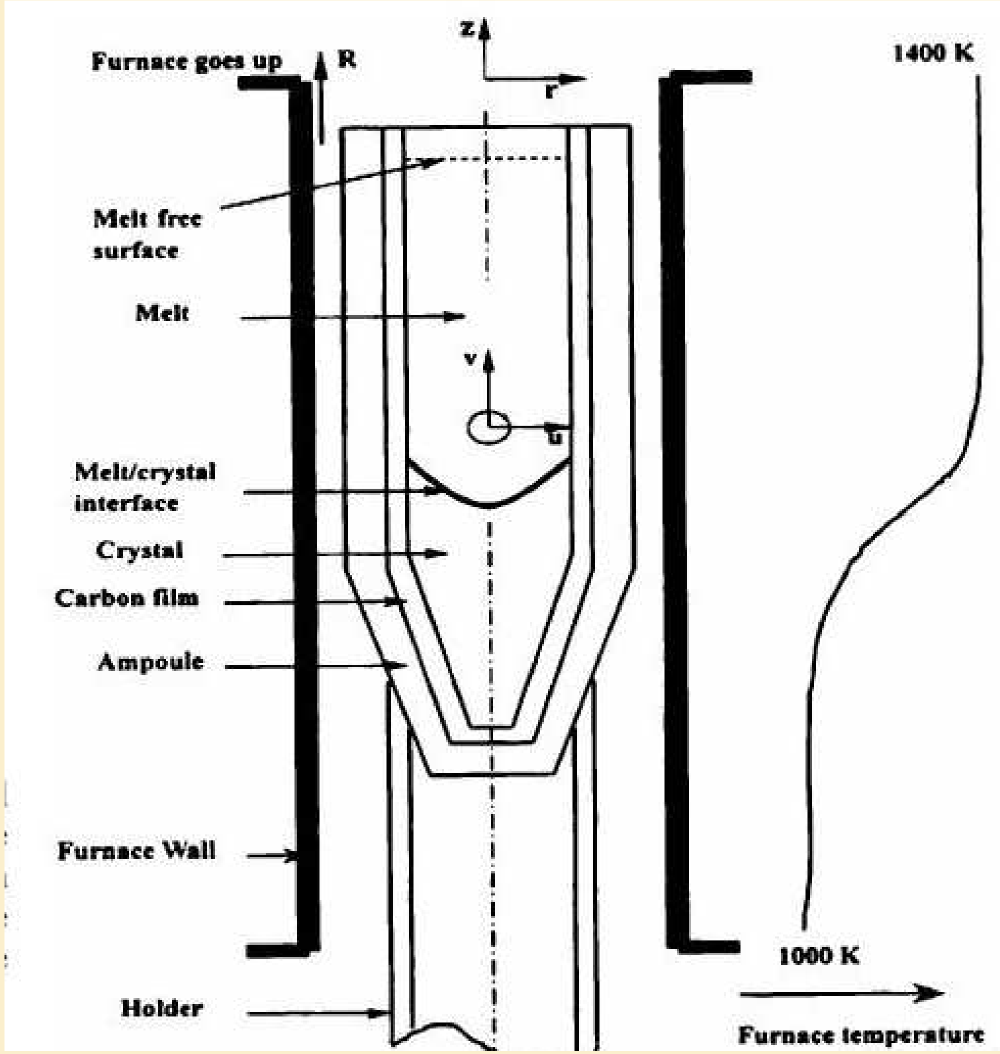
II-VI ternary synthesis

- Thin films

 - metalloorganic chemical vapour deposition (MOCVD)

- Bulk:

- Bridgman-Stockbarger technique



Samples

1) ZnSe doped with Be, Mg, Mn,
2) ZnTe doped with Cr

From the melt (ZnSe + Be, Mg, Mn):

1) hydrostatic pressure
10-13 MPa Ar
1850 K 1.5 h + 2.7 mm/h
2) upper part removed, crushed, repeated
3) cut, mechanically polished and chemically etched

Zn_xSe: Be 15% Mn 7%
Be 5% Mn 15%
Be 14% Mg 6%
Be 6% Mg 14%

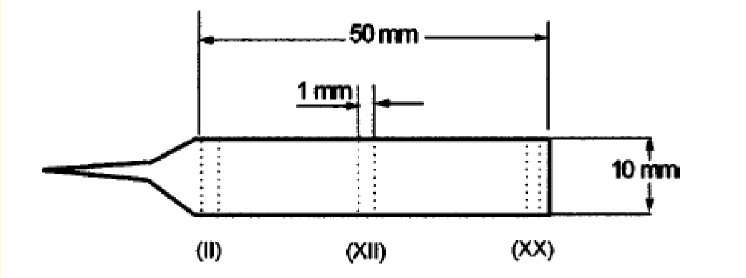
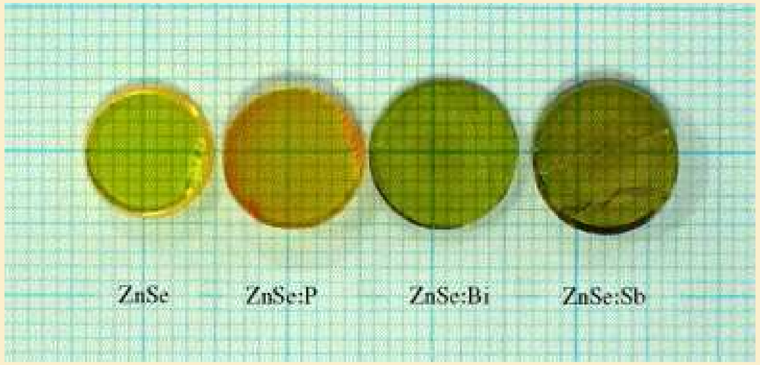


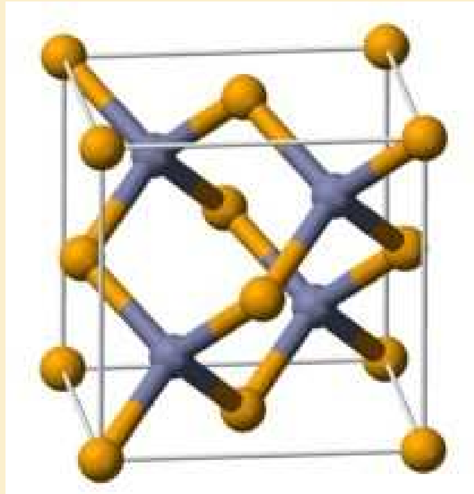
FIG. 1. Shape and dimensions of $Zn_{1-x-y}Be_xMn_ySe$ mixed crystal. Sequence of plates cut from different places of the crystal is indicated schematically.

