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international centre for theoretical physics

SMR.1135 - 14

THIRD WORKSHOP ON
THIN FILMS PHYSICS AND TECHNOLOGY
(8 - 24 MARCH 1999)
including
TOPICAL CONFERENCE ON
MICROSTRUCTURE AND SURFACE MORPHOLOGY
EVOLUTION IN THIN FILMS
(24 - 26 MARCH 1999)

"Thin film growth by supersonic seeded beams"

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Thin Films Growth From Seeded Supersonic Beams

Salvatore Iannotta

CEFSA

*C.N.R./I.T.C. Research Center
on the Physics of Aggregates
Povo di Trento - ITALY*

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(Research Center on the Physics of Aggregates)

- *Gas-Surface Dynamics Dept:*
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  - *Researchers and Fellowships: -G. Ciullo -F. Biasioli - M. van Opbergen - T. Toccoli - M. Moratti -M. Malacarne*
  - *Technicians: C. Corradi - M. Mazzola*

- *Collaboration with:*
  - *Physics Dept. University of Milan (P. Milani - A. Podestà - P.Piseri -E. Barborini)*
  - *University of Nijmegen (- J. Reuss -A.Parker)*
  - *Max Planck Institute Göttingen (H.G. Rubhan)*
  - *ICM - CNR Milano (W. Porzio)*
  - *University of Aveiro (A. Kharlamov)*
  - *PF MADESSII: ISM - CNR Trieste (M. Pedio),TASC - INFM Trieste (M. Sancrotti), Univ. ROMA III (F. Evangelisti, M. Deseta)*
  - *PF MAT II: TEMPE-CNR - Lecco (A.Tuissi), LAMEL-CNR*

Summary

- *Aims*
- *Nozzle versus Knudsen Beams*
  - *Basic Properties*
- *Hyperthermal Seedable Beams of Fullerene*
  - *Synthesis of SiC on Si(111)7x7*
- *PAGACS Source for Refractory Materials*
  - *Growth of SMA films (TiNi)*
- *Seeded Bems of Oligo-Polimers*
  - *Preparation of High Quality Thin Films of Oligo-Thiophenes*

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AIMS:

(P.Milani and S. Iannotta, "Synthesis of Nanophase Materials By Cluster Beam Deposition" - Springer Verlag 1999

- *High Quality Thin Films by Controlling Precursors by the Beam Parameters:*
  - *Kinetic Energy and Momentum*
  - *State of Aggregation (Clustering)*
  - *Internal Energy*
  - *Flux on a large range (up to 10^3 Times than in Knudsen cells)*
- *Synthesis of Nanocrystalline Films from Controlled Nanoparticles Building Blocks*
  - *Fundamental and Technological Relevance*
- *Control Crystalline or Amorphous Character of the Films from the Initial State of the Particles in the Beam*

↓

Characterization of the Beam

↓

Correlation between the properties of the precursors in the beam and of the films

Supersonic Free Jets ⇔ Classical (Knudsen)

λ = mean free path
d = nozzle diameter
K_n = Knudsen Number
h_0 = enthalpy per unit mass
$\gamma = C_p/C_v$
M=Mach Number=v/v_s

Supersonic Free Jets

- $K_n=\lambda/d < 1$ ⇨ *gas is under-expanded* ⇨ *a large number of collisions still occur*
- $T_f \ll T_0$, $P_f \ll P_0$ ⇨ Isoentropic Expansion, Very High Gradients

  $h_0=h+v^2/2$ ⇨ $v_f \gg v$

  supersonic flow

  $v_f=(2kT_0/m)^{1/2}(\gamma / \gamma -1)^{1/2}$ $M \gg 1$
- Narrow Velocity Spreads: $\Delta v/v \approx (2/\gamma)^{1/2}/M$

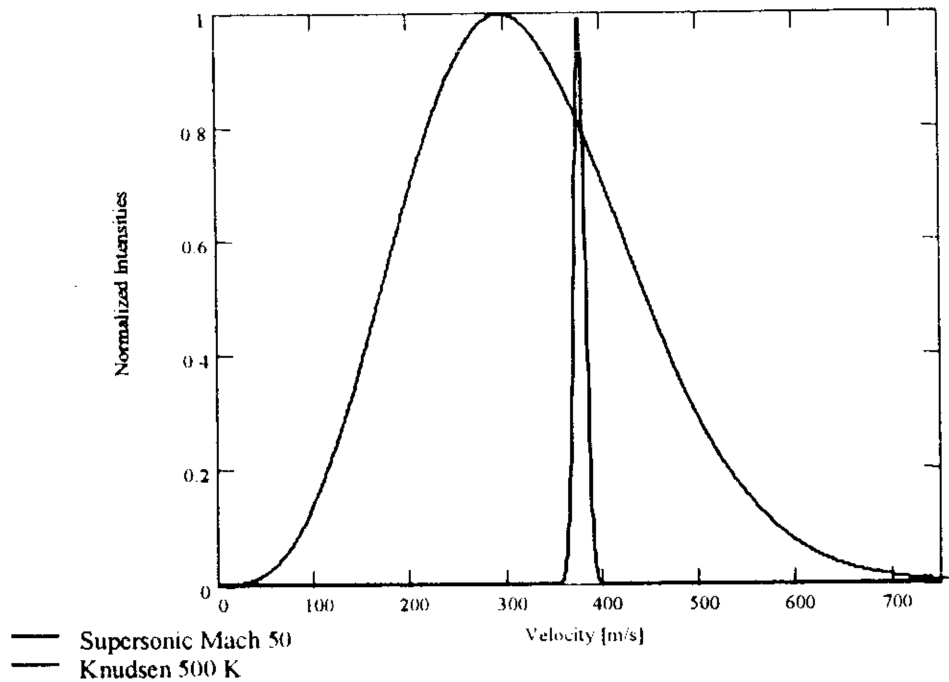
  $\Delta v/v \approx 1 \div 15$ %
- Very high forward intensity
- Ro-vibrational cooling (non equilibrium)
- Clustering by constrained nozzles

Classical (Knudsen)

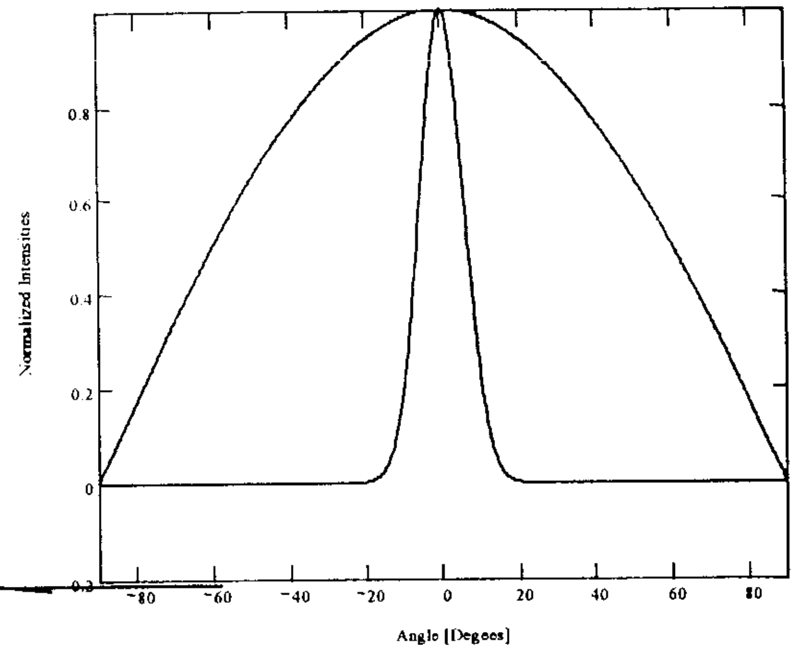
- $K_n=\lambda/d > 1$ ⇨ molecular effusion no collision afterwards
- $T_f \approx T_0$
- $v_f \approx v_0$
- Maxwellian velocity distribution
- Cosine-like angular intensity distribution
- No cooling (equilibrium with the oven)
- Clustering by esternal cooling and gas aggregation

Supersonic Free Jets ⇄ Classical (Knudsen)

Velocity Distributions



Angular Distributions



$I_{nozzle}(v_{mp})/I_{knudsen} = n_{0(nozzle)} f(M,\gamma)/n_{0(Knudsen)}$ $f(M, \gamma) \approx 8\text{-}10$ ➡ $I_{nozzle}(v_{mp})/I_{knudsen} \approx 10^2\text{-}10^3$

Seeding in Light Gases

⇨ $E_i \approx (m_i/\langle m \rangle) T_0$ $\langle m \rangle = \Sigma_i X_i m_i$ *High dilution* ➡ *Aerodynamic Acceleration*

example C_{60} in He: E>60 eV

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Nozzle Sources

- *Vaporization Methods:*
  - *Joule Heating*
  - *Plasma*
  - *Laser Vaporization*
  - *Glow and Arc Discharges*
- *Regime of Operation:*
  - *Continuous*
  - *Pulsed*
- *Type of Nozzles*
  - *Sonic (No aggregation)*
  - *Conical (Converging-Diverging)*
  - *Campargue*

→ *Clustering*

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Why Seeded (Aerodynamically Accelerated) Supersonic Molecular Beams (HSB) of Fullerenes?

- *Investigate Fullerenes Properties.*
- *Direct Tool to Study Interactions with Atoms, Molecules and Surfaces.*
- *A Very Interesting Range of Kinetic Energies 1-60 eV:*
  - *Gas Surface Energy Transfer:*
    - *from adsorption-desorption to impulsive;*
    - *angular scattering and kinetic energy induced corrugation;*
  - *Molecular Vibrational Excitation:*
    - *important processes which couples directly to the dissociative reaction coordinates.*
  - *Hyper-thermal Surface Chemistry :*
    - *chemical processes in a non equilibrium regime;*
    - *chemistry with a "hammer": scattering from absorbates. One can promote chemisorption, dissociation, surface modifications etc..*
    - *kinetic energy induced chemisorption.*
  - *Thin Films Synthesis*

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SiC synthesis on Si: Limits and Goals

The Growth Process is Severely Limited by:

- *Large Mismatches in Lattice Constants (20%) and Thermal Expansion Coefficients (8%).*
- *Large Temperatures for the Synthesis (larger then 1000-1300°C) Using CVD and PECVD.*
- *Formation of Voids at the SiC/Si Interface.*

⬇

- *Control of the Different Steps of the Growth Process and of State and Density of Precursors.*

SiC from C_{60} as Precursor

- *Lower Temperature for the Synthesis (850-950 °C).*
  (A.V. Hamza et al., Surf.Sci. 317 (1994) L1129)
- *Vapor Pressure Well Controllable by Sublimation.*
- *Can be Used in Hyperthermal Supersonic Beams (HSB)*
  (F. Biasioli et al., Chem.Phys. Lett. 270 (1997) 115)

↓

SiC Synthesis by Kinetic Energy Activated Processes

Impact of Fullerene From Si and H-Si

(K.Beardmore and R. Smith, Nim B 106 (1995) 74)

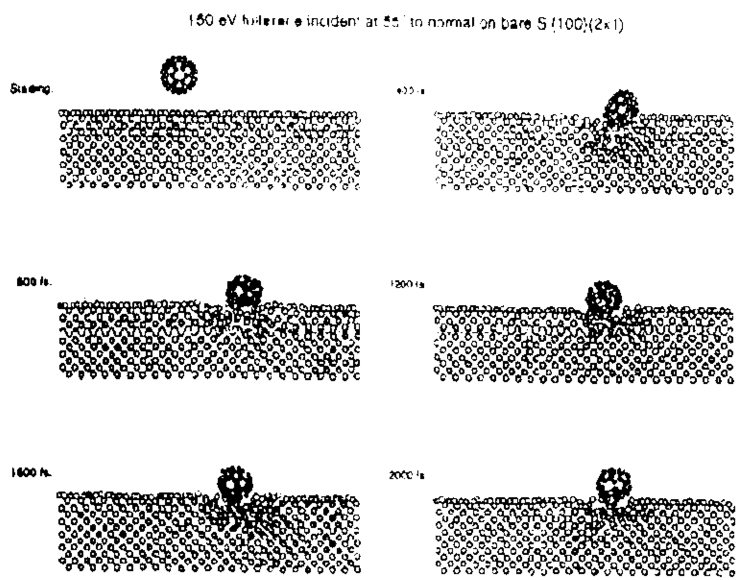


Fig. 2. Atomic positions for a 150 eV C_{60} molecule incident at 55° to normal on bare Si(100) after various times: 0, 400, 800, 1200, 1600 and 2000 fs. For clarity in Figs. 2–4, the atomic positions of only a section of the lattice, 12 Å thick, centred around the impact point are drawn.

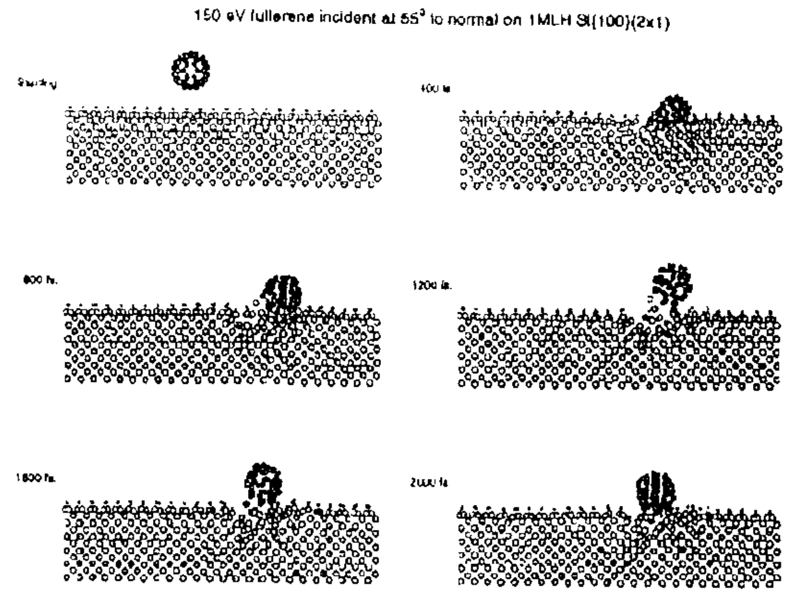
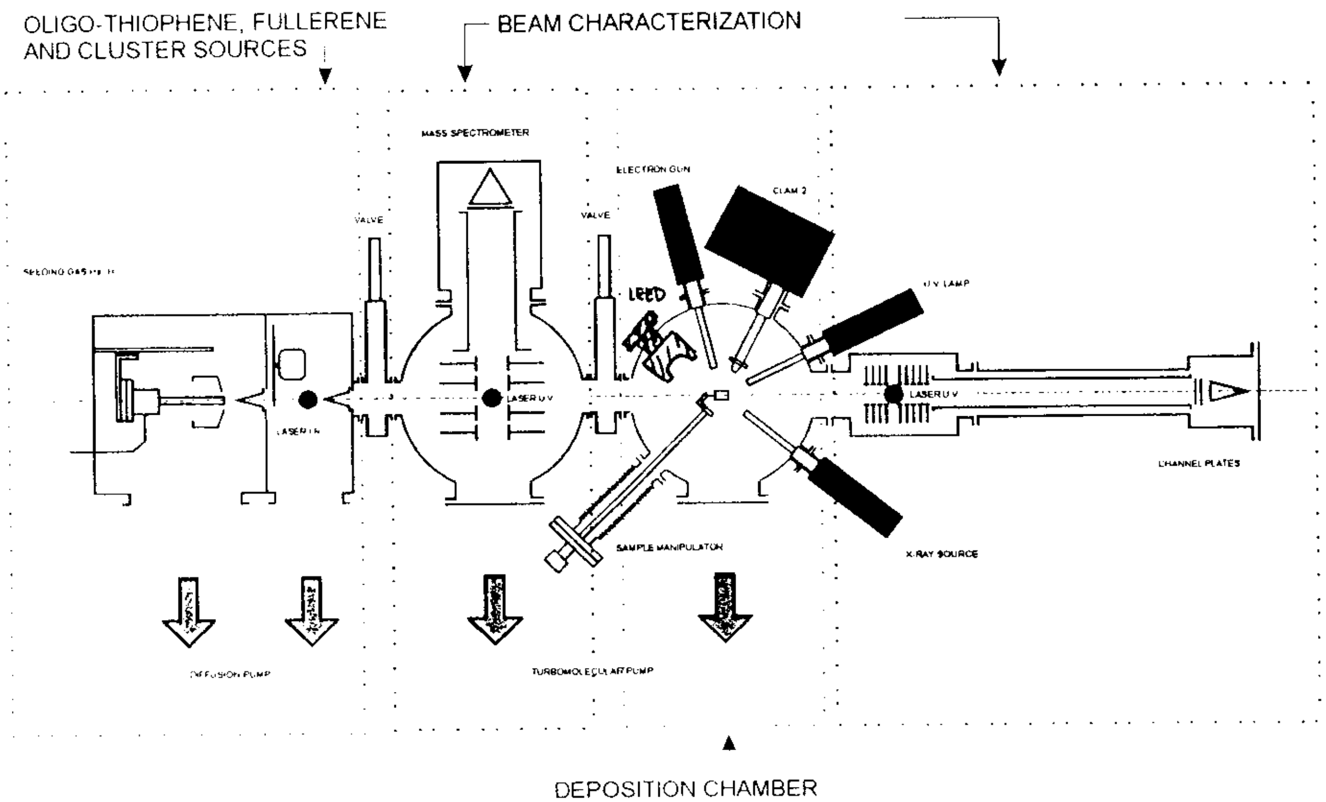
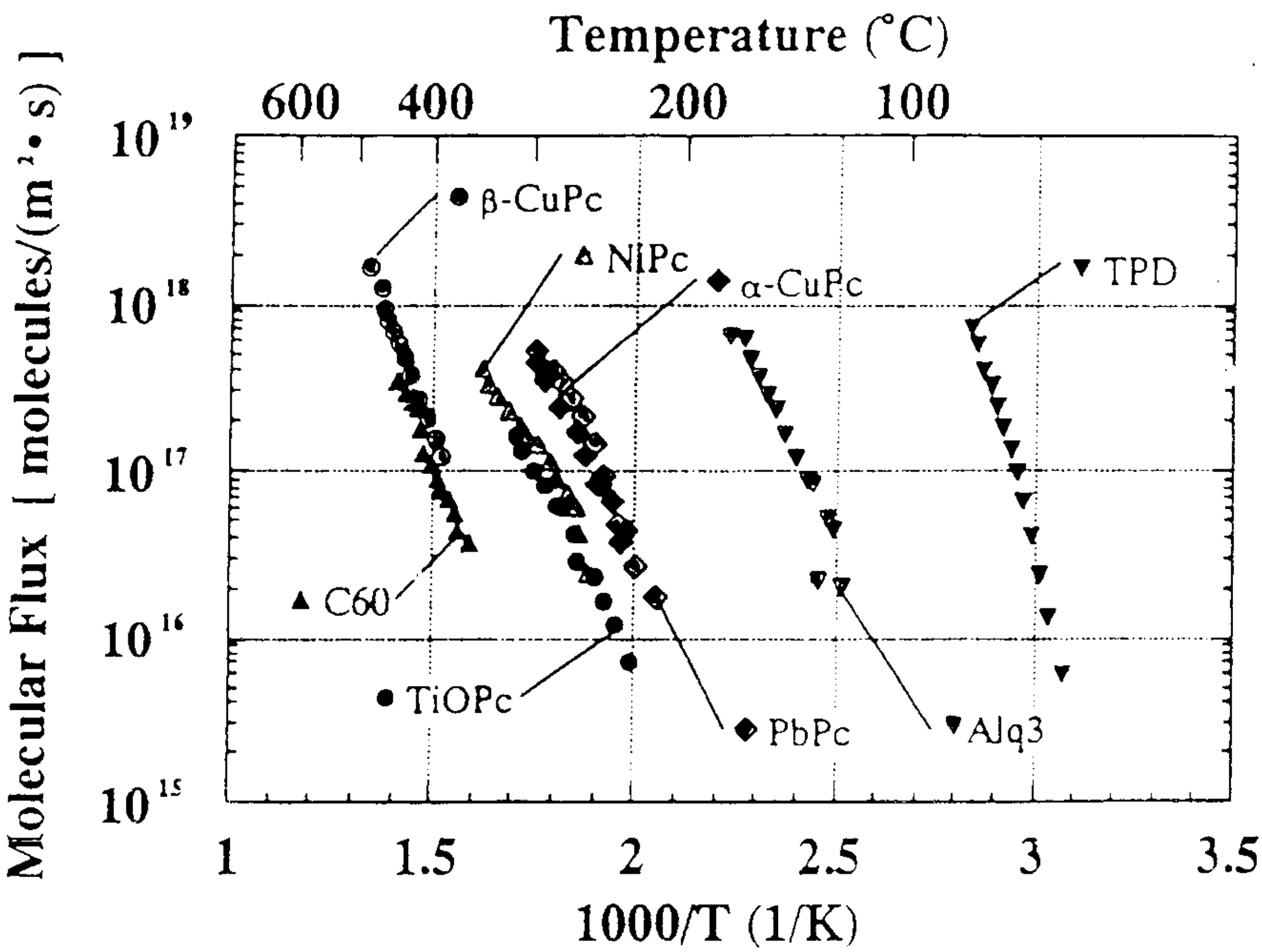


Fig. 3. Atomic positions for a 150 eV C_{60} molecule incident at 55° to normal on 1MLH Si(100) after various times: 0, 400, 800, 1200, 1600 and 2000 fs.



OLIGO-THIOPHENE, FULLERENE
AND CLUSTER SOURCES
BEAM CHARACTERIZATION
MASS SPECTROMETER
ELECTRON GUN
CLAM 2
VALVE
VALVE
LEED
LASER U.V.
U.V. LAMP
LASER U.V.
CHANNEL PLATES
SAMPLE MANIPULATOR
X-RAY SOURCE
DIFFUSION PUMP
TURBOMOLECULAR PUMP
DEPOSITION CHAMBER



Temperature (°C)
600
400
200
100
Molecular Flux [molecules/(m²• s)]
10^{19}
10^{18}
10^{17}
10^{16}
10^{15}
β-CuPc
NiPc
α-CuPc
TPD
C60
TiOPc
PbPc
Alq3
1
1.5
2
2.5
3
3.5
1000/T (1/K)

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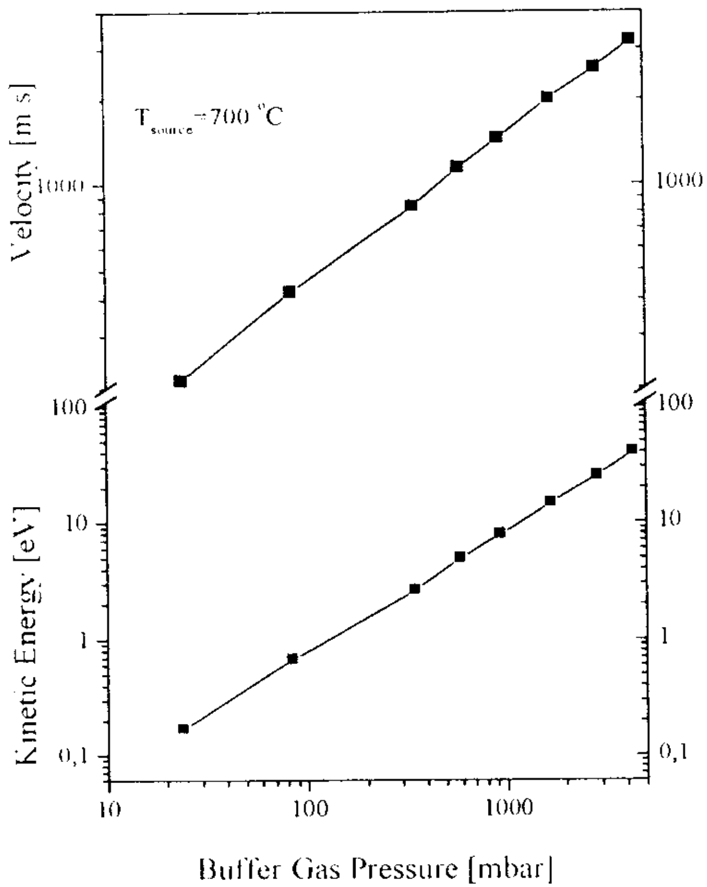
C_{60} Seeded in He - HSB



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C_{60} Beam Characteristics

	Achievable	At Present
Nozzle Diameter	20-2000 μm	60-1500μm
Seeding gas Pressure	10 Atm	2 Atm
Seeding Dilution	1:10000	1:2000
Energy range	1-60 eV	1-35 eV
Energy Spread	7%	$\cong$15%
Intensity	10^{17} s^{-1}	10^{16} s^{-1}
Oven Temperature	>2000 K	1300 K

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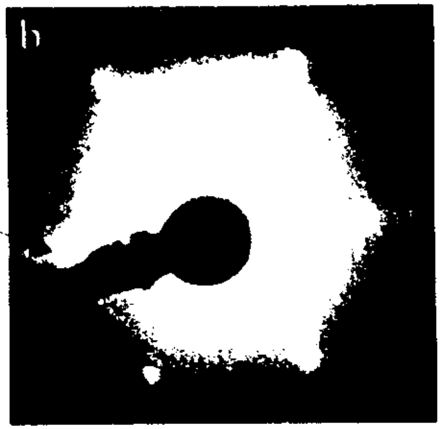
LEED Patterns Carbonization Processes (C_{60}-Si (111) 7x7)

■Clean Si(111) 7x7

■SiC Epilayer Grown on Si(111) 7x7. In the following two ways

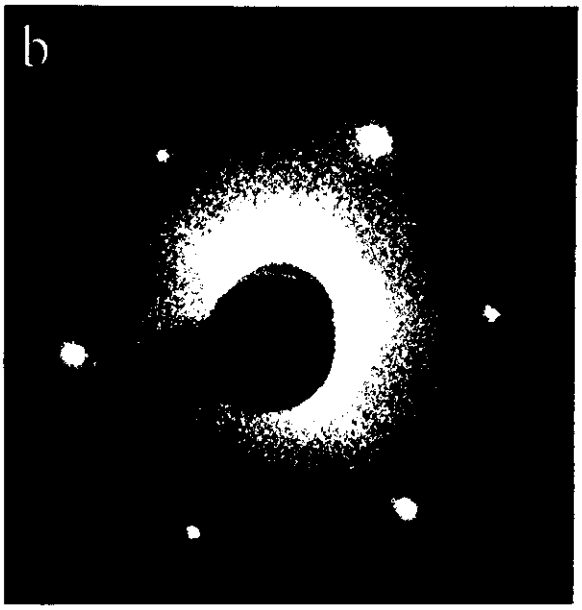


■Thermal annealing (870-950 °C) of C_{60} absorbed on the clean surface.

■Synthesis by Exposing the Hot Si (800 °C) to the C_{60} HSB

■Further Growth of SiC by Exposing the Hot (800 °C) Carbidized Surface to the C_{60} HSB

CLEAN Si (111) 7x7

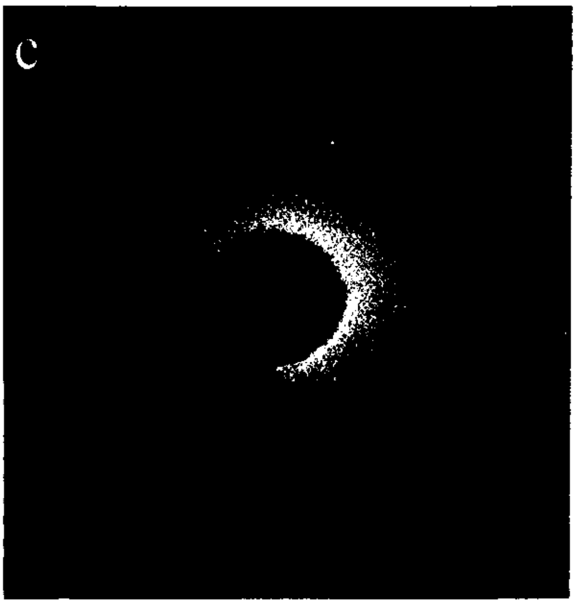


SiC EPILAYER ON Si

- GROWN BY THERMAL ANNEALING OF A C_{60} ABSORBED FILM (870-950°C)

(OR)

- GROWN BY EXPOSING THE HOT Si SURFACE (800°C) TO THE HSB.



FURTHER GROWTH OF SiC BY EXPOSING THE HOT (800°C) CARBIDIZED SURFACE

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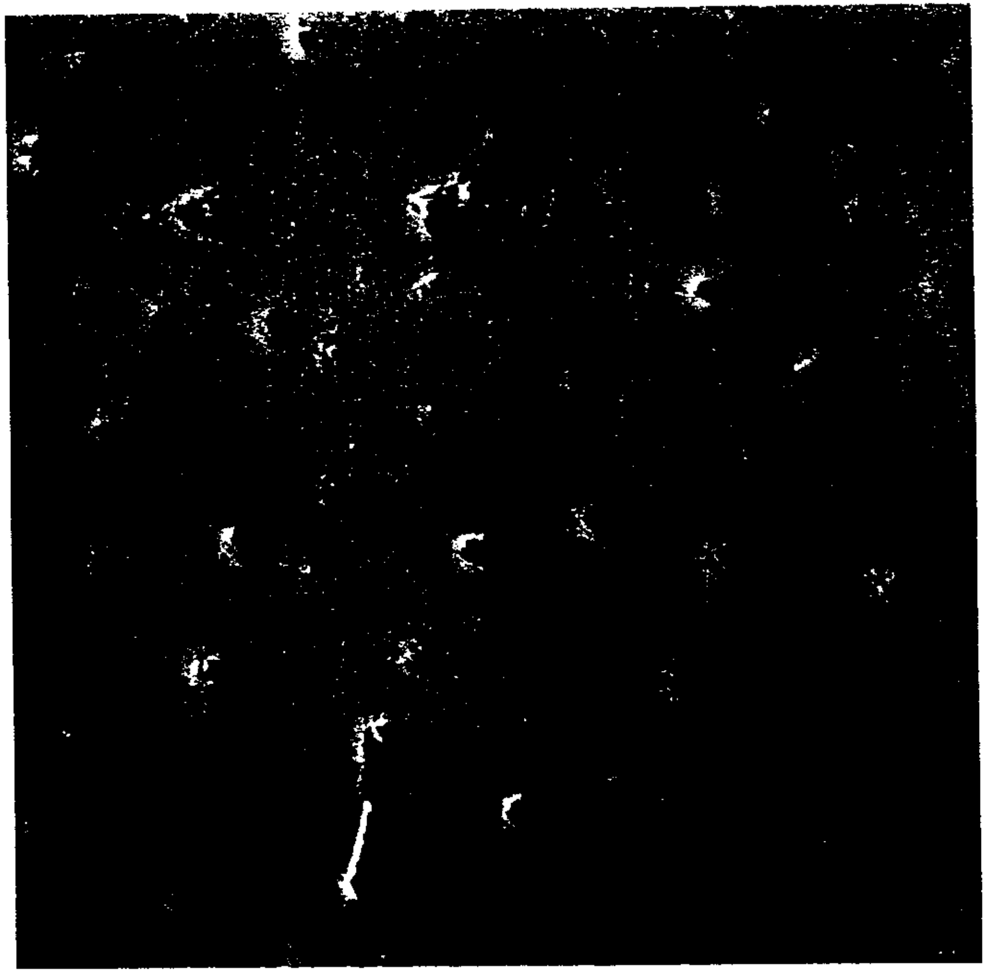
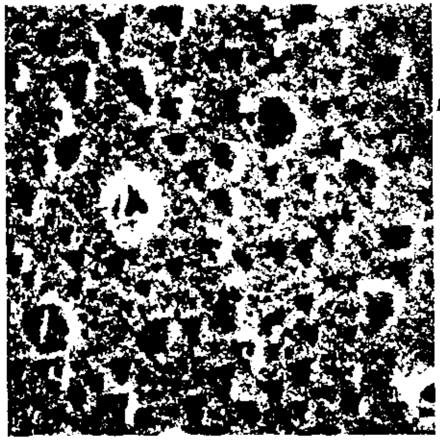
Typical SEM Micrograph from SiC Directly Synthesized By Direct Exposure To C_{60} HSB

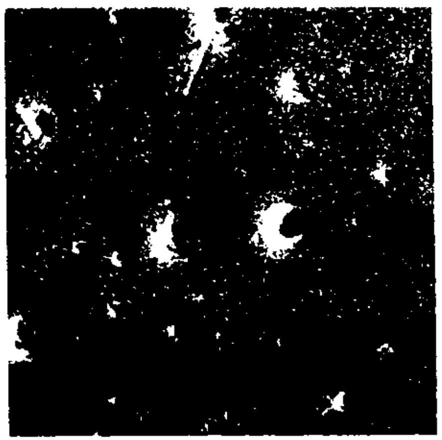


SiC Morphologies at Different Growth Regimes



- **High C_{60} Beam Fluxes**
  - Diffuse Shallow SiC LEED Spots

- **Medium C_{60} Beam Fluxes**
  - SiC Sharper LEED Spots



- **Low C_{60} Beam Fluxes**
  - Co-presence of Si and SiC Spots

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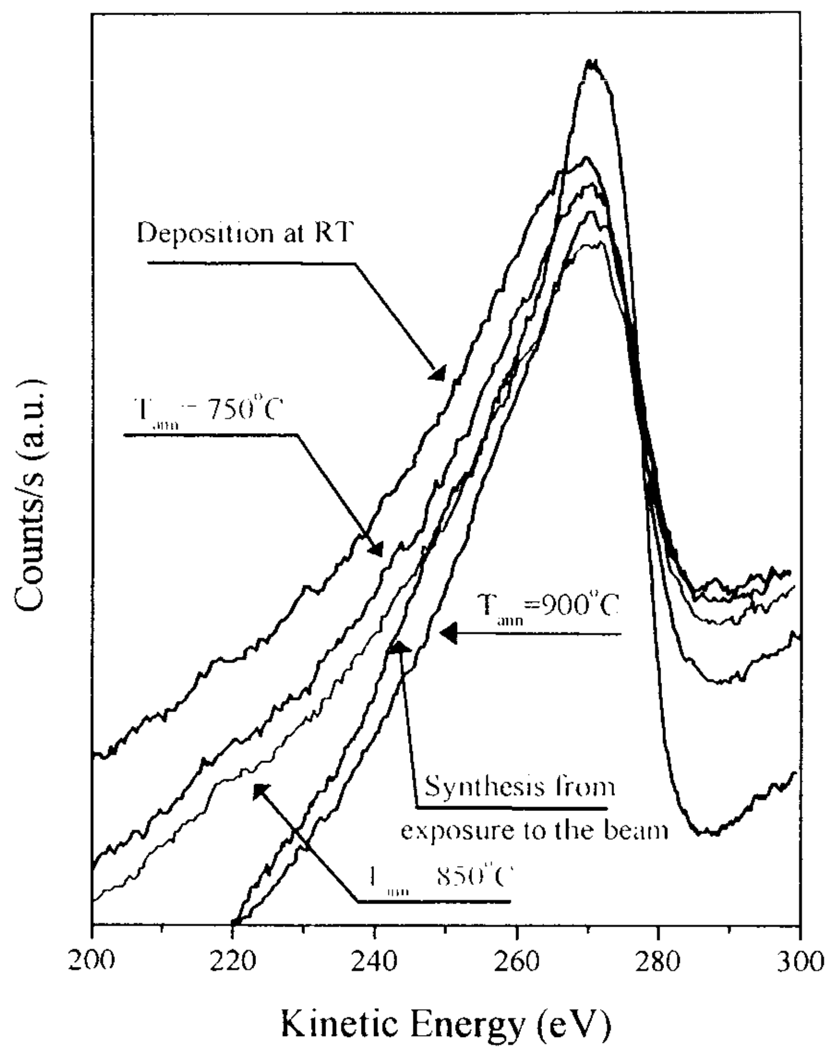
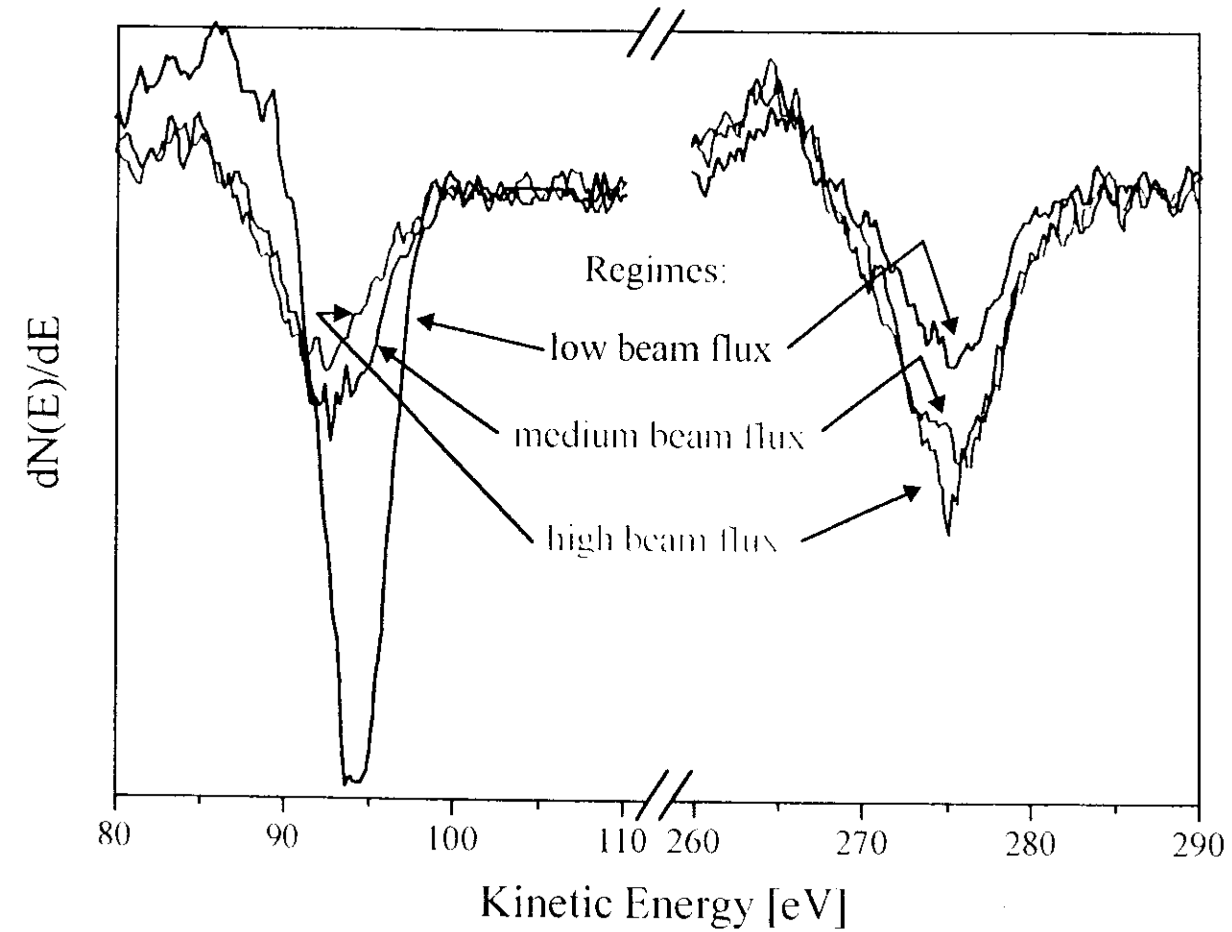
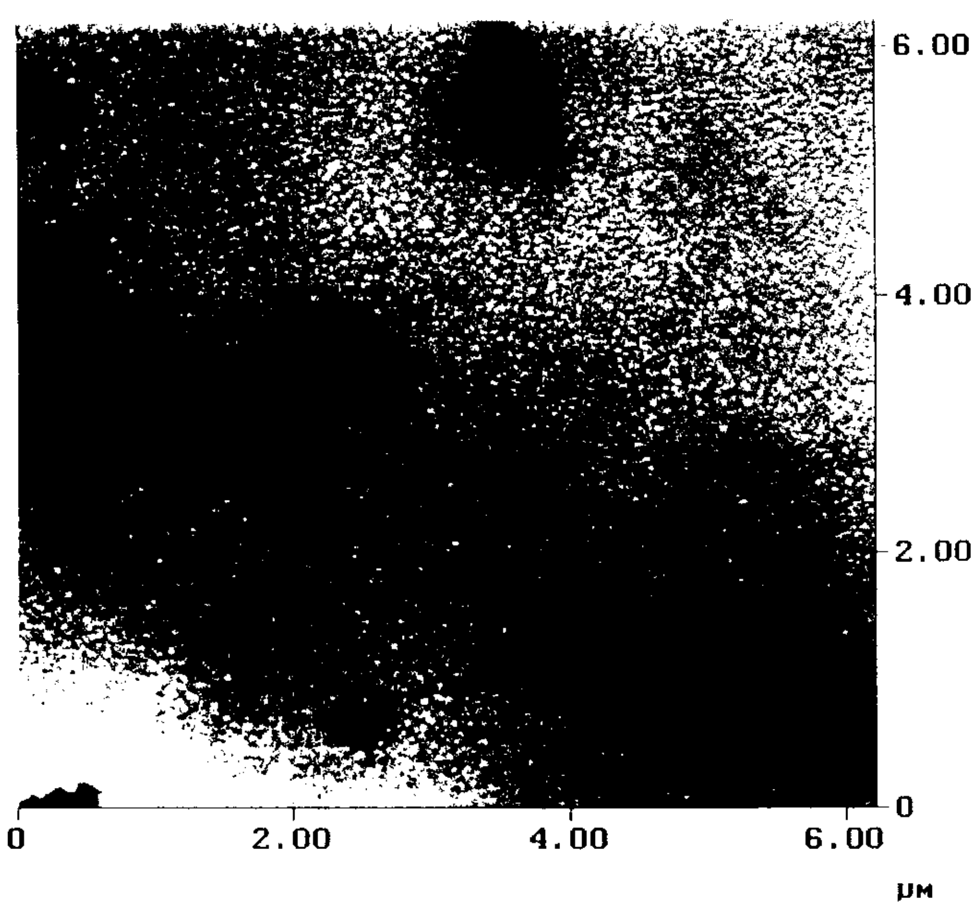
Carbonization Of SiC - Auger Lineshape of C-line