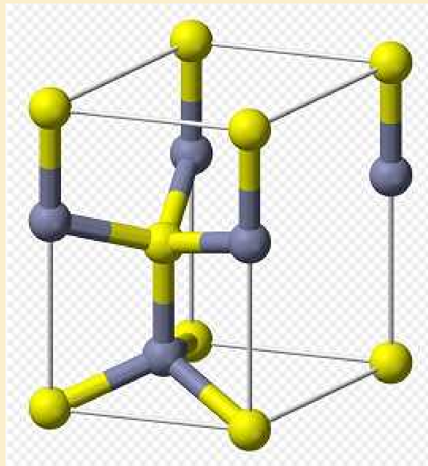


Samples

Features

- resistivity MΩ cm,
- main defects: Zn - vacancies
- cubic (sphalerite) for Mg<16%
- wurtzite for Mg>16%
- non annealed in Zn vapour
- Slow growth – few defects ($<10^{15} cm^{-3}$) in undoped





Photoluminescence

1) $Zn_{0.94}Mg_{0.06}Se$

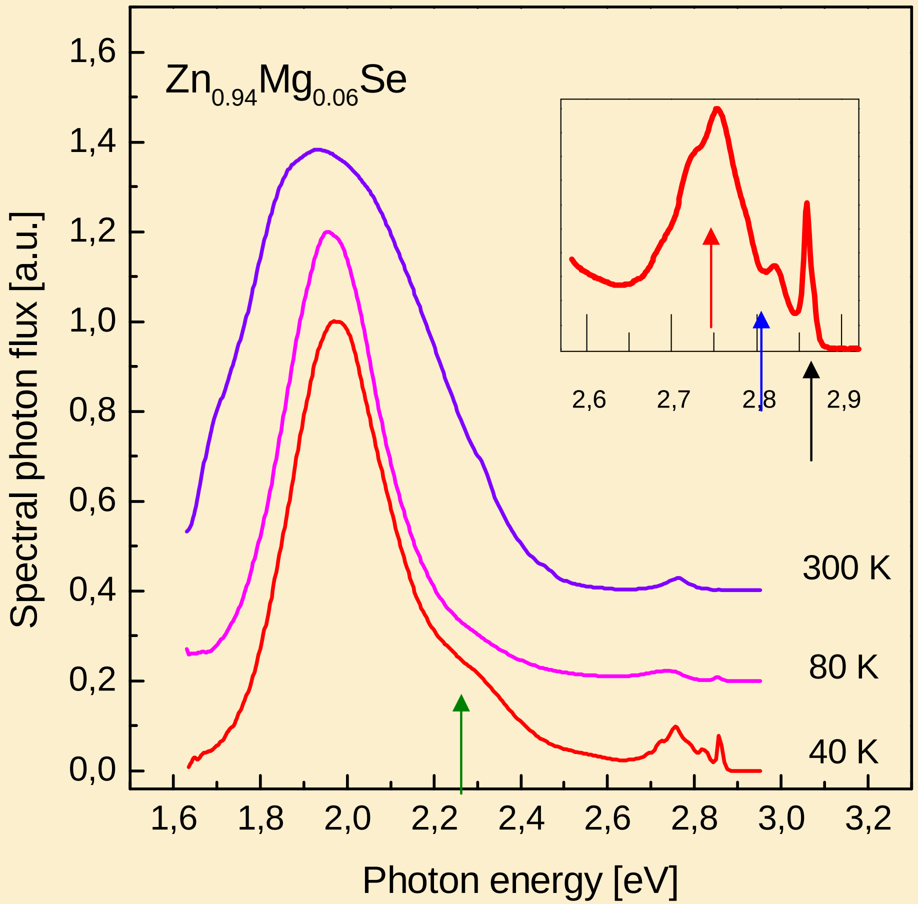
2.86 eV exciton line

2.75 „edge emission" (shallow D-A pairs)

2.2 eV, 1.98 eV **deep level** emission bands

2.816 eV an exciton bound to „some" deep defect center

2.2 eV **cation vacancy?**



He-Cd, 325 nm
55 mW

Nb. 2.2 eV emission disappears after 2 days annealing at 1230K in Zn vapour !

Photoluminescence

1) $Zn_{0.96}Be_{0.04}Se$

J. Appl. Phys. **103**, 013501 (2008)

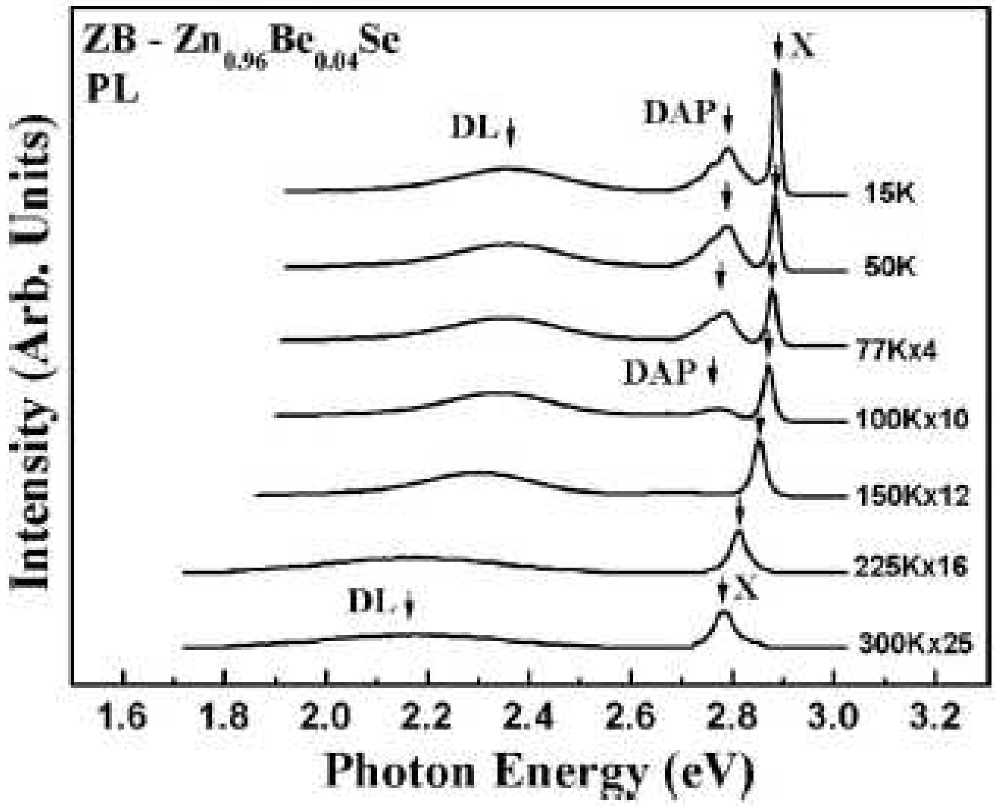


FIG. 1. The PL spectra of a $Zn_{0.96}Be_{0.04}Se$ at several temperatures between 15 and 300 K.

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Photoluminescence

$Zn_{0.88}Be_{0.06}Mg_{0.06}Se$ $Zn_{0.68}Be_{0.06}Mg_{0.26}Se$

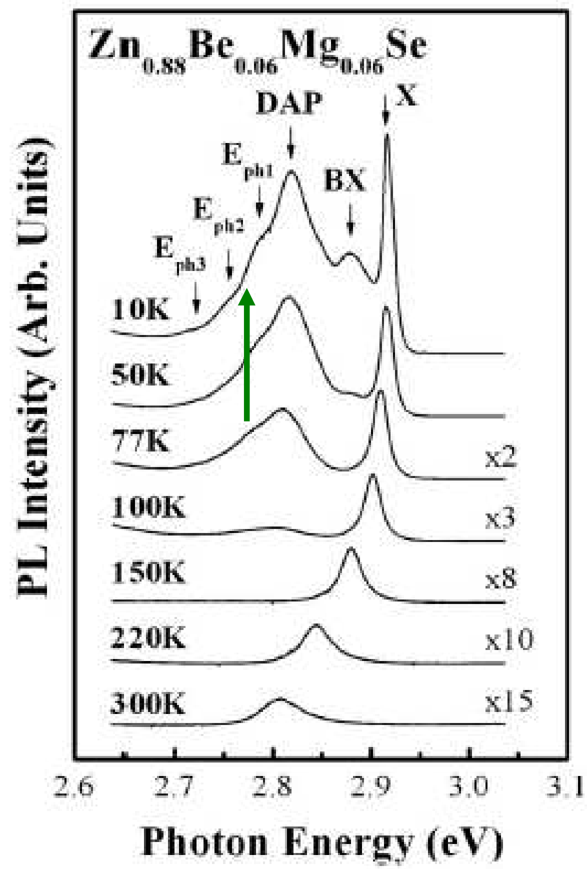

FIG. 2. The PL spectra of $Zn_{0.88}Be_{0.06}Mg_{0.06}Se$ mixed crystal at several temperatures between 10 and 300 K. The band-edge excitonic line, free to band radiative recombination and DAP emission with clearly seen LO-phonon replicas are indicated by arrows.

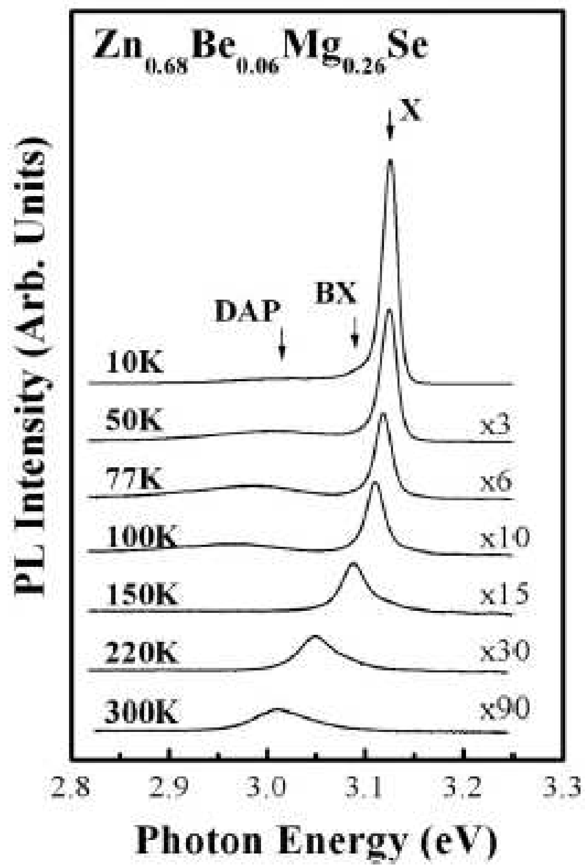

FIG. 4. The PL spectra of $Zn_{0.68}Be_{0.06}Mg_{0.26}Se$ crystal at several temperatures between 10 and 300 K. The band-edge excitonic line, free to band radiative recombination and DAP emission are indicated by arrows.

Previous positron studies

JOURNAL OF APPLIED PHYSICS VOLUME 94, NUMBER 3 1 AUGUST 2003

Defect characterization of ZnBeSe solid solutions by means of positron annihilation and photoluminescence techniques

F. Plazaola,[a] J. Flyktman, and K. Saarinen
Laboratory of Physics, Helsinki University of Technology, 02150 Espoo, Finland

L. Dobrzynski
Institute of Experimental Physics, University of Bialystok, Lipowa Street 41, 15-424 Bialystok, Poland and The Soltan Institute for Nuclear Studies, 05-400 Otwock–Swierk, Poland

F. Firszt, S. Legowski, and H. Meczynska
Instytut Fizyki, Uniwersytet Mikolaja Kopernika, Grudziadzka 5, 87-100 Torun, Poland

W. Paszkowicz
Institute of Physics, Polish Academy of Sciences, Aleja Lotników 32/46, 02668 Warsaw, Poland

H. Reniewicz
Institute of Experimental Physics, University of Bialystok, Lipowa Street 41, 15-424 Bialystok, Poland

Photoluminescence

- $Zn_{0.96}Be_{0.04}Se$

J. Appl. Phys., Vol. 94, No. 3, 1 August 2003

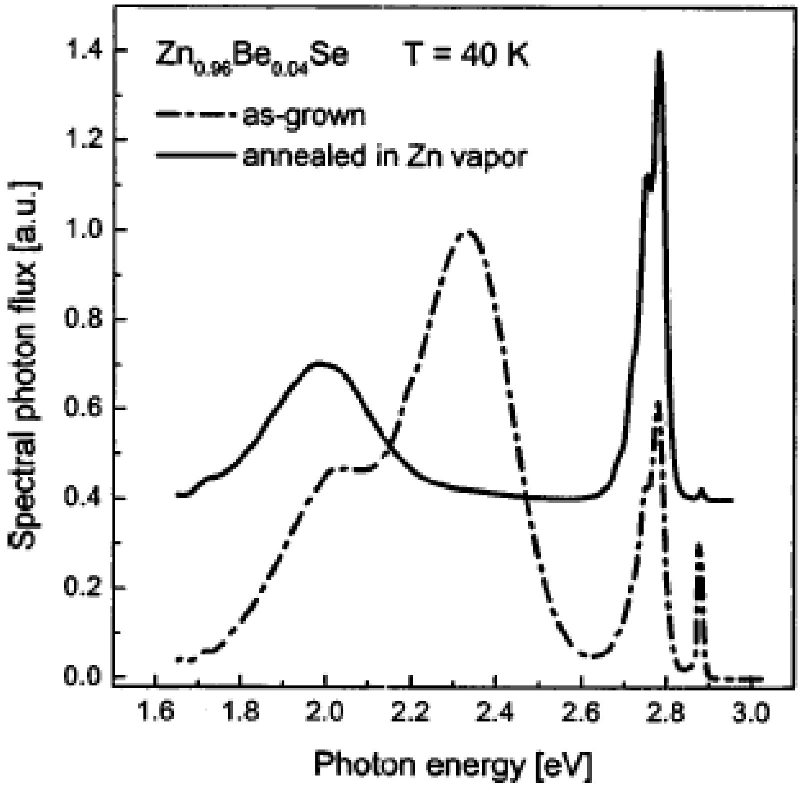

FIG. 5. Photoluminescence spectra measured at $T = 40$ K of $Zn_{0.96}Be_{0.04}Se$ as grown and annealed in zinc vapor at $T = 1230$ K for 48 h.

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Photoluminescence

- $Zn_{1-x}Be_xSe$

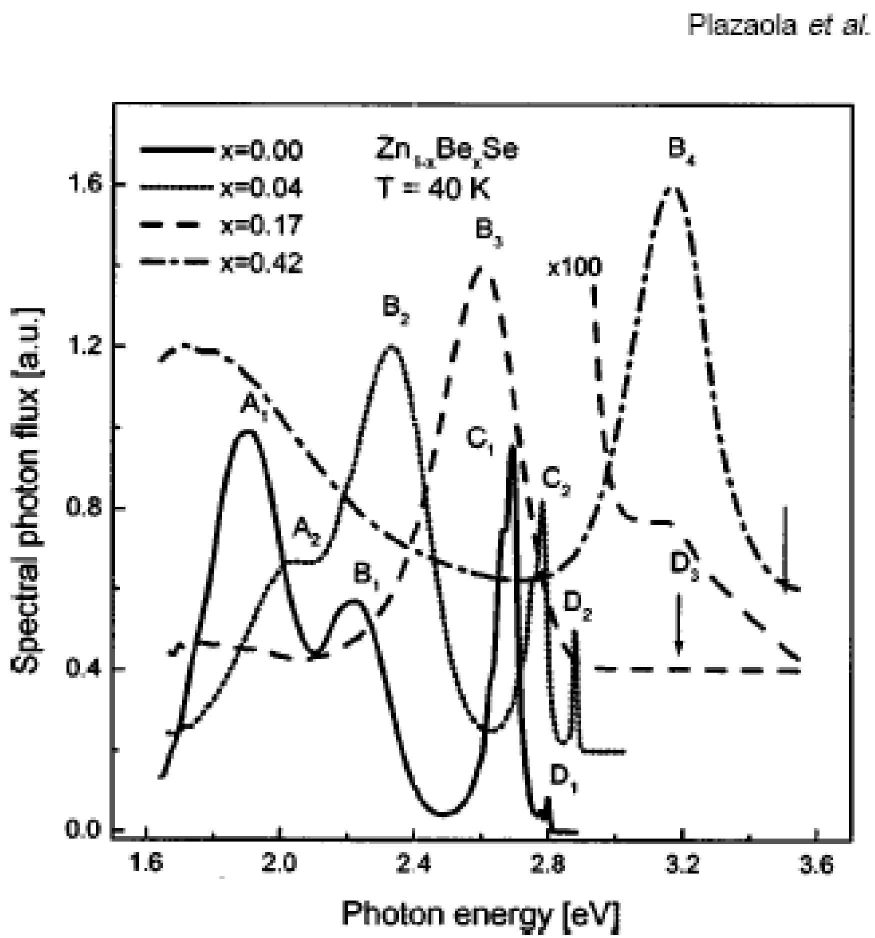

FIG. 4. Photoluminescence spectra measured at $T = 40$ K of $Zn_{1-x}Be_xSe$ crystals with $x = 0$, 0.04, 0.17, and 0.42.