Carbonization Of SiC in Different Beam Regimes
- Auger Lineshape of Si and C



AFM Image Of SiC Synthesized from C_{60} HSB - Medium Flux

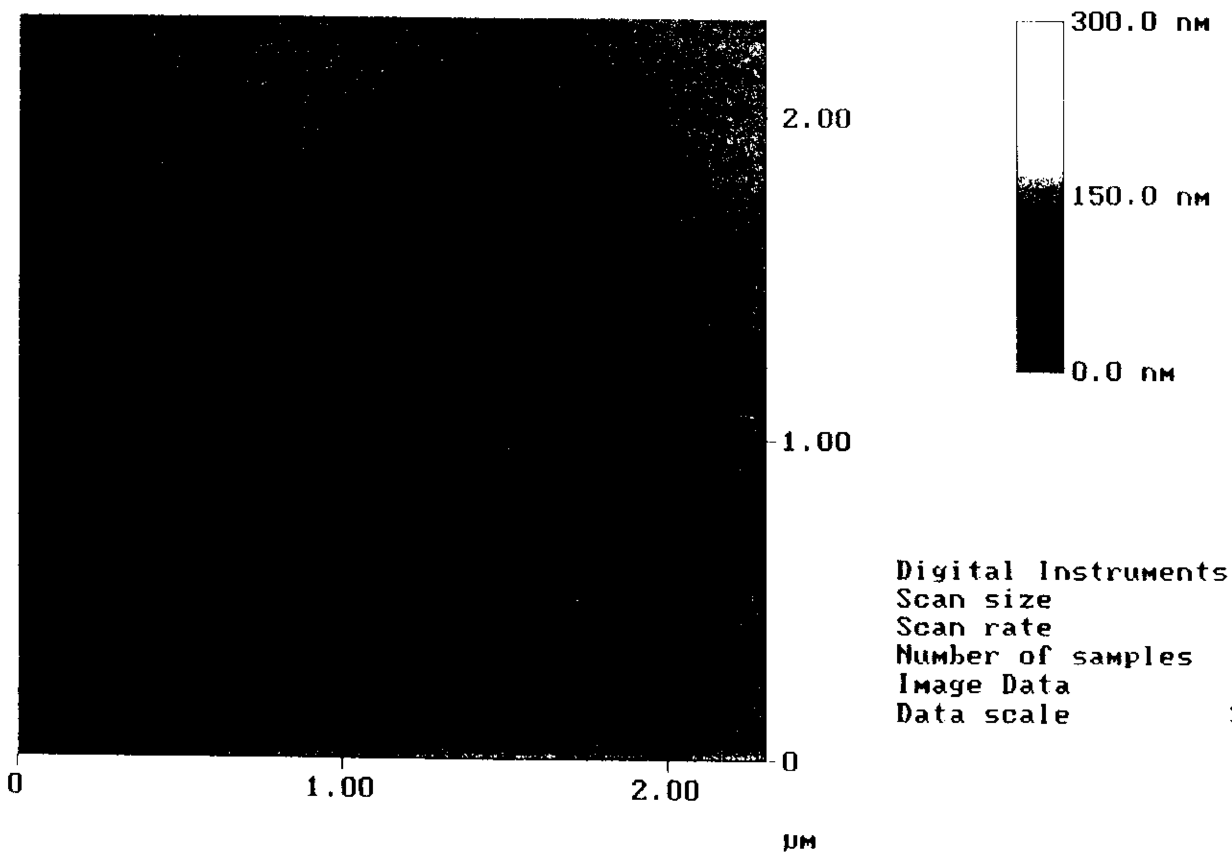


Digital Instruments NanoScope	
Scan size	6.221 µm
Scan rate	2.497 Hz
Number of samples	512
Image Data	Height
Data scale	100.0 nm

a_zona3.004

Trieste'99_1

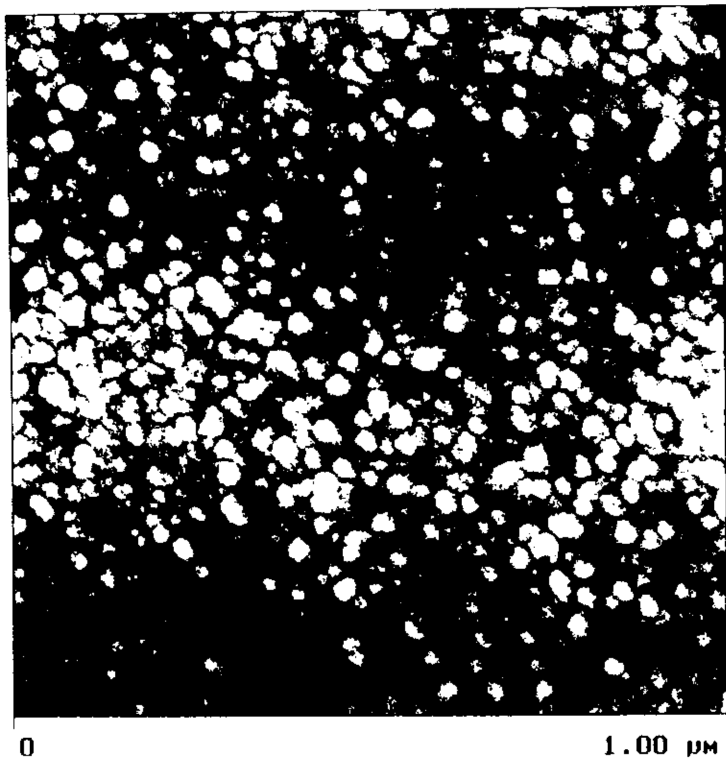
AFM Image Of SiC Synthesized from C_{60} HSB Medium Flux



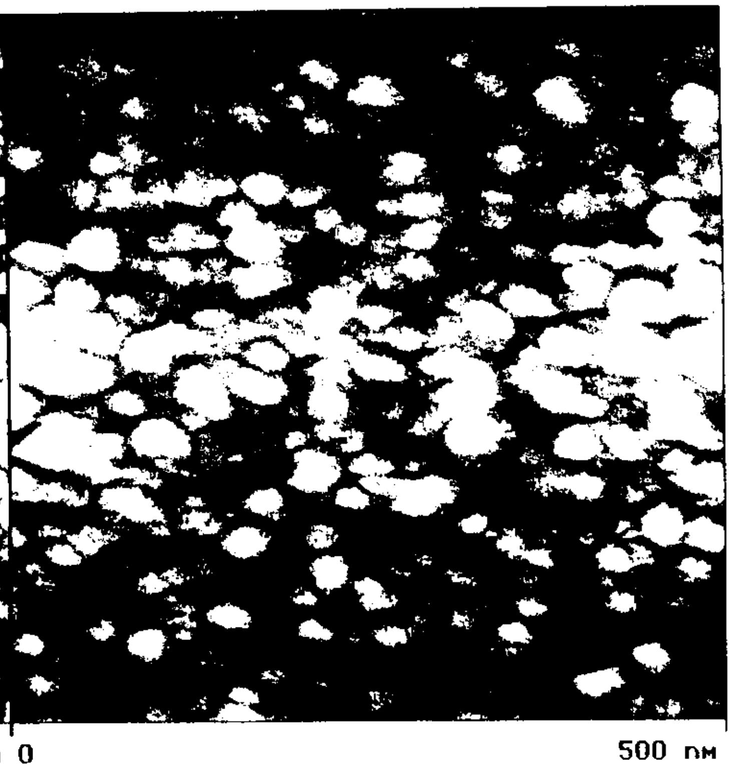
Digital Instruments NanoScope
Scan size 2.307 µm
Scan rate 2.497 Hz
Number of samples 512
Image Data Height
Data scale 300.0 nm

a_zona3.001

AFM Image Of SiC Synthesized from C_{60} HSB Medium Flux



a_zona3.003



a_zona3.002

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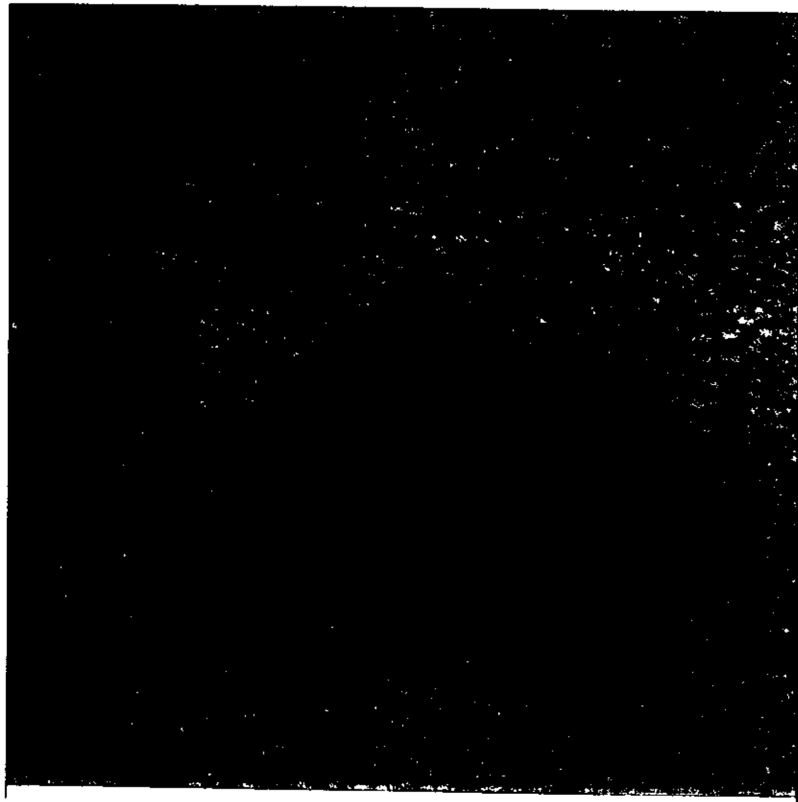
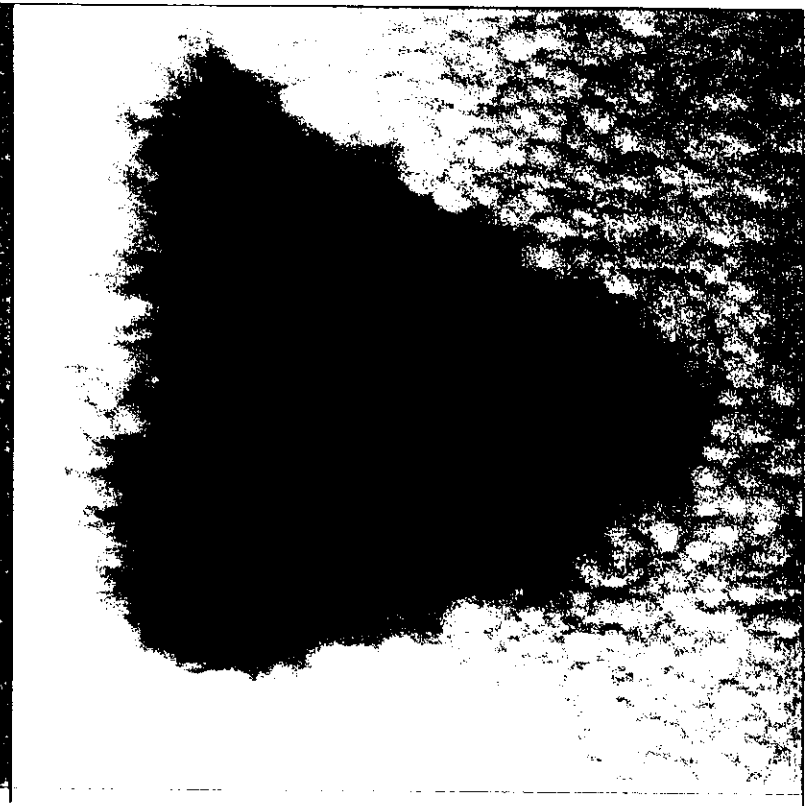
AFM Image Of SiC Synthesized from C_{60} HSB
Medium Flux



0 2.07 µm

Data type Height
Z range 200.0 nm

a_zona3.005

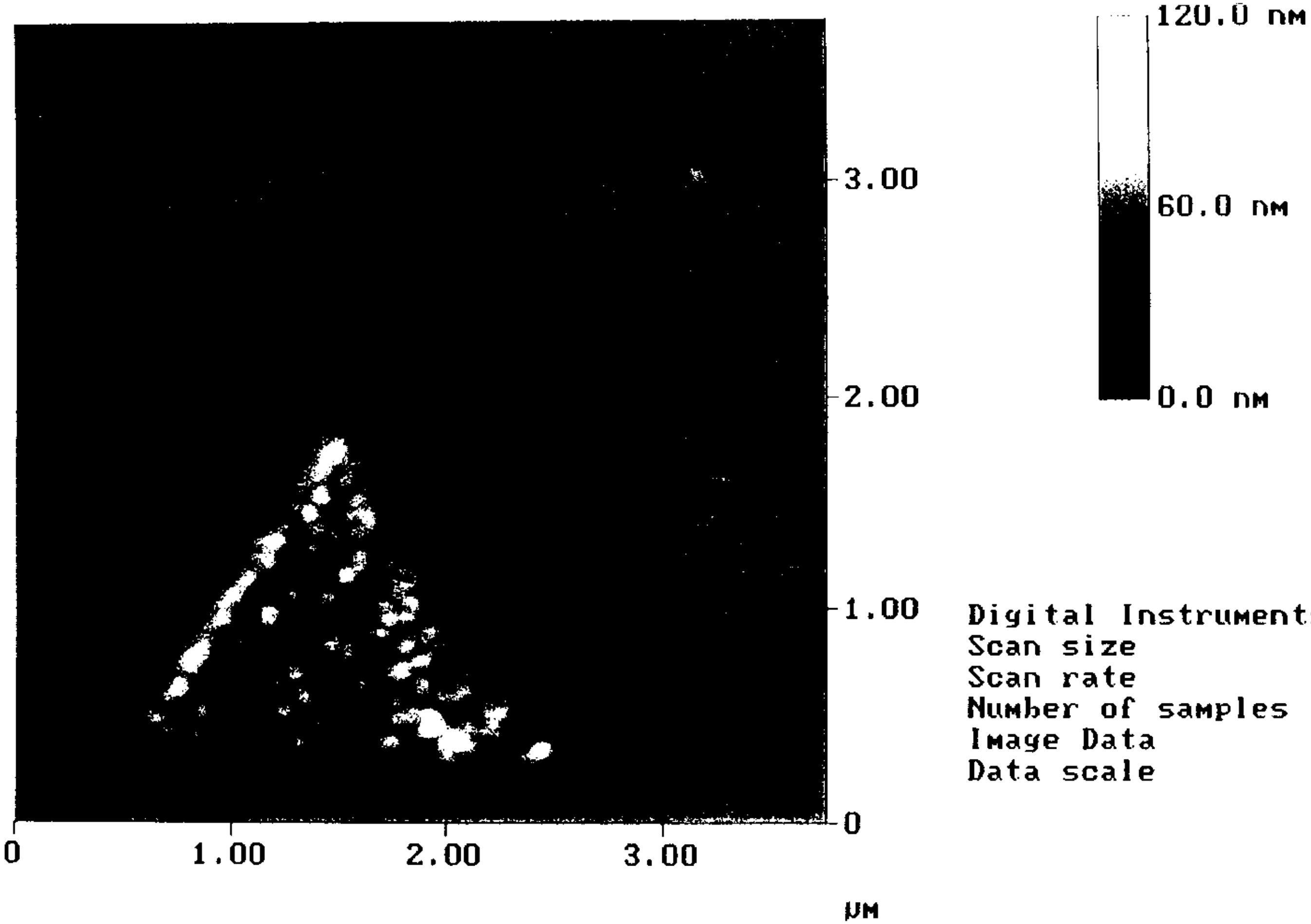


0 1.04 µm

Data type Height
Z range 200.0 nm

a_zona3.006

AFM Image Of SiC Synthesized from C_{60} HSB
Medium Flux



Digital Instruments NanoScope	
Scan size	3.755 µm
Scan rate	2.069 Hz
Number of samples	256
Image Data	Height
Data scale	120.0 nm