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Positron lifetime

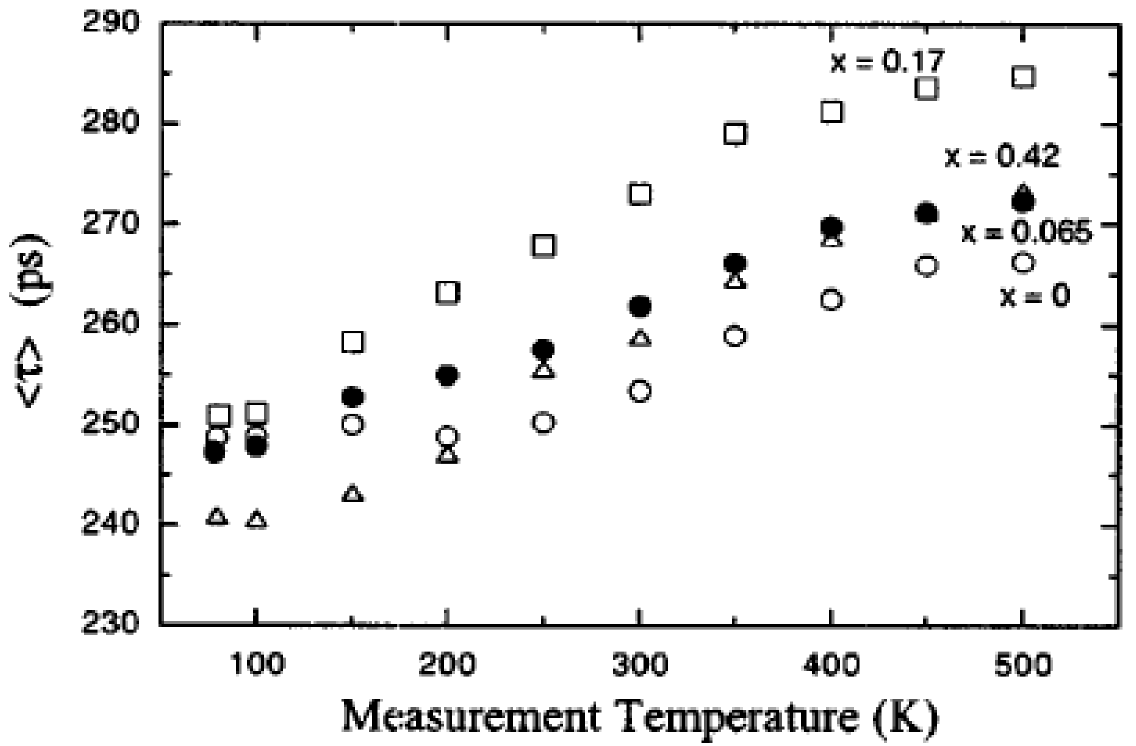

FIG. 1. Positron average lifetime $\langle\tau\rangle$ vs the temperature for $Zn_{1-x}Be_xSe$ crystals with $x=0$ (open circles), 0.065 (closed circles), 0.17 (squares), and 0.42 (triangles).

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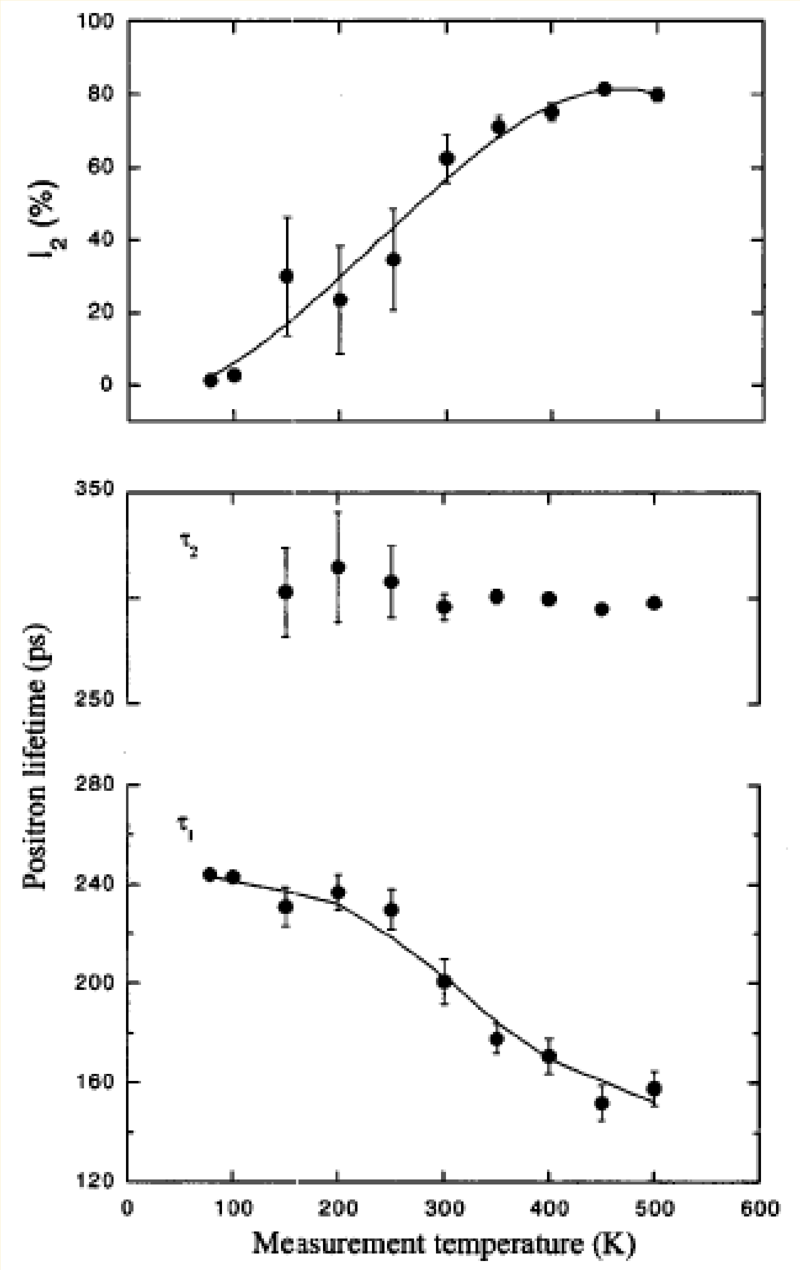
Positron lifetime

Be -6.5%



J. Appl. Phys., Vol. 94, No. 3, 1 August 2003

TABLE I. Data for the $Zn_{1-x}Be_xSe$ sphalerite structures used in the calculations. The structures simulated have lattice constant a. τ_B corresponds to the theoretical bulk lifetimes calculated in bulk compound semiconductors.

x	a (Å)	Volume/atom (Å^3)	τ_B (ps)
0	5.6675	22.76	250.5
0.0625	5.6304	22.31	246.8
0.156 25	5.5817	21.74	242.1
0.25	5.5330	21.17	237.4
0.5	5.4031	19.72	225.5

TABLE II. Calculated lifetimes τ_V in different types of neutral and unrelaxed vacancy-type defects in $Zn_{1-x}Be_xSe$.

x	V_{Zn} τ_v (ps)	V_{Be} τ_v (ps)	V_{Se} τ_v (ps)	$V_{Zn}V_{Se}$ τ_v (ps)	$V_{Be}V_{Se}$ τ_v (ps)
0	264.9		278.9	343.8	
0.0625	260.8	260.5	281.0	339.4	339.9
0.156 25	255.3	255.1	275.8	333.6	333.9
0.25	252.1	250.1	270.5	330.8	328.3
0.5	240.3	238.4	262.3	317.7	315.8

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Positron lifetime

$Zn_{1-x}\ Be_x\ Se$

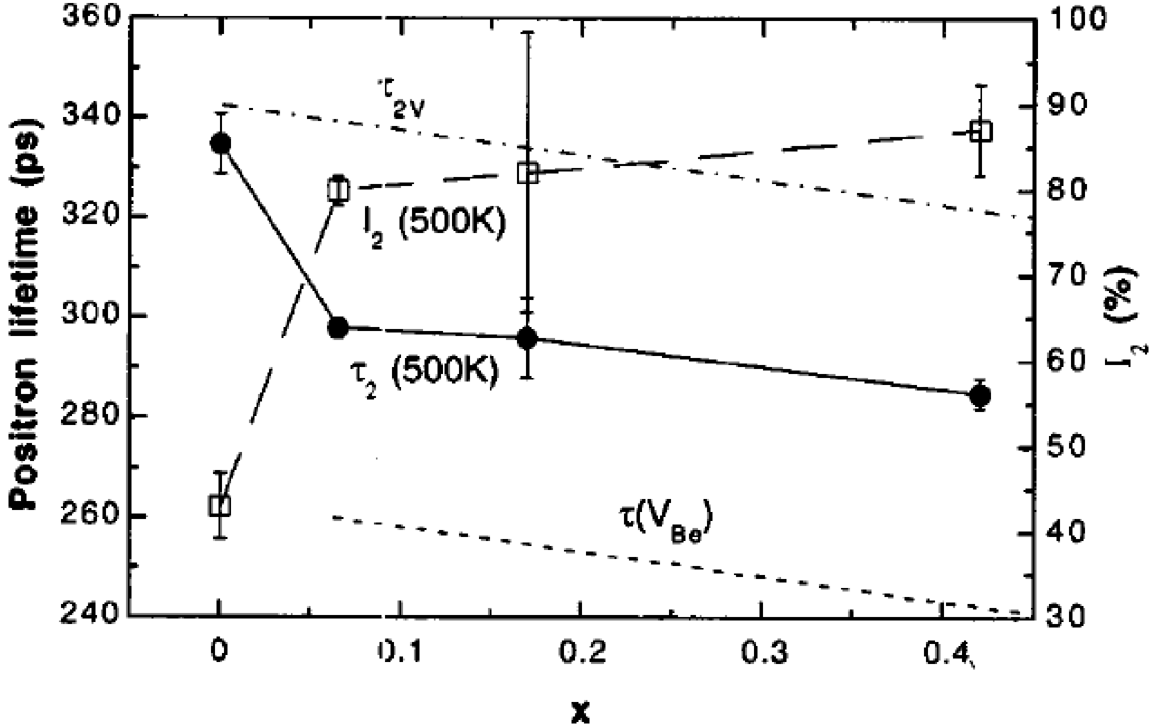

FIG. 3. τ_2 and I_2 are the lifetime and intensity, respectively, of the second component measured at 500 K vs the Be content in the compound semiconductor. The continuous and broken lines correspond to fits of the theoretical positron lifetimes in monovacancies of Be and in divacancies, respectively.