Trieste'99_23

160299.007

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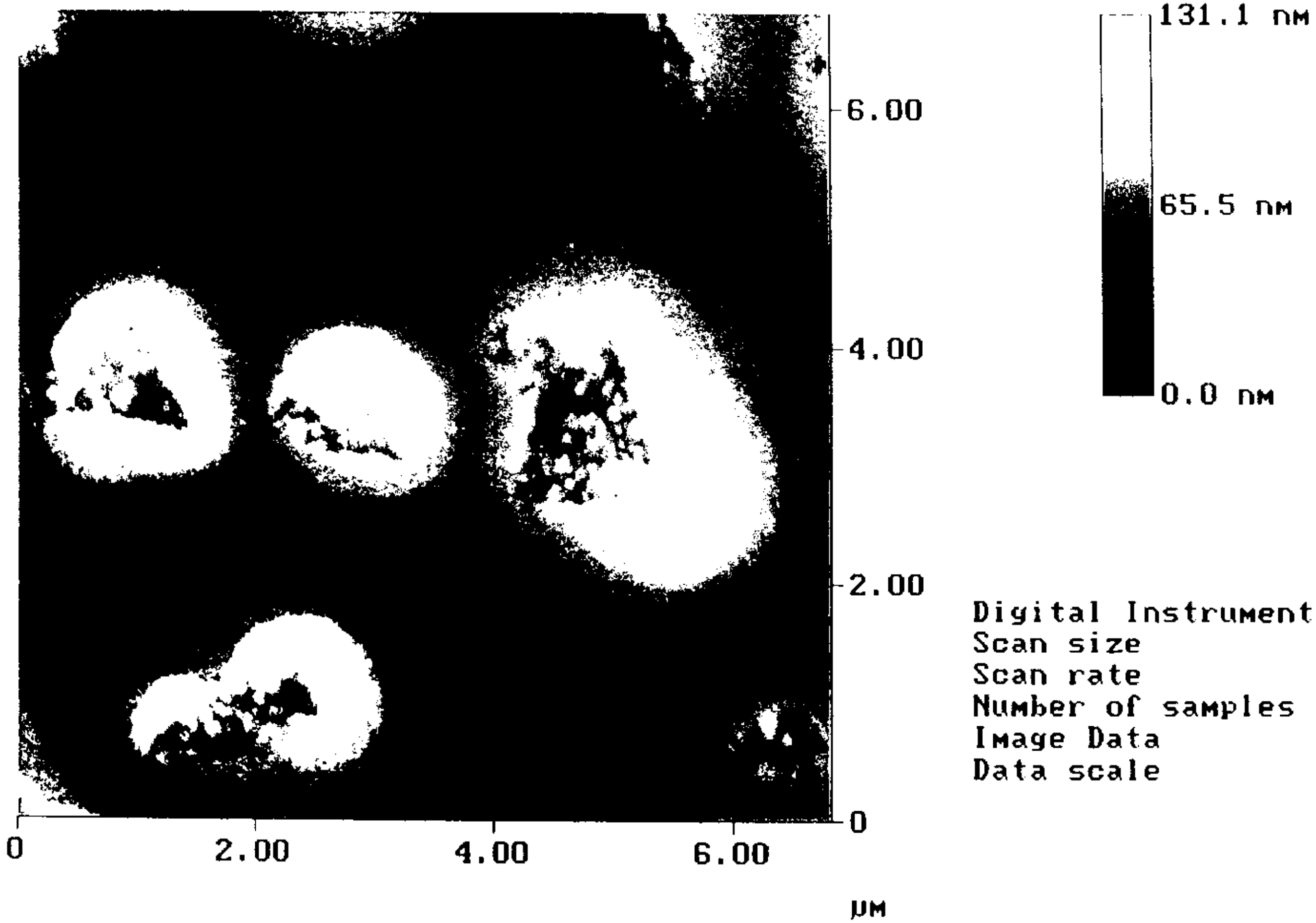
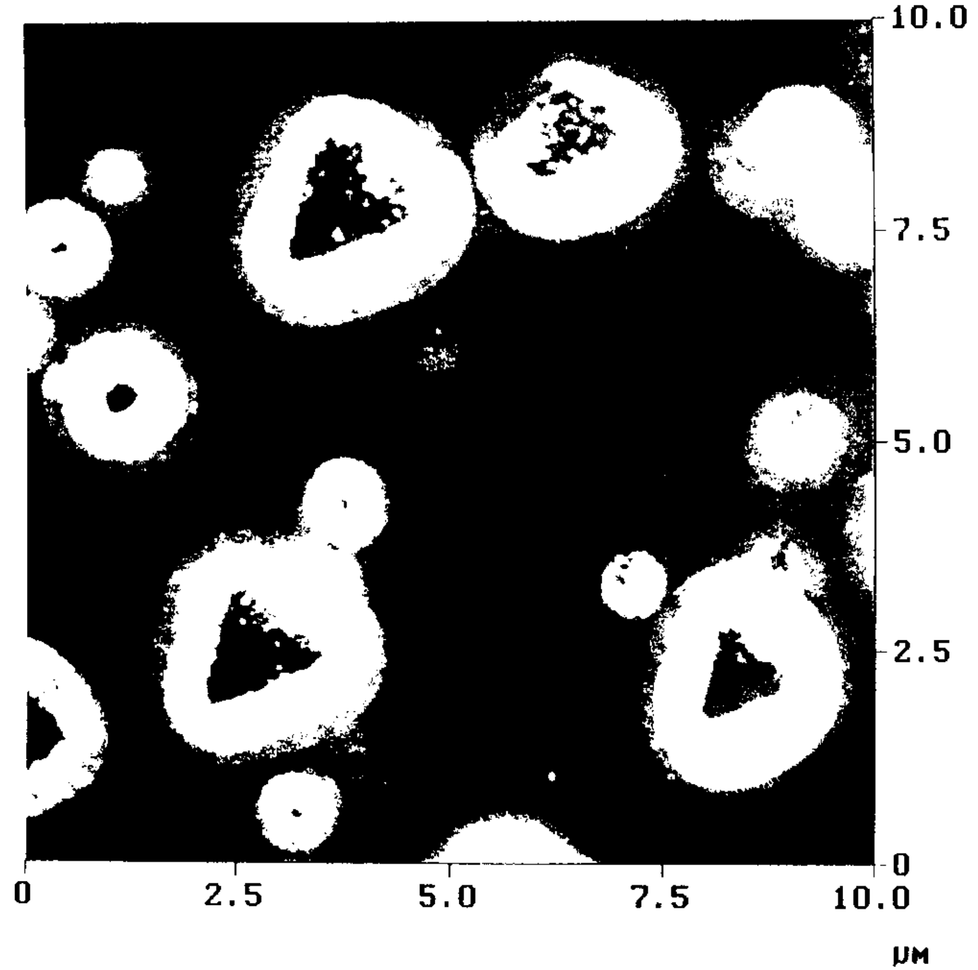
AFM Image Of SiC Synthesized from C_{60} HSB High Flux



Digital Instruments NanoScope	
Scan size	6.832 µm
Scan rate	1.565 Hz
Number of samples	256
Image Data	Height
Data scale	131.1 nm

170299.008

AFM Image Of SiC Synthesized from C_{60} HSB
Low Flux



Digital Instruments NanoScope	
Scan size	10.00 μm
Scan rate	2.594 Hz
Number of samples	256
Image Data	Height
Data scale	100.0 nm

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Conclusions and Perspectives

C_{60} HSB Advantages:

- *The Synthesis of SiC on Si Could be Achieved at Lower Temperatures by Kinetic Enbergy Activation.*
- *Basic Properties of the Films:*
  - *Morphology*
  - *Density of Voids*
  - *Growth rate etc.*

can be Controlled by Changing Beam Source Parameters: (Kinetic Energy

and Flux of the Beam)

A C_{60} HSB IS A VIABLE AND PROMISING TOOL TO SYNTHESIZE SiC ON SI.

Synthesis of Nano-crystalline TiNi Thin Films by Cluster Beam Deposition

[illegible]

CNR Research Center
on the Physics of Agggregates - TRENTO
ITALY
in Collaboration with
*Department of Physics University of Milan
**TEMPE-CNR

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CLUSTER Beam Deposition

("Synthesis of Nanophase Thin Films by Cluster Beam Deposition" P. Milani, S. Iannotta - Spinger Verlag Jan. 1999)

- *Synthesis of Nanostructures by Assembling Nanoparticles*
- *Characterization of the Aggregates Before or During the Deposition Process*
  - ***Cluster Size Distribution***
  - ***Cluster Kinetic Energy***
  - ***Charge States***
  - ....
- *Control on Film Properties such as Grain Size, Crystallinity, Stoichiometry for SMA alloys ???*

E. Barborini et al.
Nanostr. Mat. [illegible]

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TiNi -SMA- Films

Interests:

- *Actuators or combined Sensor-Actuators in Micro-Electro-Mechanical Systems (MEMS);*
- *Biomedical Systems and BioMEMS;*
- *Micro-Mechanics.*

Advantages over other micro-actuation methods (Piezoelectric, Magnetostrictive or bimetallic effects, etc..):

- *High work output unit volume;*
- *High power / mass ratio;*
- *Capability to be driven by standard logic level signals;*
- *Bio-compatibility;*
- *Scalability.*

Open Questions and Present Limits of Deposition Methods for Good Quality SMA Films

- *High Temperatures (>500-550 °C) of Deposition or Need of Thermal Treatments (Annealing):*
  - *DC and RF Sputtering and laser ablation produce amorphous films at room temperature.*
- *Processes Incompatible with SMA Microsystems Fabrication Directly Integrated with other MEMS Fabrication Technologies.*
- *Poor control on Films Quality due to Growth Environment and Pollutants.*
- *Fine control on Stoichiometry.*
- *Fine Control and Role of Crystallinity and Grain Size.*
- *Interface Film-Substrate*

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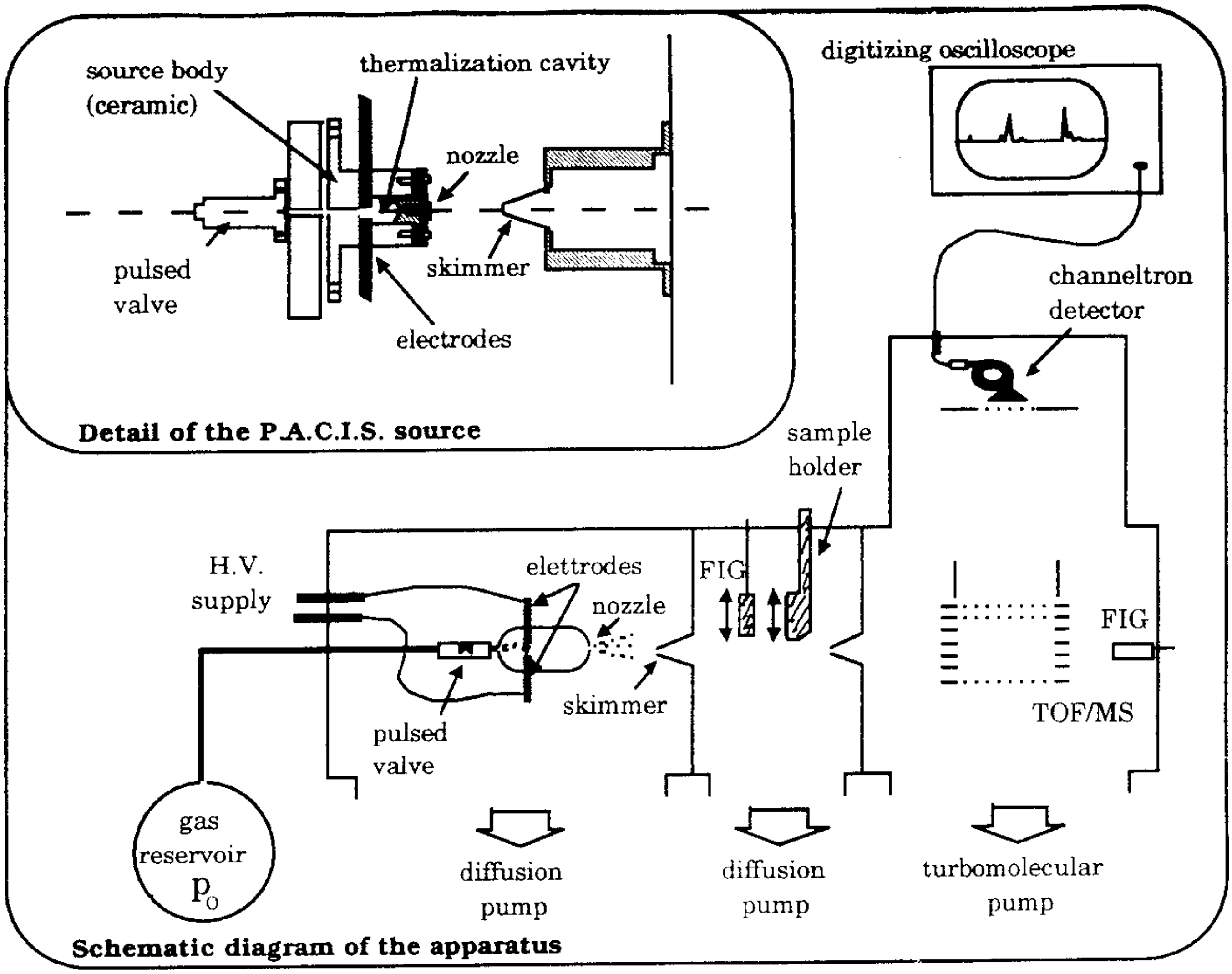
AIMS

- ***Synthesis of Nanocrystalline Materials from Controlled Nanoparticles Building Blocks***
  - *Fundamental and Technological Relevance*
- ***Film Growth and Properties Controlled By Cluster Beam Parameters***
  - *Cluster Mass Distribution*
  - *Kinetic Energy and Momentum*
  - *Internal Energy*
  - *Deposition Rate*
- ***Crystalline or Amorphous Character of the Particles***

Characterization of the Beam

Correlation between the properties of the nanoparticles and of the films

E. Barborini et al. NanoStructured Mat 10(6) (1998) 1313



source body
(ceramic)
thermalization cavity
nozzle
pulsed
valve
skimmer
electrodes
Detail of the P.A.C.I.S. source
digitizing oscilloscope
channeltron
detector
sample
holder
H.V.
supply
elettrodes
nozzle
FIG
FIG
skimmer
pulsed
valve
TOF/MS
gas
reservoir
p_0
diffusion
pump
diffusion
pump
turbomolecular
pump
Schematic diagram of the apparatus

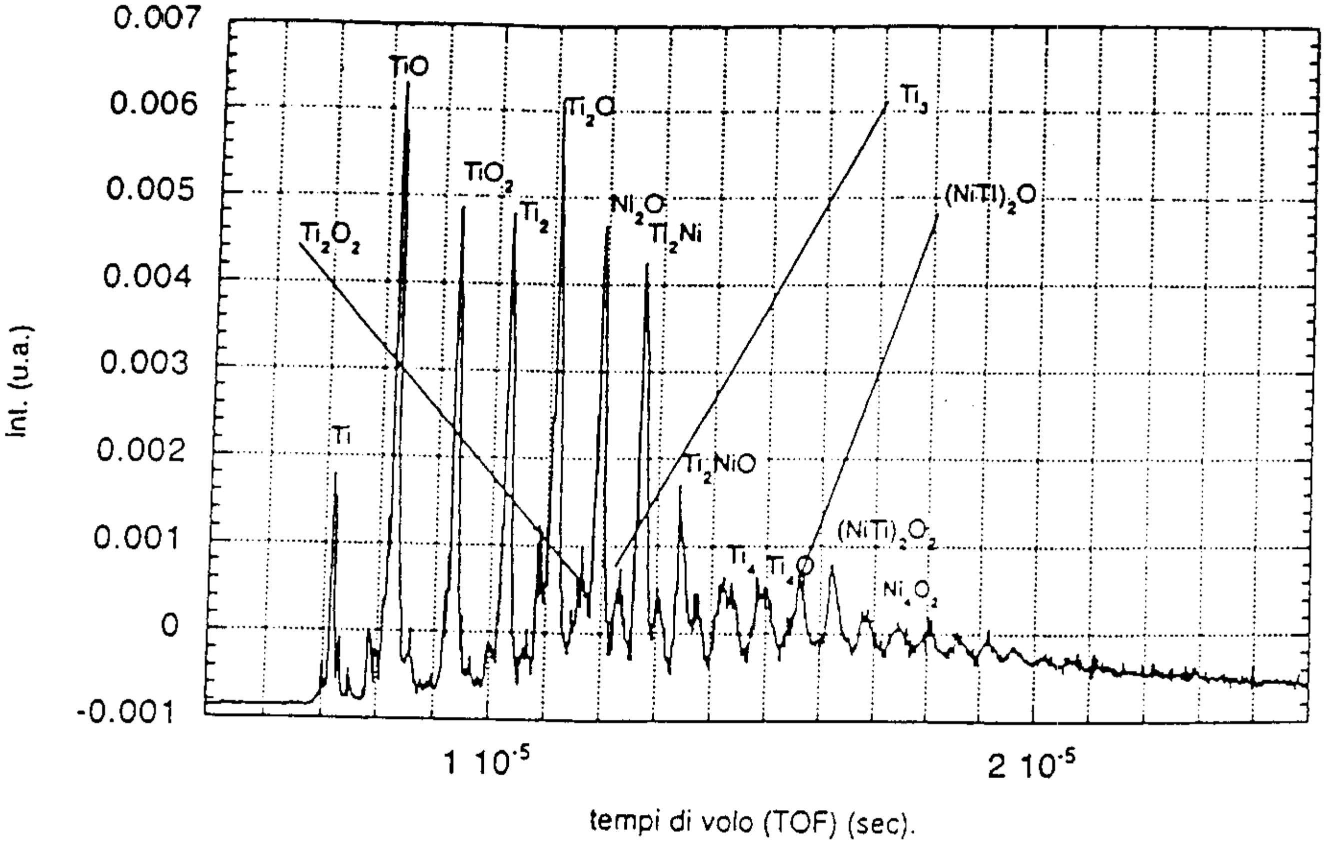
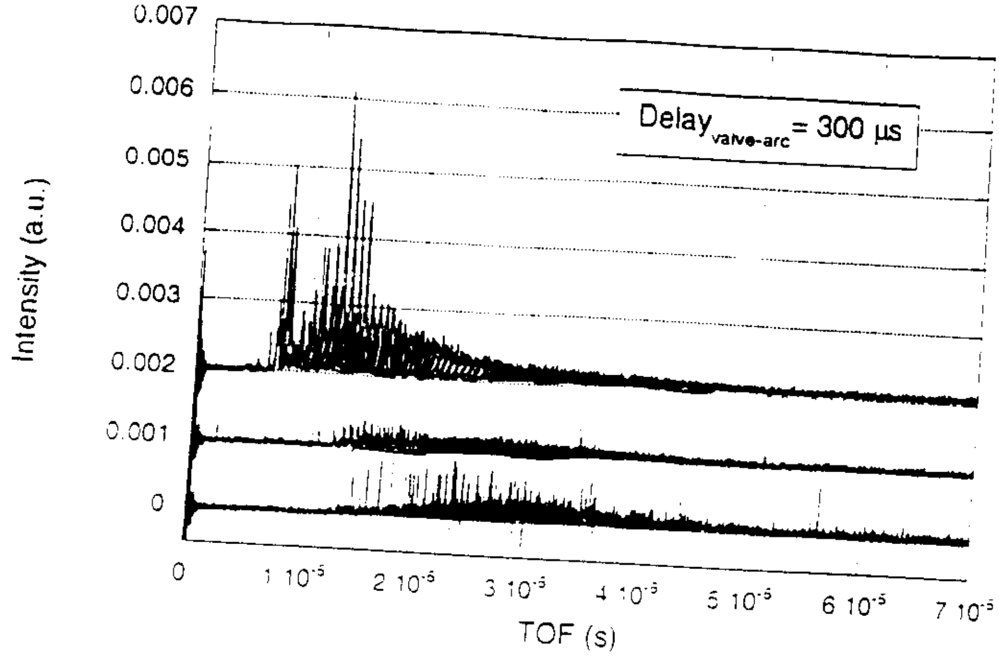
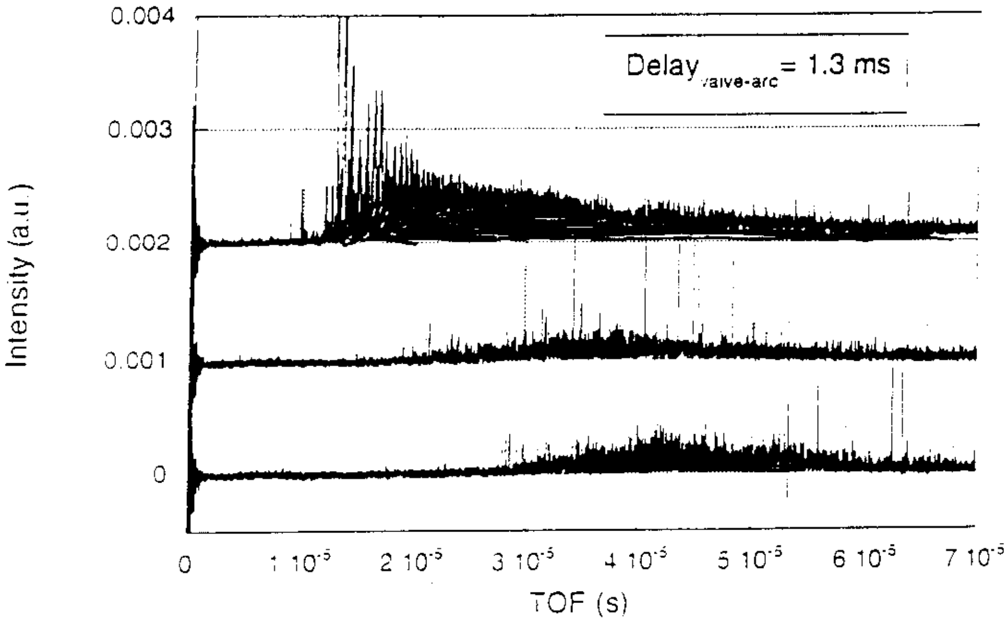
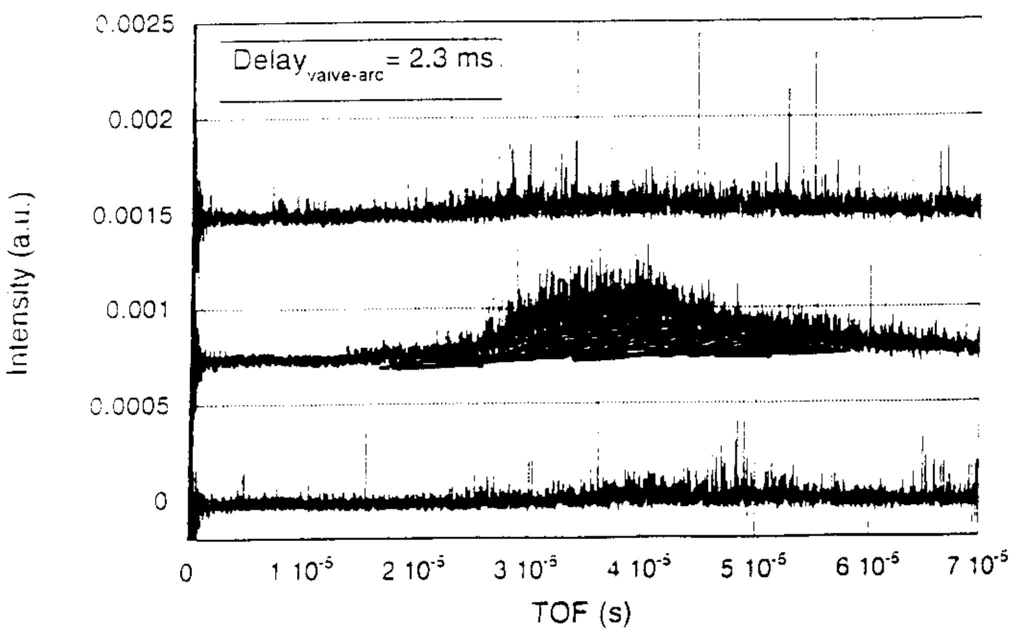