divacancy relaxed inward
monovacancy relaxed outward

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Trento slow positron beam

E=100 eV – 25 keV
spot < 5 mm

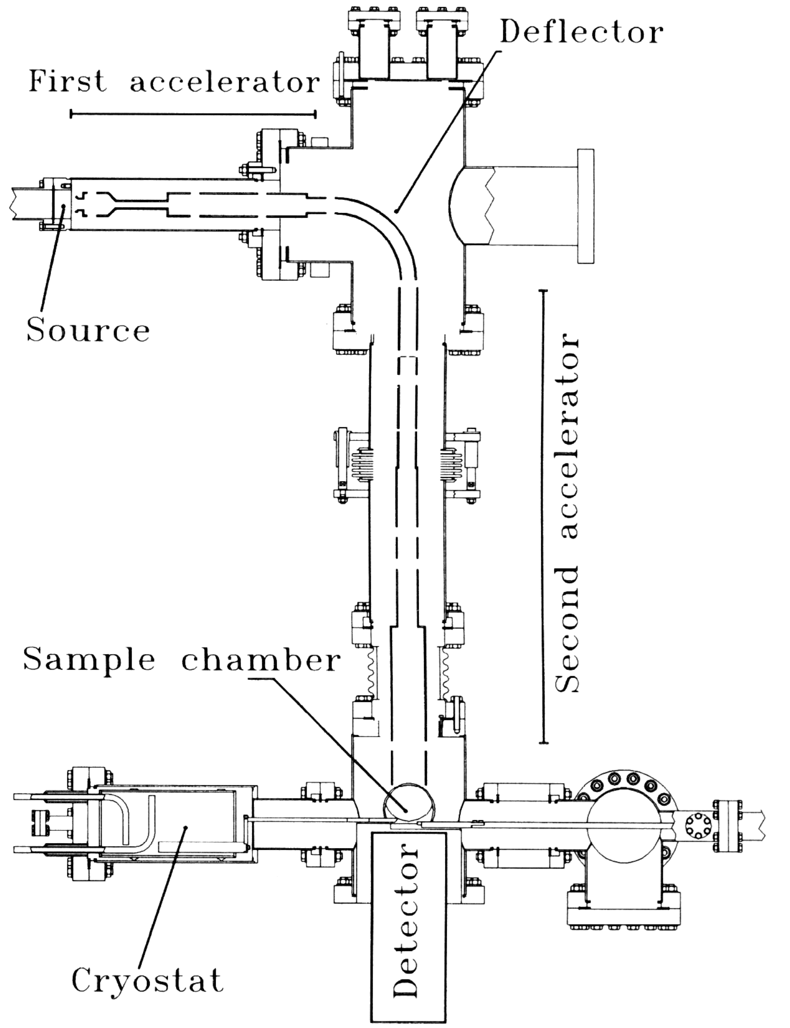
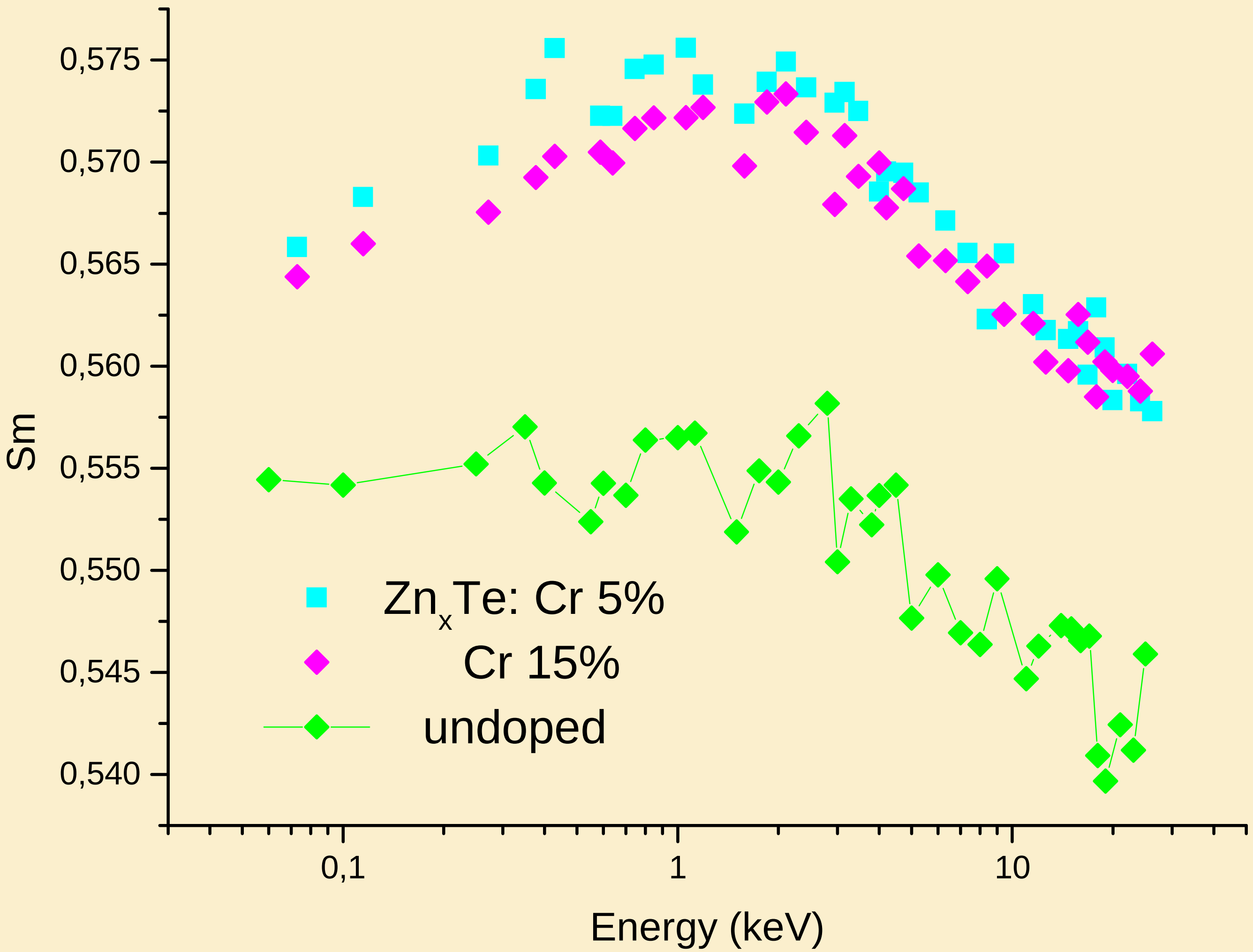
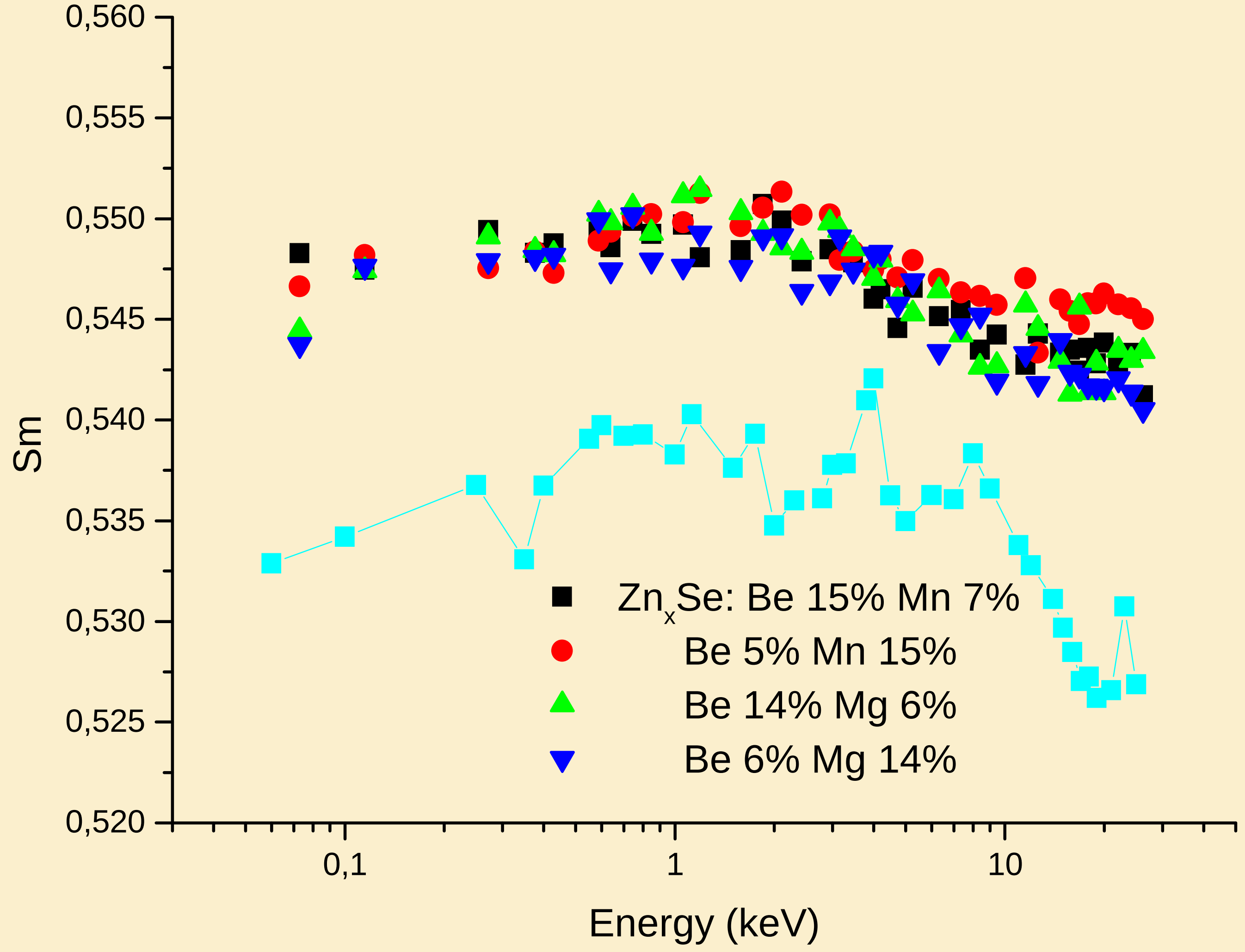


Fig. 1. A schematic layout of the electrostatic positron beam constructed in the Trento laboratory.