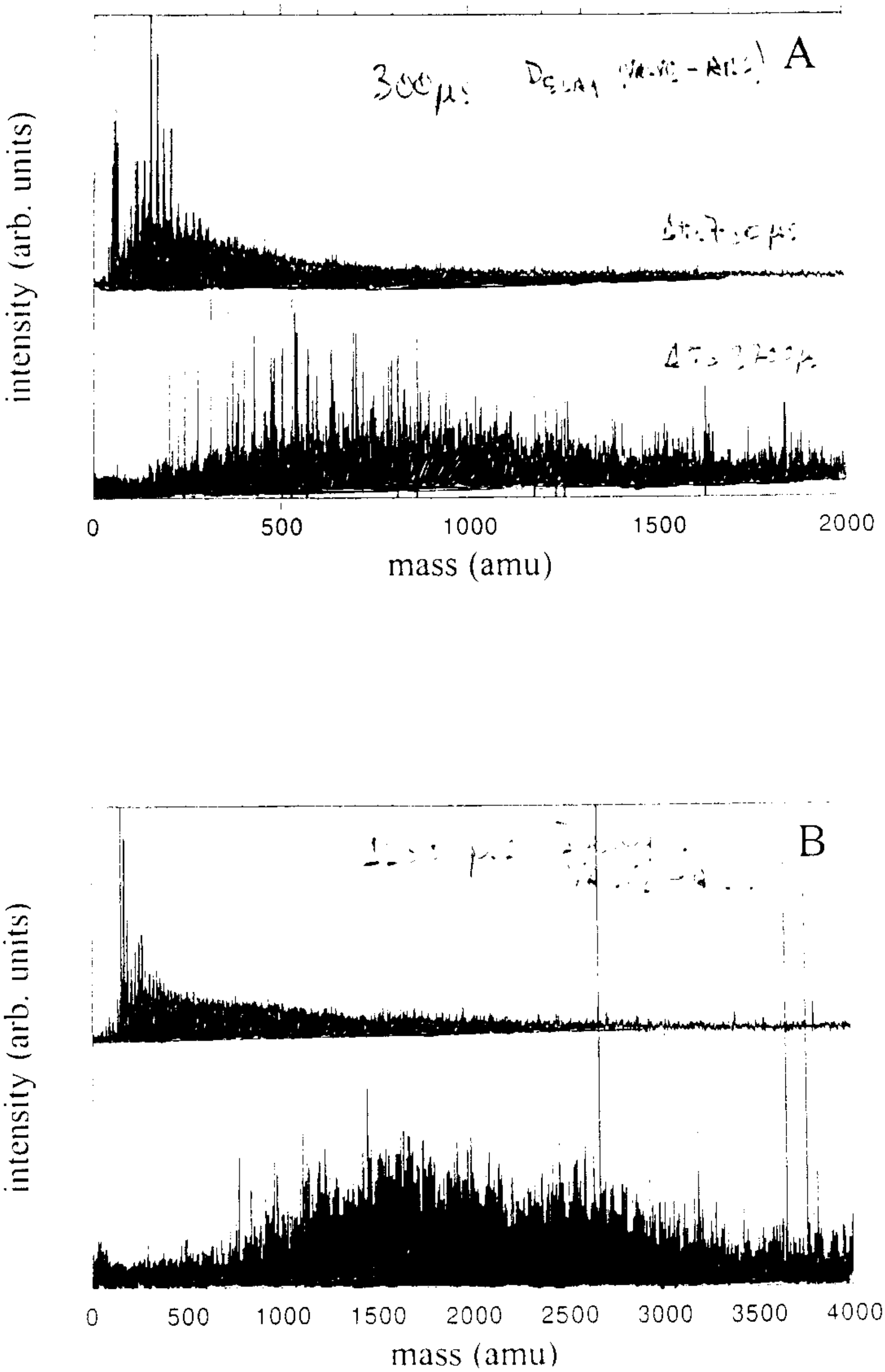
Figura 6.7 Spettro di massa raccolto con ritardo valvola-scarica di 1200 μsec e ritardo scarica-spettrometro di 800 μsec. Ai picchi più intensi é stata assegnata una massa.

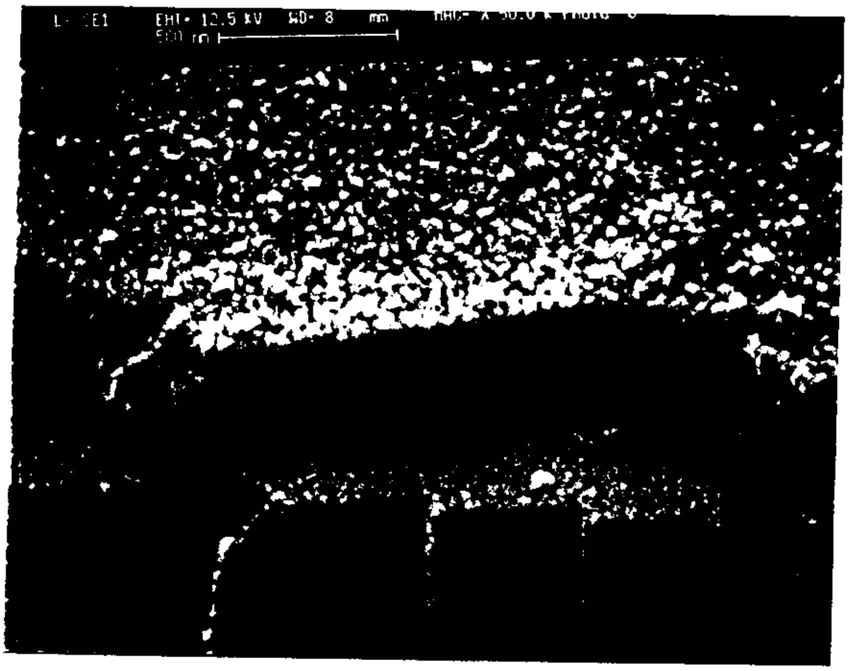


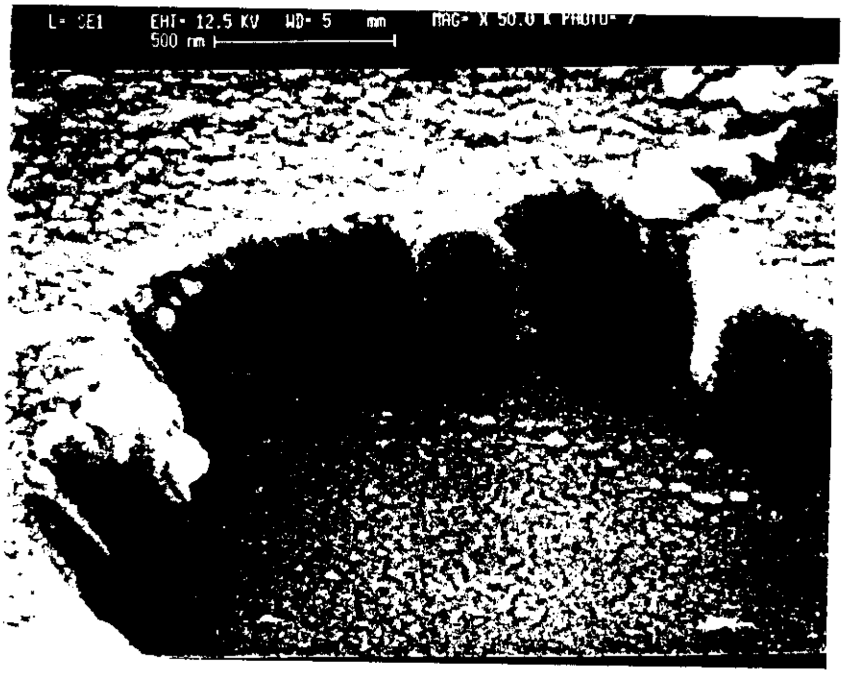
Nickel-Titanium [redacted]



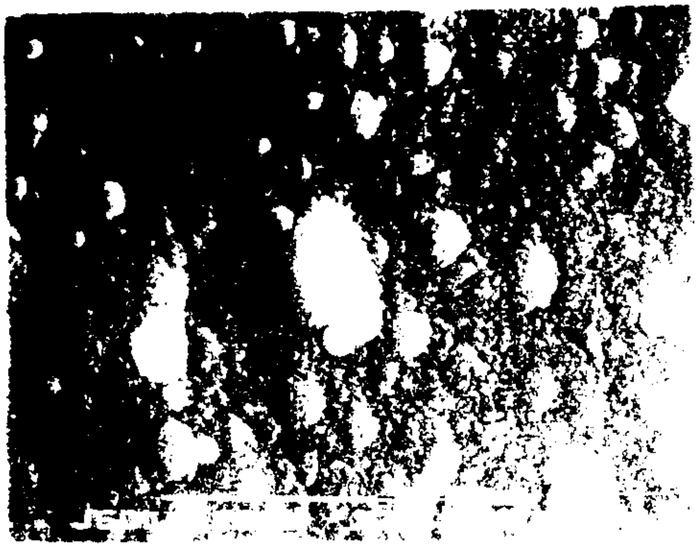



A
300μs
intensity (arb. units)
0
500
1000
1500
2000
mass (amu)
B
intensity (arb. units)
0
500
1000
1500
2000
2500
3000
3500
4000
mass (amu)