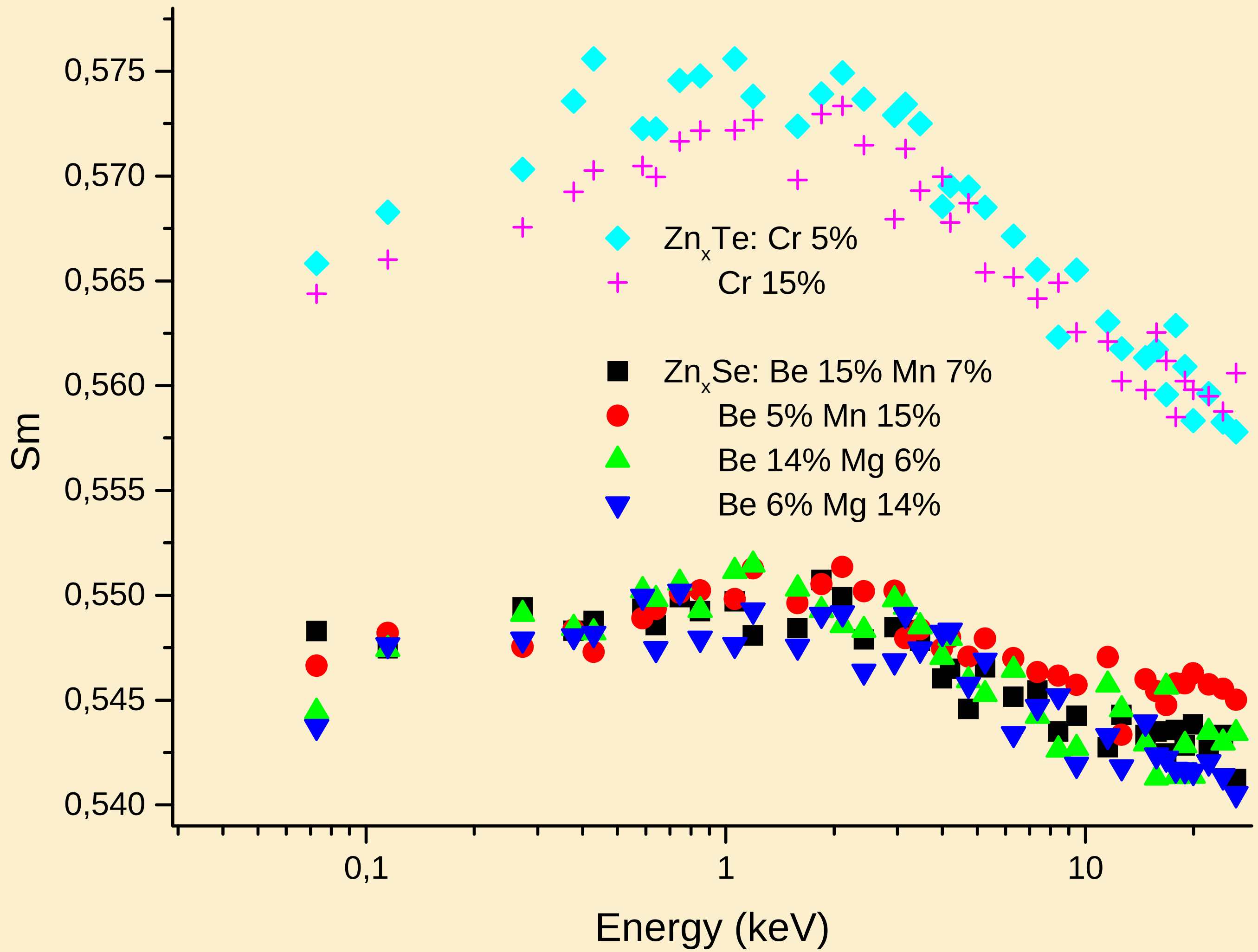
Doppler broadening ZnTe



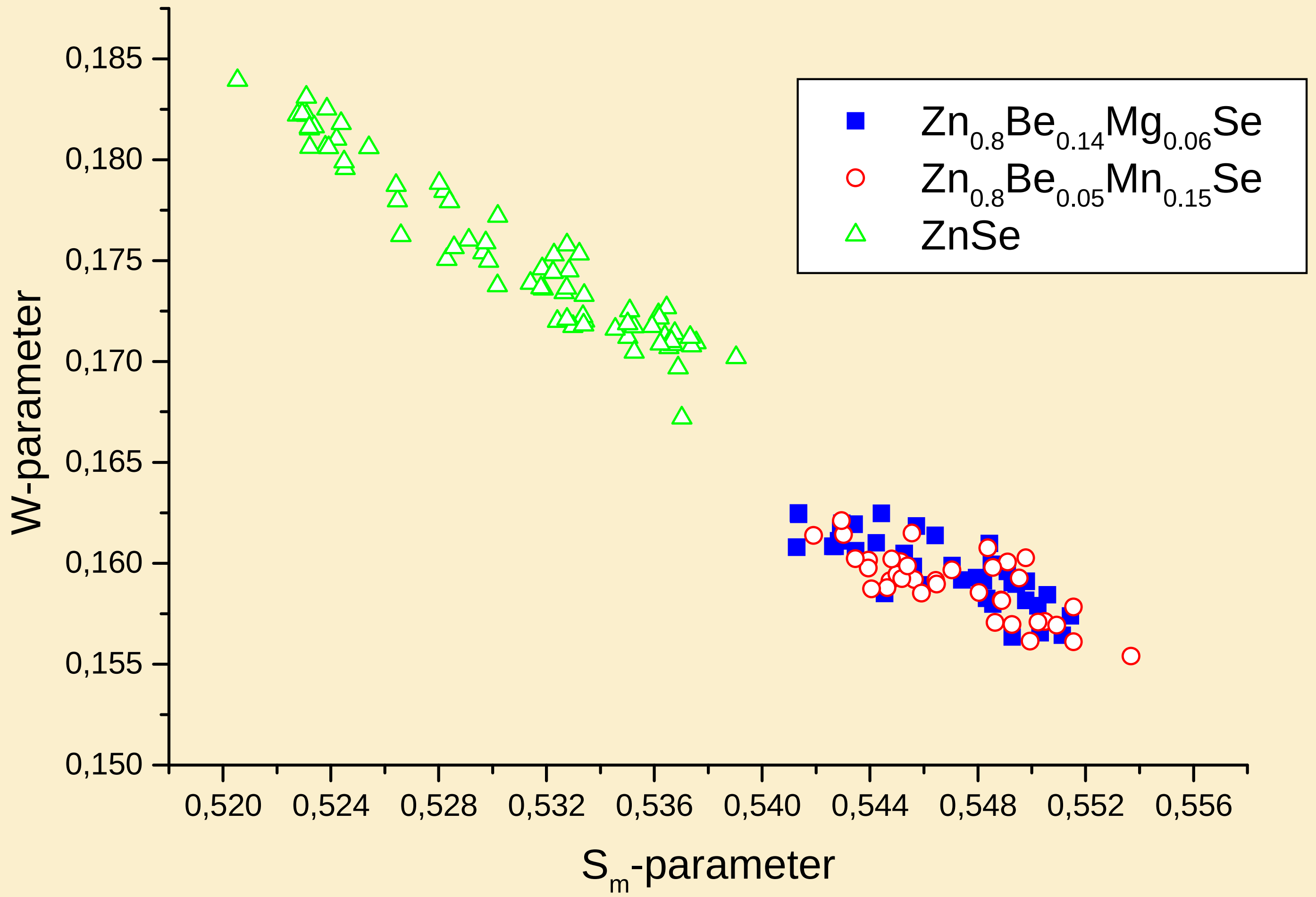
Doppler broadening ZnSe



Comparison ZnTe - ZnSe

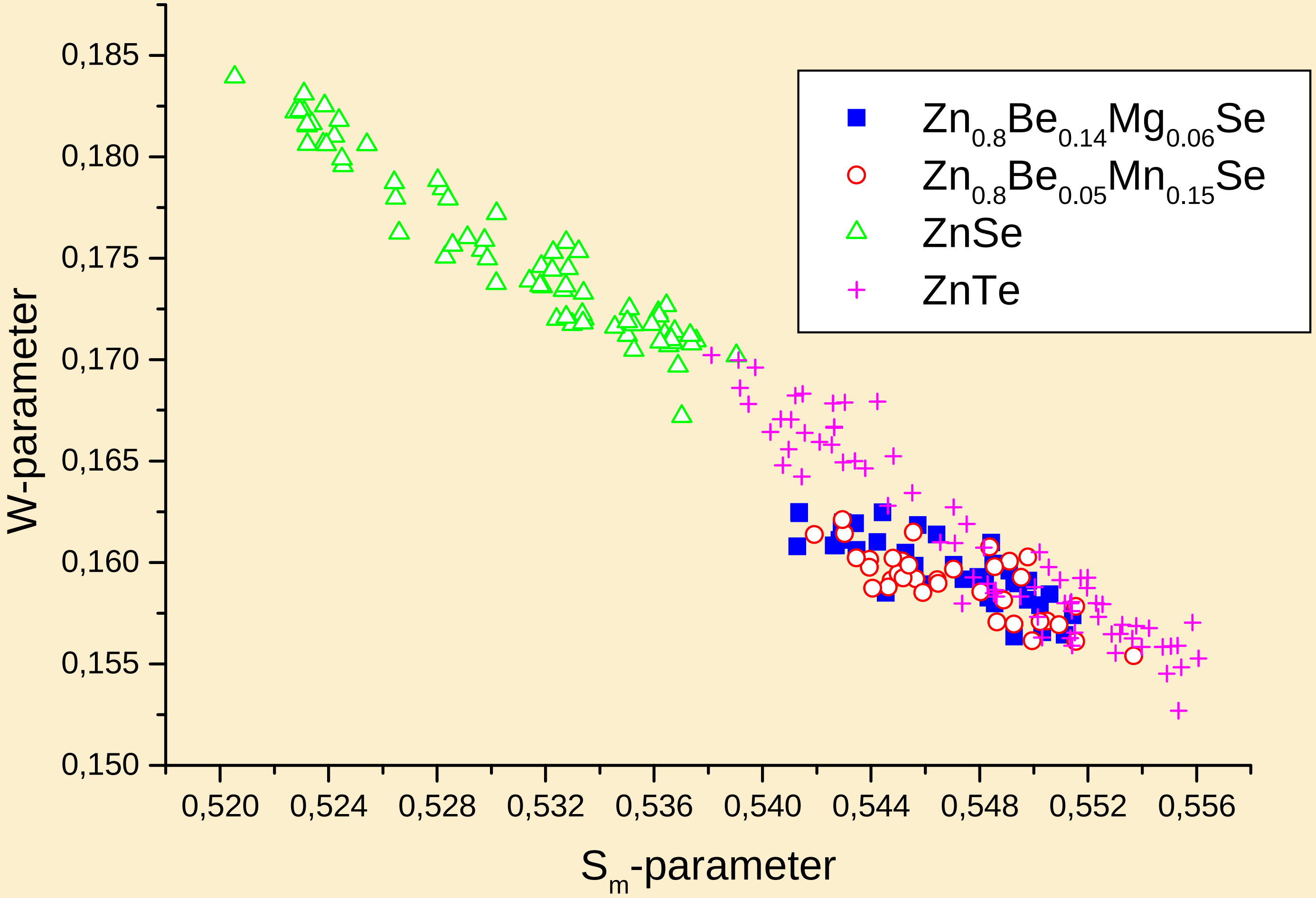


S-W curve



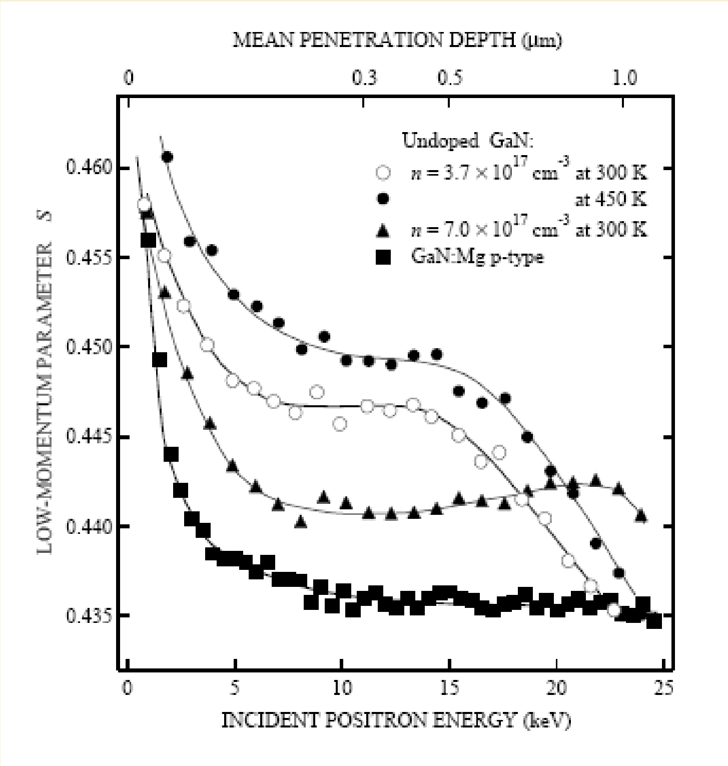
0,185
0,180
0,175
0,170
0,165
0,160
0,155
0,150
W-parameter
0,520
0,524
0,528
0,532
0,536
0,540
0,544
0,548
0,552
0,556
S_m-parameter
$Zn_{0.8}Be_{0.14}Mg_{0.06}Se$
$Zn_{0.8}Be_{0.05}Mn_{0.15}Se$
ZnSe

S-W curve



0,185
0,180
0,175
0,170
0,165
0,160
0,155
0,150
W-parameter
0,520
0,524
0,528
0,532
0,536
0,540
0,544
0,548
0,552