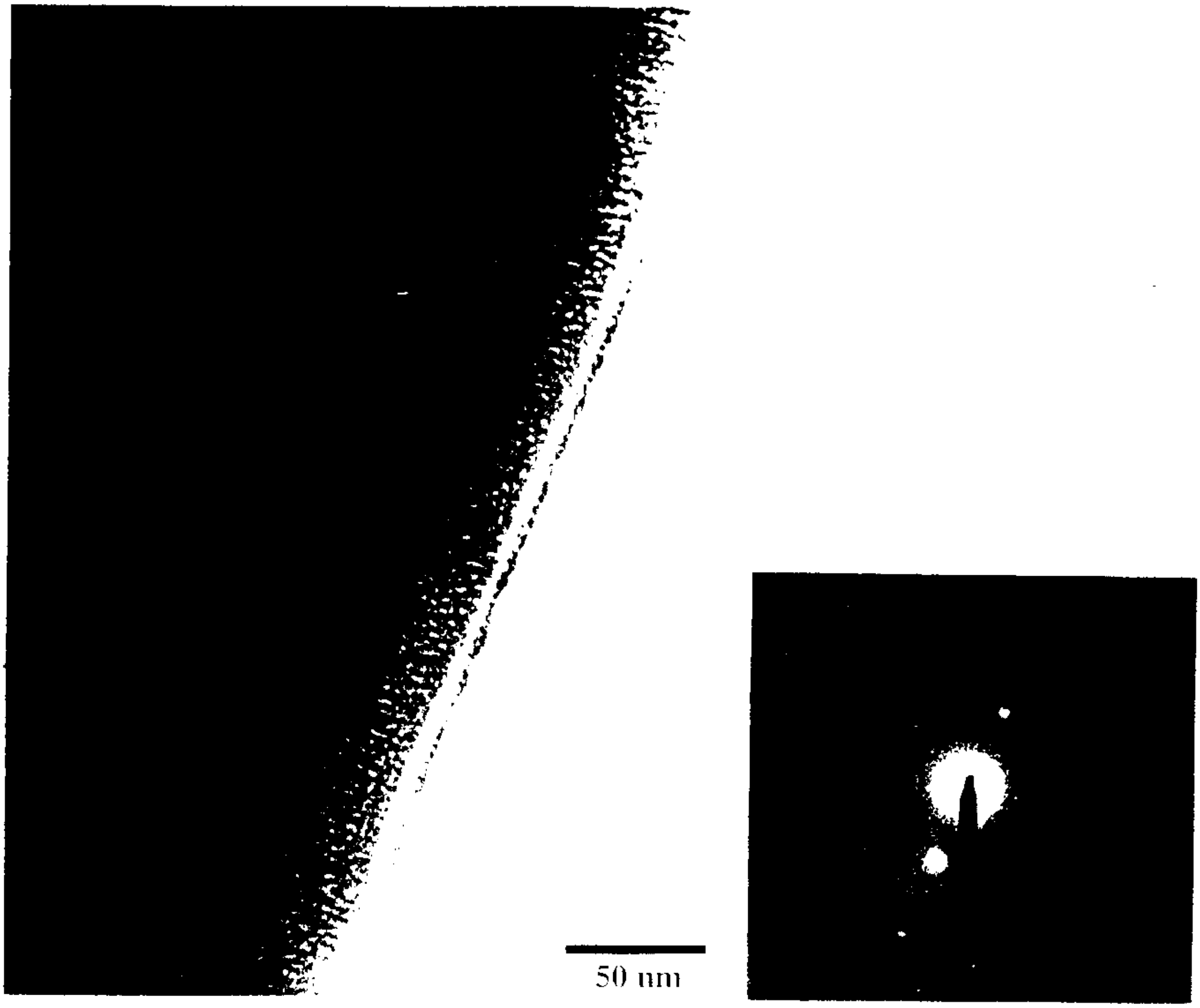

EHT= 12.5 kV WD= 8 mm


L= SE1 EHT= 12.5 KV WD= 5 mm MAG= X 50.0 K
500 nm

A



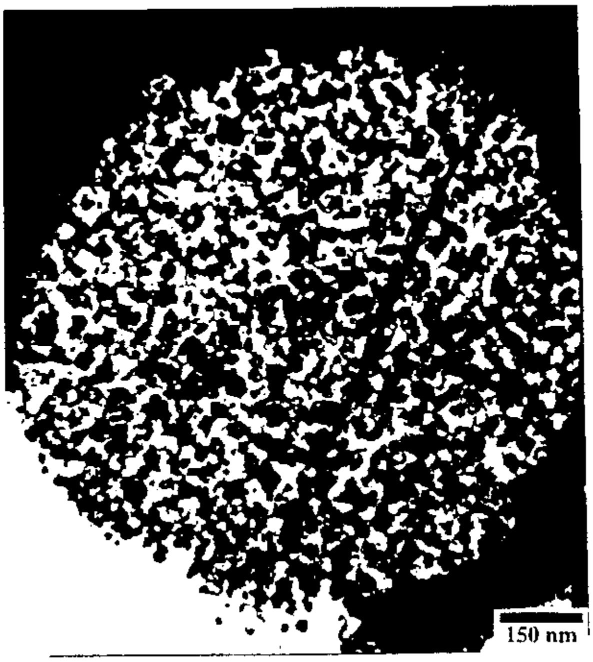
B

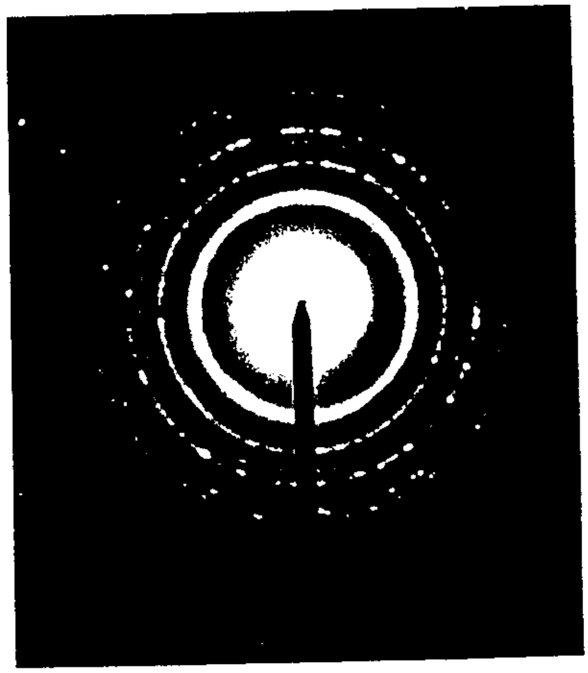


- CROSS SECTION MICROGRAPH OF A FILM GROWN FROM BEAMS MADE OF ATOMS AND SMALL CLUSTERS -

FILMS TYPE B

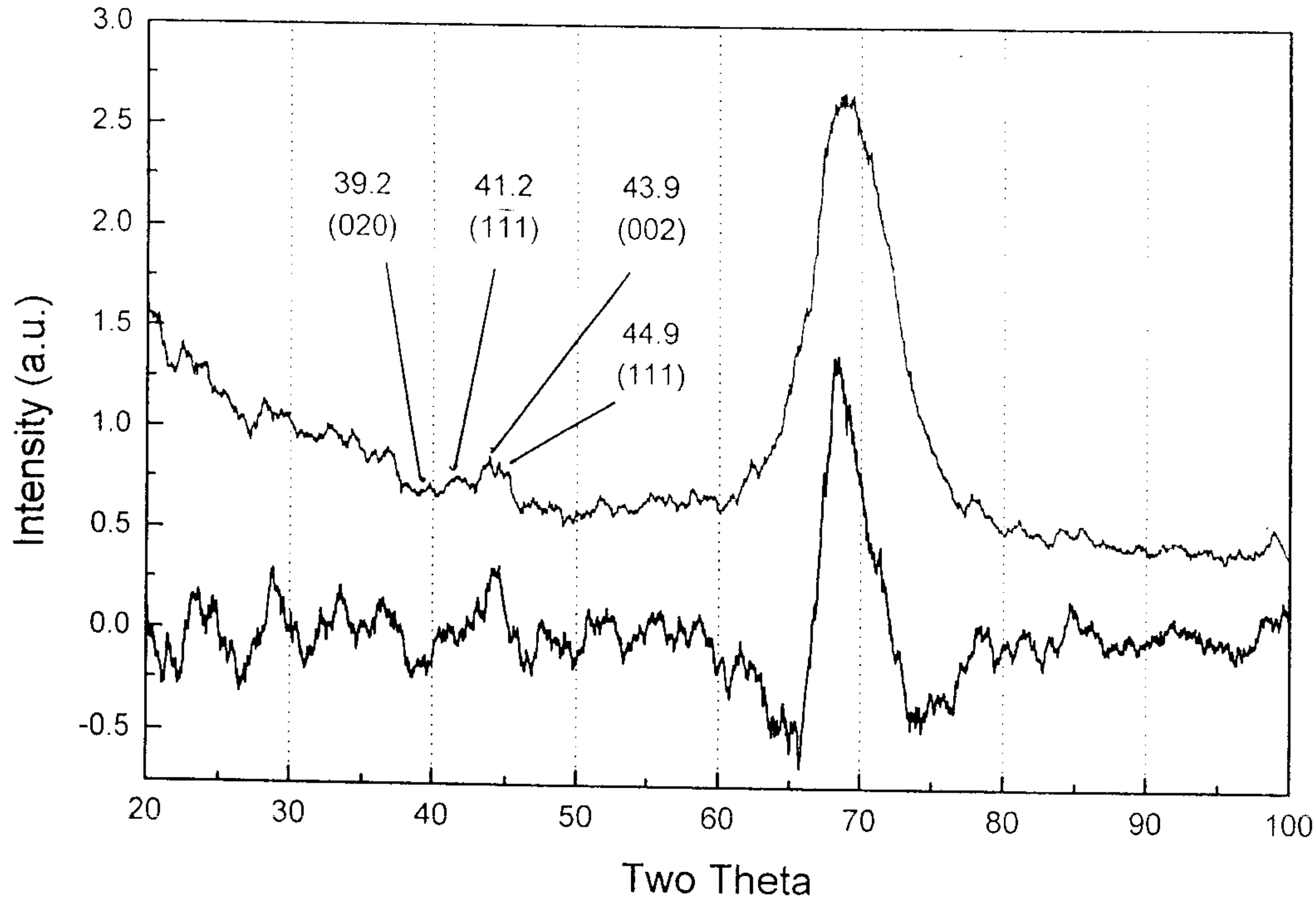
TYPICAL AMORPHOUS CHARACTER





- MICROGRAPHS OF FILMS MADE WITH BEAMS WITH LARGER CLUSTERS - FILMS TYPE A

- NANOCRYSTALS ARE CLEARLY VISIBLE.



3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
Intensity (a.u.)
39.2
(020)
41.2
(11̄1)
43.9
(002)
44.9
(111)
20
30
40
50
60
70
80
90
100
Two Theta

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Conclusions and Perspectives

- *PAGACS Sources can be efficiently used to synthesize TiNi -SMA alloys.*
- *Amorphous and Crystalline thin films are produced with different cluster size distributions in the beam.*
- *Nanocrystalline films are obtained on room temperate substrates without any need of thermal treatments.*
- *Cluster beam deposition preserves stoichiometry of the original alloy used.*
- *The sources are scalable and compatible with ultra clean environment and processing.*
- *The cluster size distribution of the beam can be efficiently controlled by source parameters and skimmer selection (segregation).*
- *TOF mass spectrometry can be efficiently used to characterize cluster beam distribution and ionic structure of the particles.*
- *The preparation of high quality, grain size controlled, SMA films is envisaged.*

Seeded Supersonic Beams of Thiophene-Based Oligomers

A tool:

- *to study the properties of the isolated aggregates.*
- *to grow high quality thin films.*

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On the Physics of Aggregates
Povo di Trento - ITALY

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Open Questions and Present Limits in films Growth

- *Control on Quality and Crystallinity of Thin films;*
- *Interaction with substrates and interface properties and correlation with devices design and fabrication;*
- *Functionalization to tailor the electronic and optical properties;*
- *Better understanding of correlation between structural, morphological , electronic and optical properties.*

Growth Methods:

- *Chemical*
  - *Spinning*
  - *Langmuir Bludgett*
- *Physical*
  - *OMBE (Organic Molecular Beam Epitaxy)*
  - *SuMBE (Supersonic Seeded Molecular Beam Epitaxy)*

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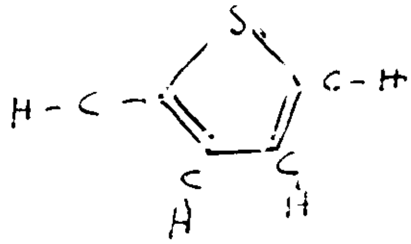
Oligo-thiophenes: Interests

- *Prototype π-conjugated organic molecule: Basic and Fundamental Interest.*

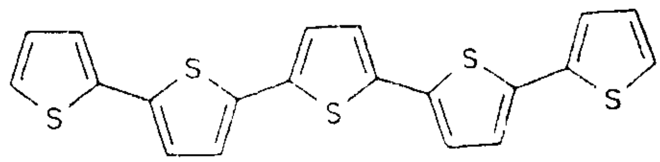
- *Technological interests:*
  - *organic elecronics (FETs: R.Hajlaoui et al. Adv. Mat., 9 (1997) 389, G. Horowitz Adv. Mat. 10(1998) 365).*
  - *LEDs and other electro-optical devices (H. Mauch E.Gumlich Springer Verlag 1996)*
  - *NLO applications (M.G. Harrison et al. Synth. Met. 67 (1994) 215; D. Fischou et al. Adv. Mater. 6 (1994) 64)*
  - *Photovoltaic cells (J. Simon, Molecular Semiconductor, Spinger Verlag (1985)).*

A PROTOTYPICAL CONJUGATED MOLECULAR SYSTEM

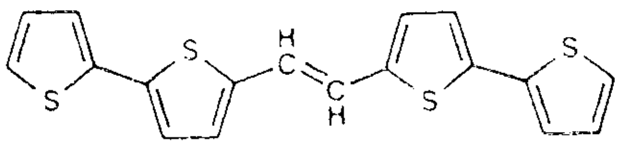
THIOPHENE



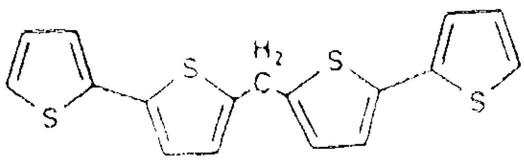
T_5



T_2VT_2



T_2MT_2



OLIGO-THIOPHENE

$$(C_4H_2S)_n H_2$$

SYNTHESIS OF ORGANIC FUNCTIONAL MATERIALS:

- LANGMUIR - BLODGETT (SELF-ASSEMBLING)
- SPINNING
- OMBE (ORGANIC MOLECULAR BEAM)
- ⇒ ? HSB (HYPERTHERMAL SUPERSONIC BEAMS)

T4 Possible Crystal Structures

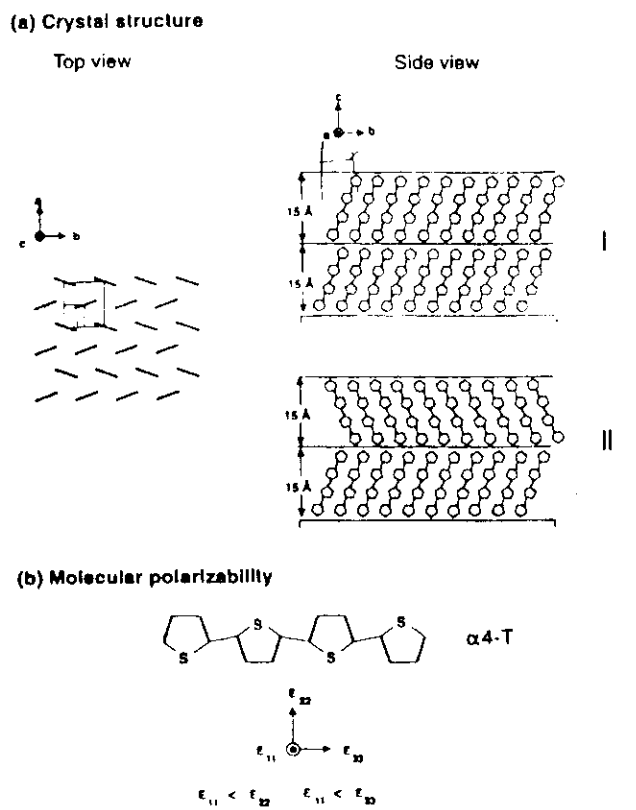


FIG. 2. (a) Possible crystal structures of evaporated quaterthiophenes consistent with the layering found from $\Theta - 2\Theta$ x-ray data on evaporated films (I) has been proposed on the basis of powder diffraction data [Porzio1]. (II) is the structure which has been proposed for α-3T [Bolhuis1] and dimethyl-substituted quaterthiophene[Hotta1]. (b) Polarizability of a single α-4T molecule. The polarizability $\varepsilon_{crystal}$ of the crystal is approximated by taking the average of the molecular polarizabilities in the unit cell.

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T4 Crystal Data

Table 1. Crystal data and structure refinement for 2,2′:5′,2M′:5M′,2M′ quaterthiophene.

Identification code	4T
Empirical formula	$C_{16}H_{10}S_4$
Formula weight	330.48
Temperature	293(2) K
Wavelength	0.71069 Å
Crystal system	Monoclinic
Space group	$P2_1/a$
Unit cell dimensions	a = 8.936(3) Å
	b = 5.7504(9) Å
	c = 14.341(3) Å
	β = 97.22(2)°
Volume	731.1(3) $Å^3$
Z	2
Density (calculated)	1.501 Mg/m^3
Absorption coefficient	0.634 mm^{-1}
F(000)	340
Crystal size	0.40 × 0.30 × 0.05 mm^3
θ range for data collection	2.86 to 27.99°
Index ranges	$-1 \le h \le 11, -1 \le h \le 7, -18 \le h \le 18$
Reflections collected	2282
Independent reflections	1644 [R(int) = 0.0487]
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	1644 / 0 / 104
Goodness-of-fit on F^2	1.098
Final R indices [$I > 2\sigma(I)$]	R_1 = 0.0431, wR_2 = 0.1417
R indices (all data)	R_1 = 0.0556, wR_2 = 0.1484
Largest diff. peak and hole	0.488 and –0.396 e. $Å^{-3}$

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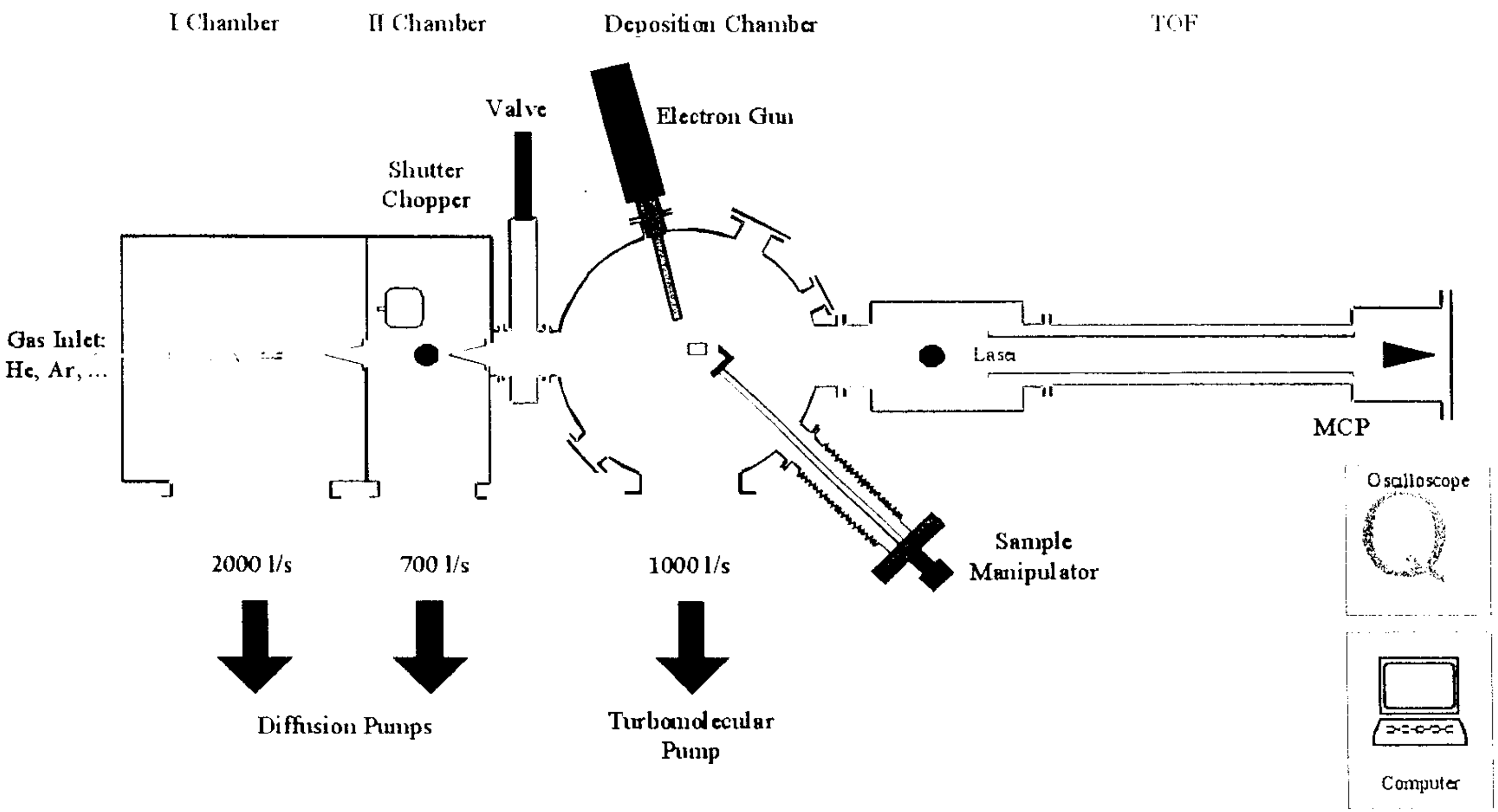

Experimental Apparatus

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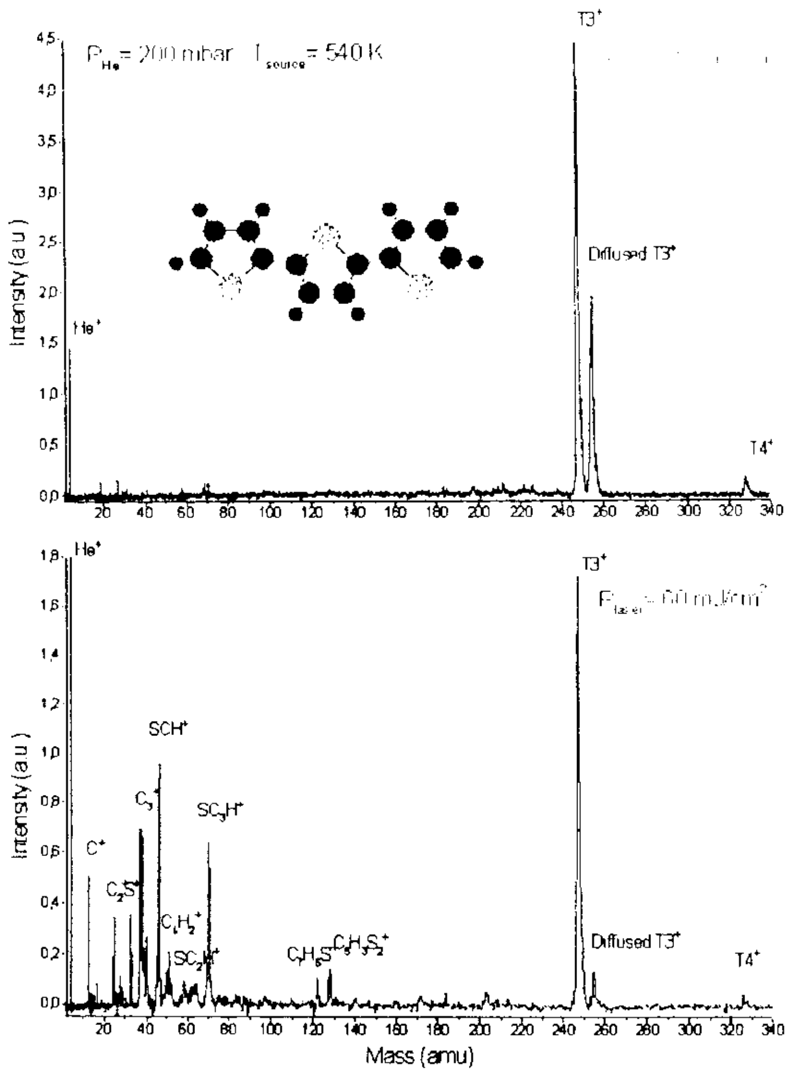
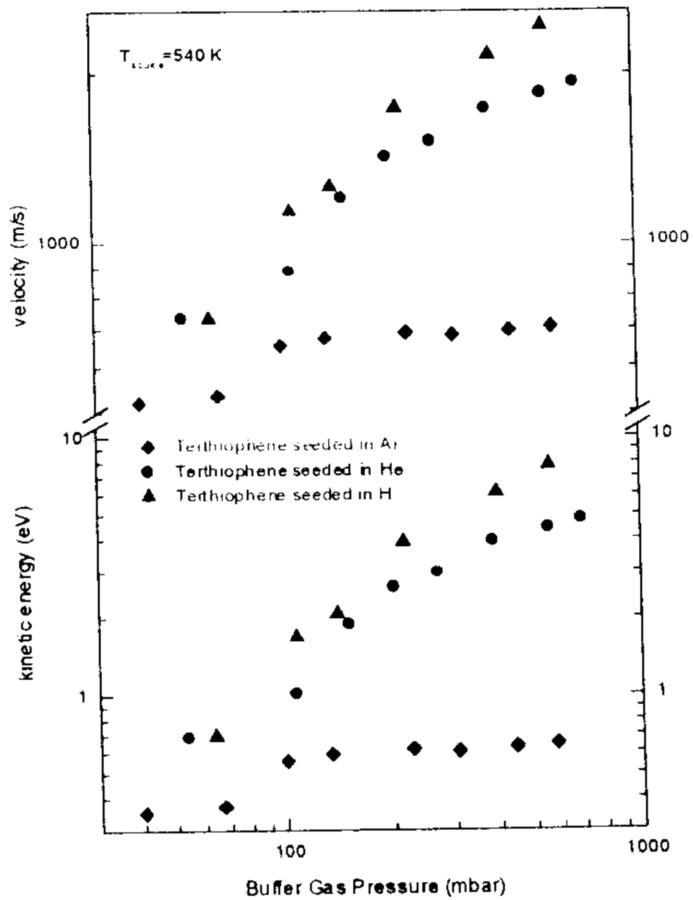
T3-T4 HSB Characterization by PI - TOF Spectroscopy



T3 HSB - Energy and Velocity as a Function of He, Ar and H2 Seedings



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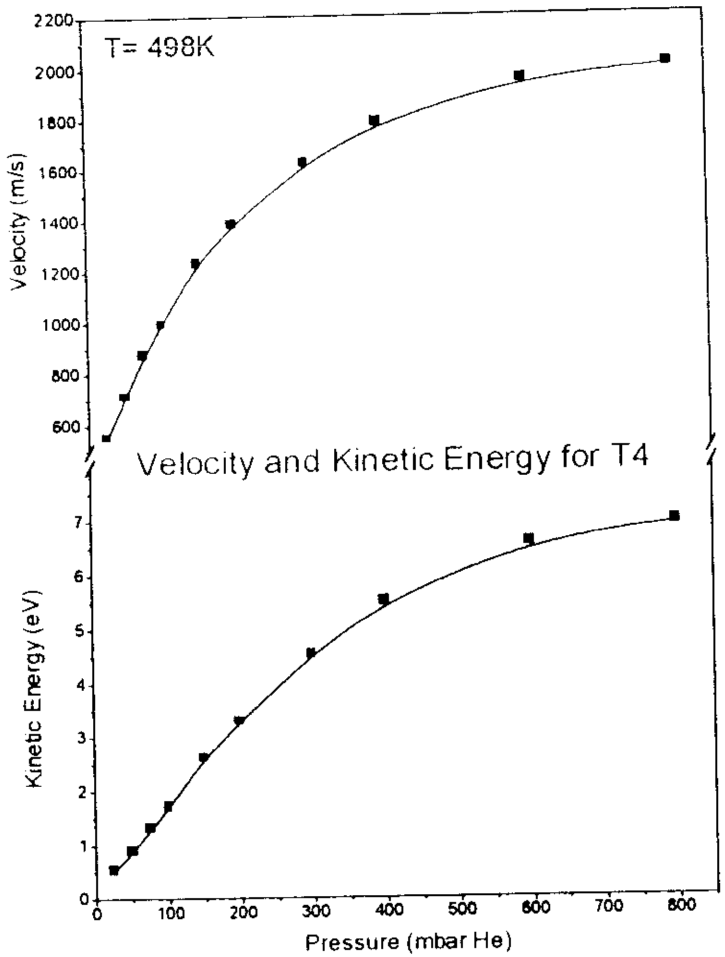
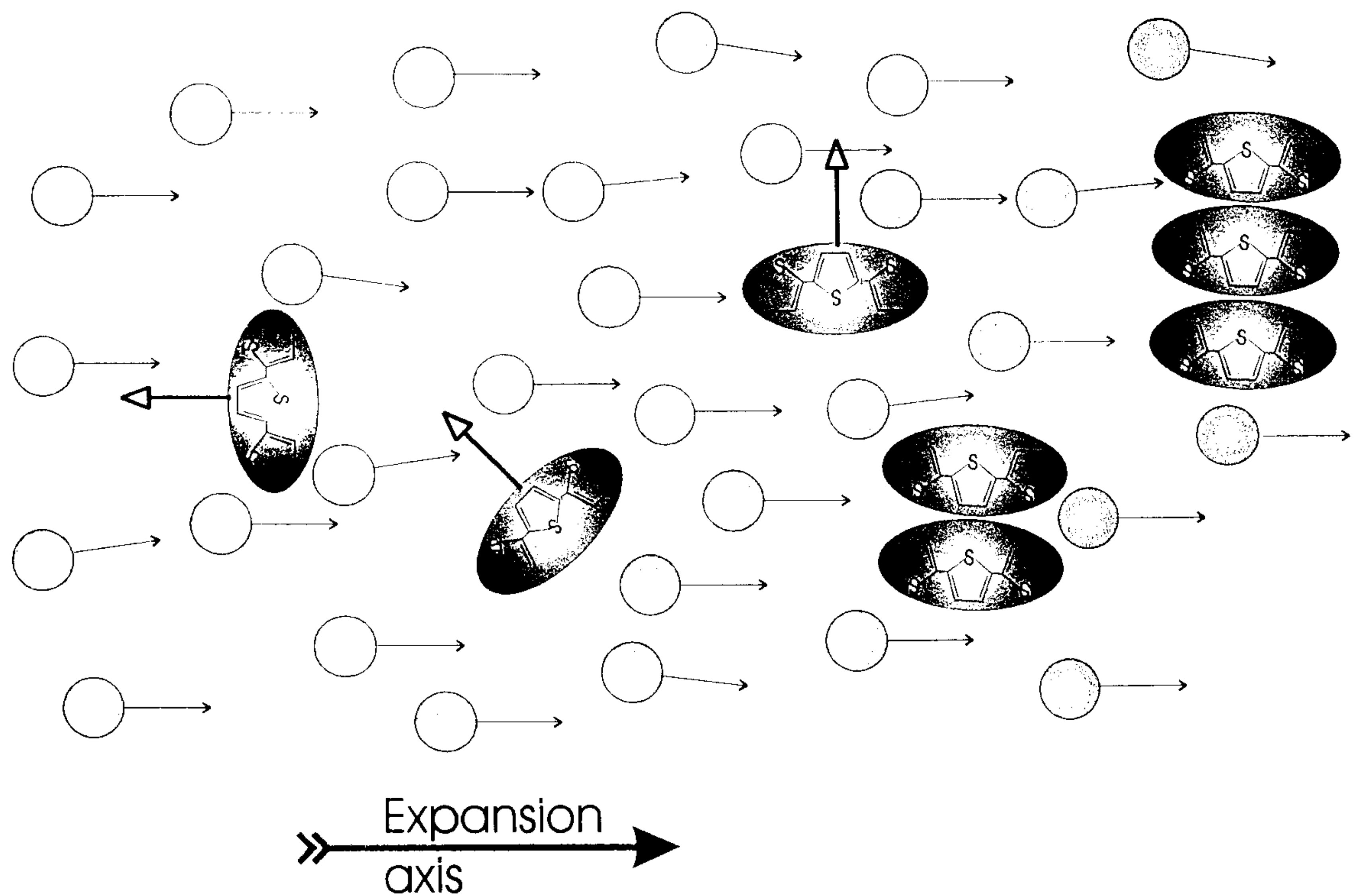
T4 - HSB seeded in He




Expansion
axis

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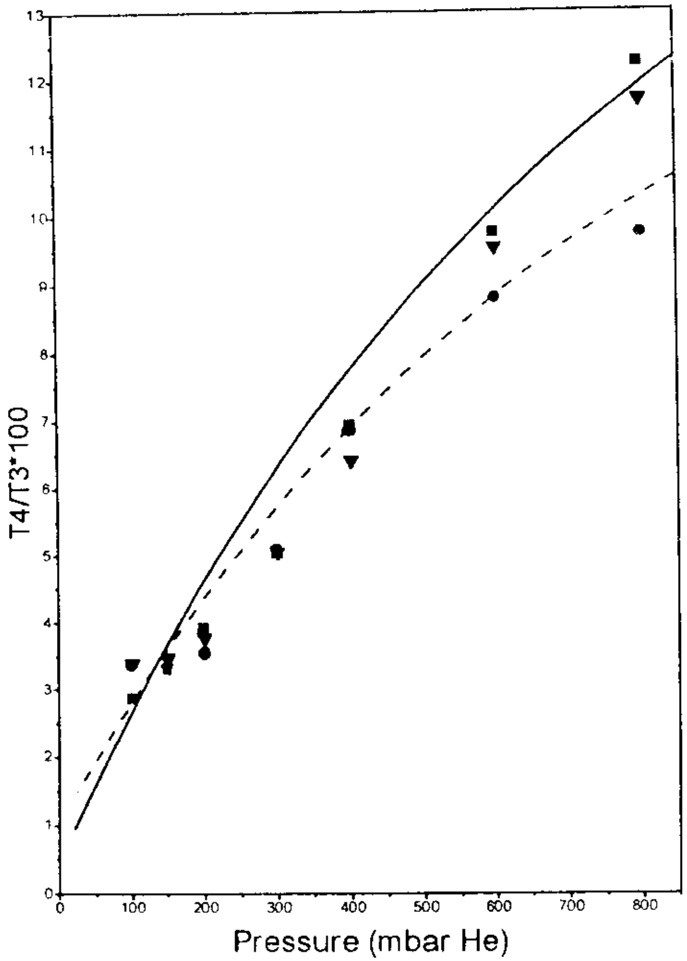
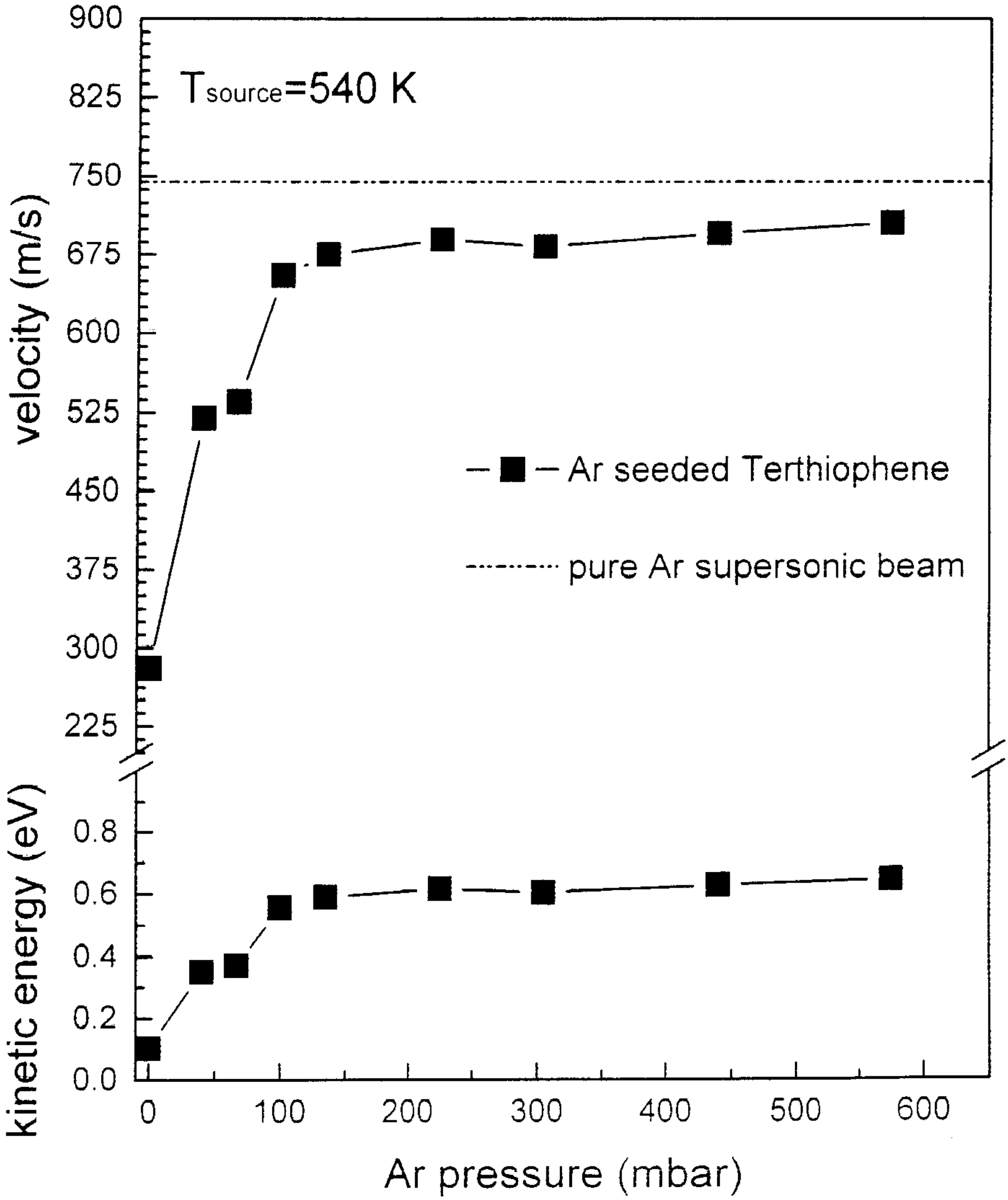
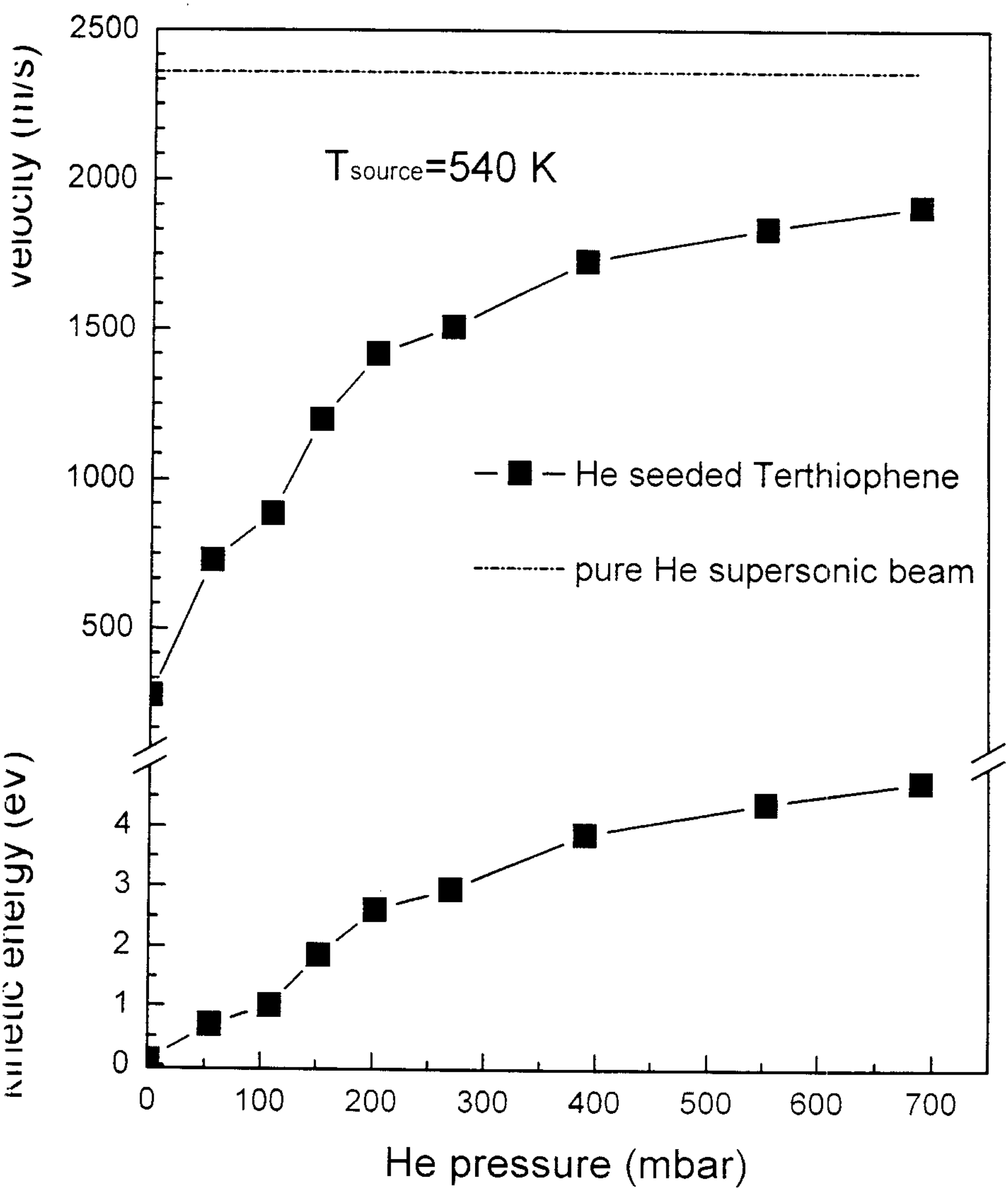
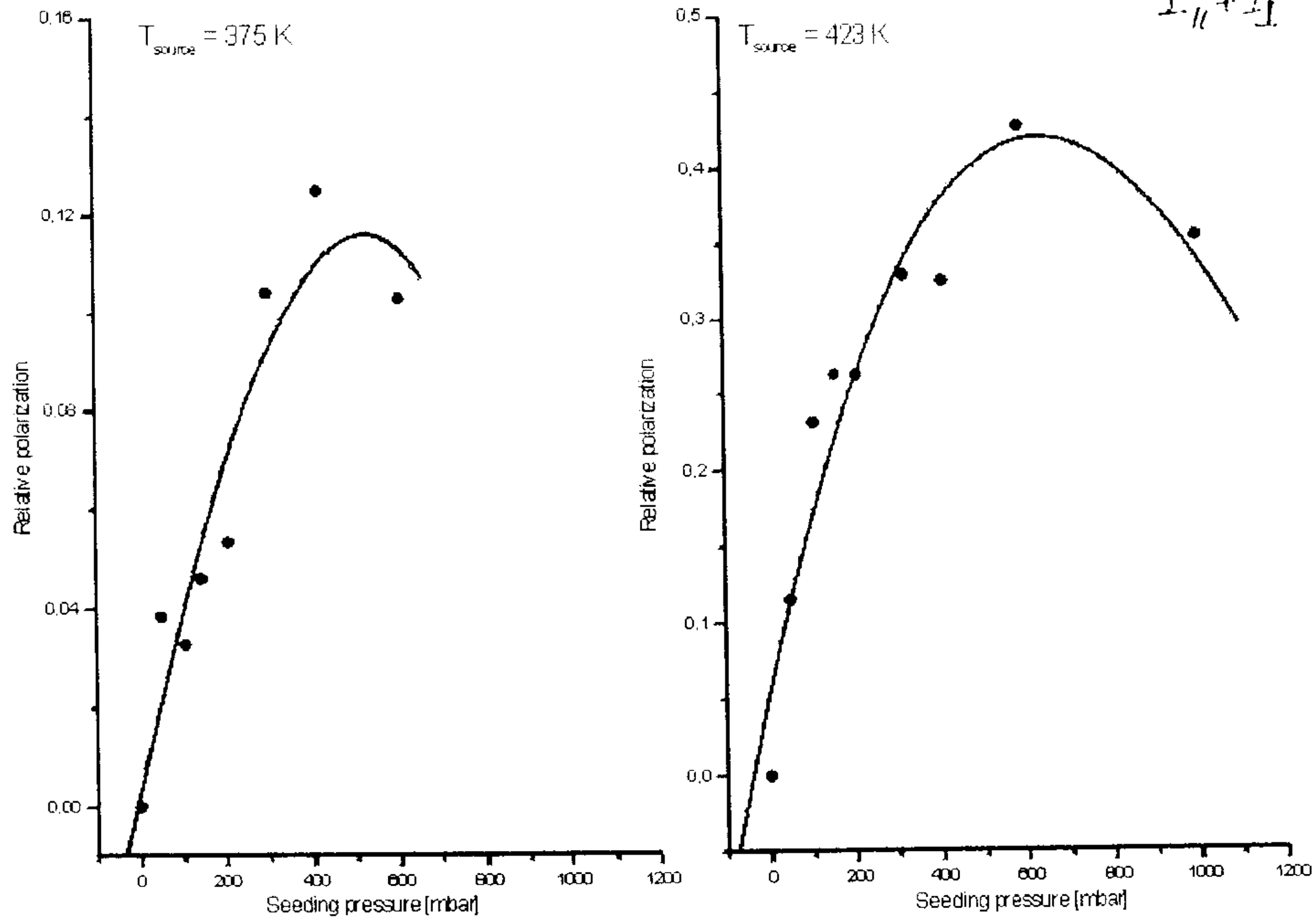
T4/T3 Abundance Increased By the Segregation in the HSB