0,556
Sm-parameter
Zn0.8Be0.14Mg0.06Se
Zn0.8Be0.05Mn0.15Se
ZnSe
ZnTe

work in progress…



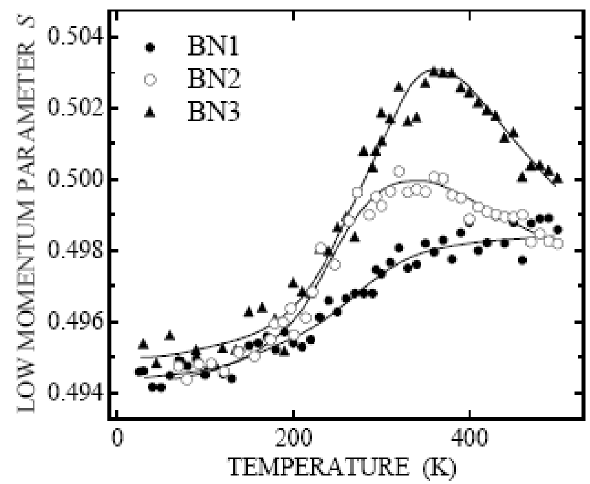


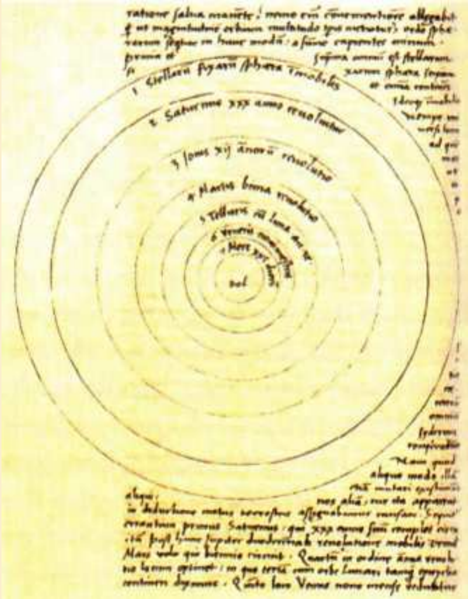
Figure 15: The low momentum parameter S vs. measurement temperature in N-doped ZnSe layers [Publ. V].

CHARACTERIZATION OF NATIVE VACANCIES
IN EPITAXIAL GaN AND ZnSe
SEMICONDUCTOR LAYERS BY POSITRON
ANNIHILATION SPECTROSCOPY

Juha Oila

Laboratory of Physics
Helsinki University of Technology
Espoo, Finland

-Temperature dependence
-Surface defects?
-Doppler coincidence
-Lifetime



Thank you for the attention!