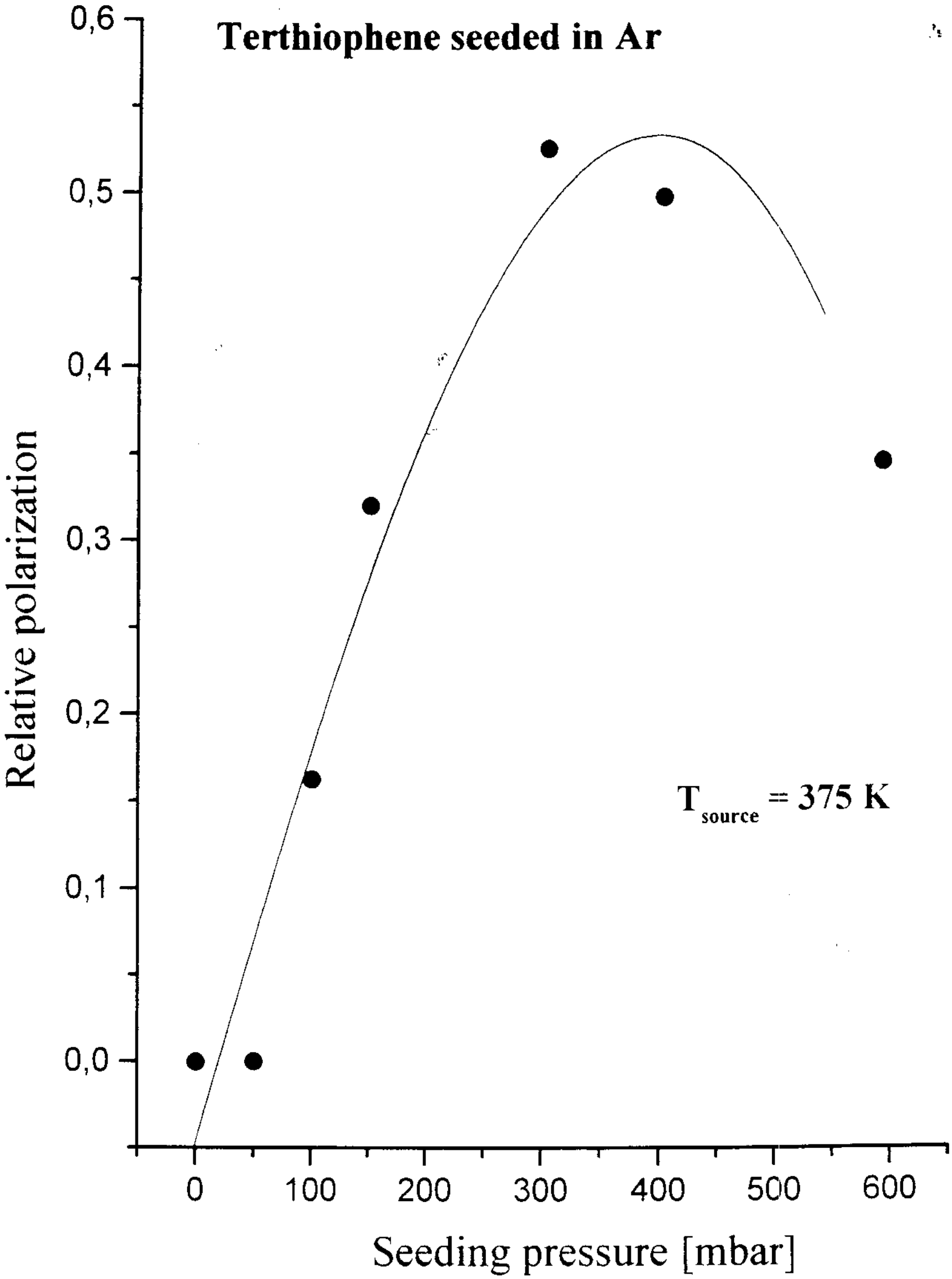
Tsource=540 K
velocity (m/s)
kinetic energy (eV)
Ar seeded Terthiophene
pure Ar supersonic beam
Ar pressure (mbar)
900
825
750
675
600
525
450
375
300
225
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600


2500
2000
1500
1000
500
4
3
2
1
0
0
100
200
300
400
500
600
700
T_{source}=540 K
He seeded Terthiophene
pure He supersonic beam
He pressure (mbar)



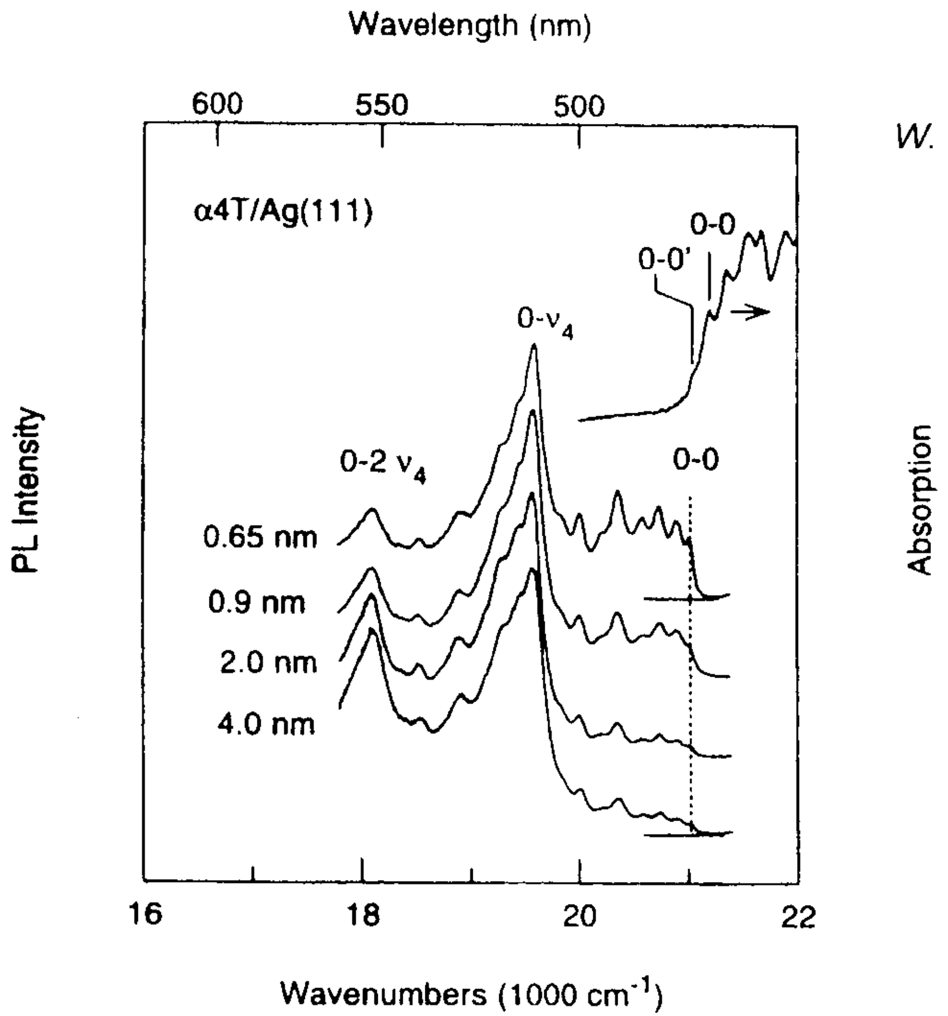
$$\frac{I_{\parallel} - I_{\perp}}{I_{\parallel} + I_{\perp}}$$

Terthiophene seeded in He



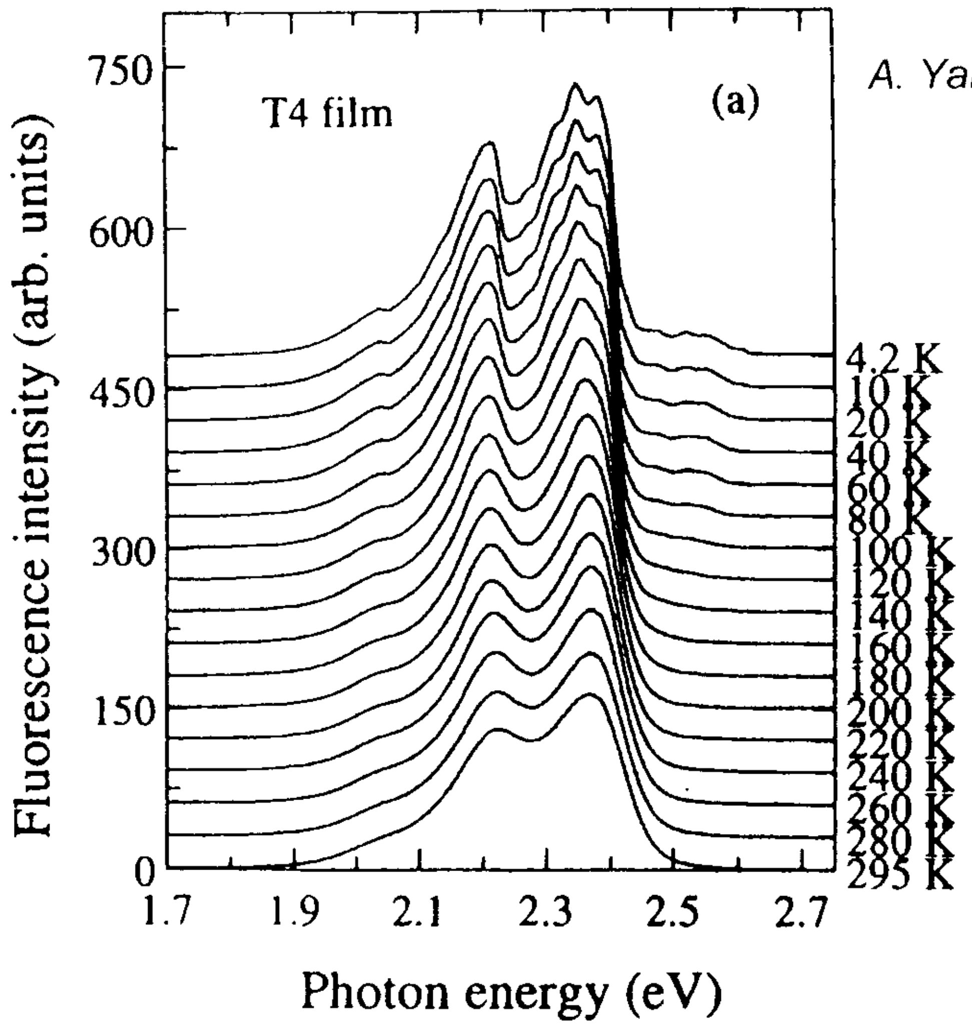
Terthiophene seeded in Ar
0,6
0,5
0,4
0,3
0,2
0,1
0,0
Relative polarization
T_{source} = 375 K
0
100
200
300
400
500
600
Seeding pressure [mbar]

T4 Grown from Standard Vacuum Deposition: Fluorescence as a Function of Thickness



W. Gebaner et al. Chem. Phys. 227 *(1998) 33*

T4 Fluorescence Spectra (3.26 eV excitation) of Vacuum Deposited Films (375 nm)



A. Yang et al. J. Chem Phys. 109 (1998) 8442

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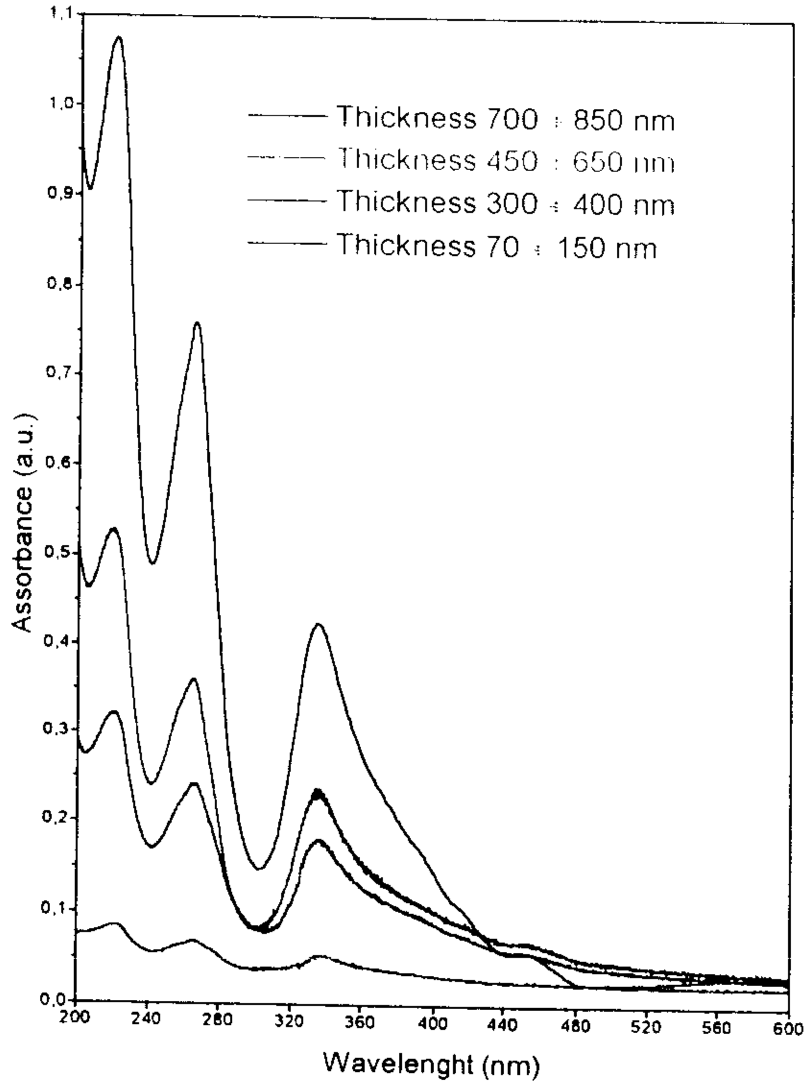
T4 - Grown from He seeded HSB - Absorbance for Films with different thickness



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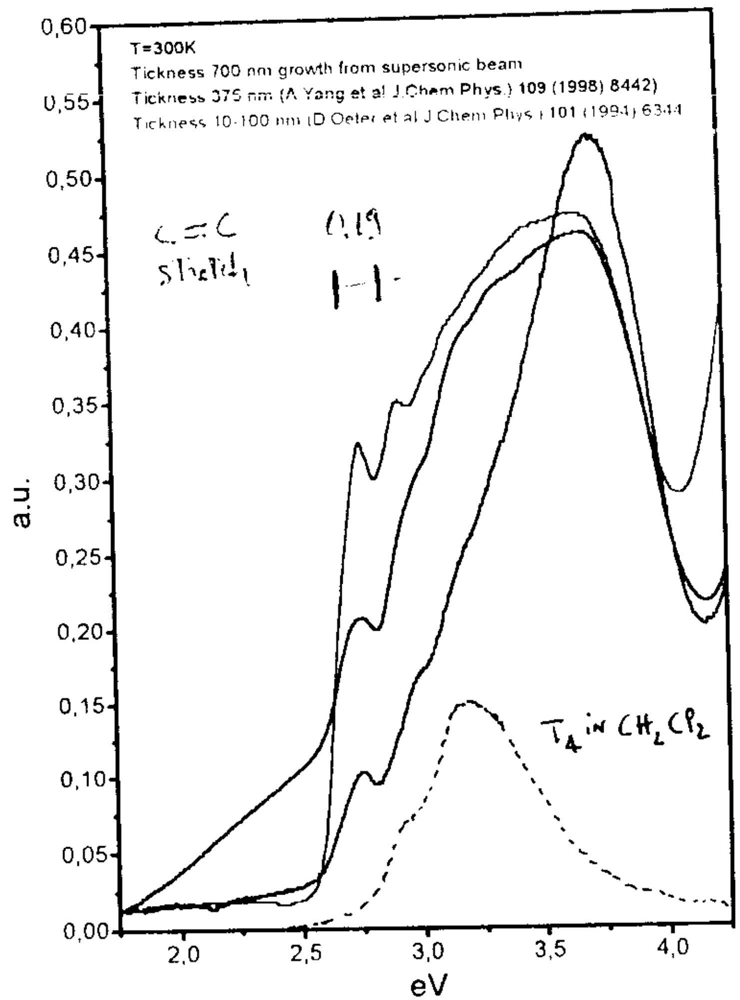
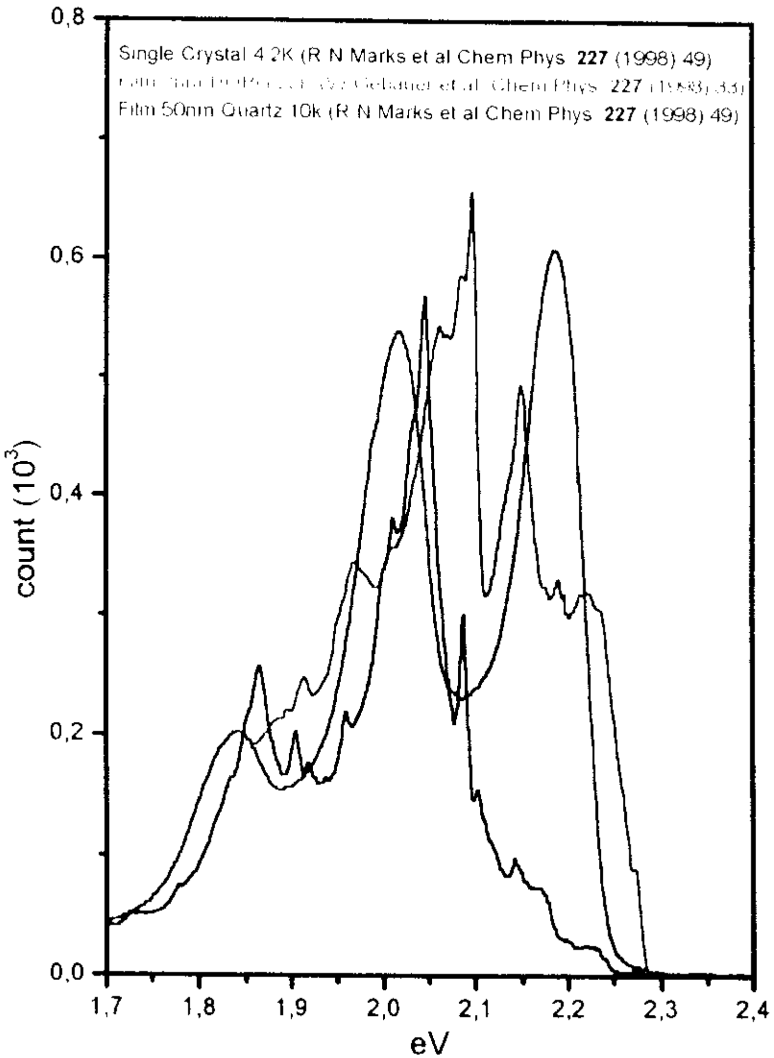
Comparison Between Films Grown from T4-HSB and Conventional Vacuum Deposition: Absorbance



Available PL data From 6T from Thin Films and Single Crystal



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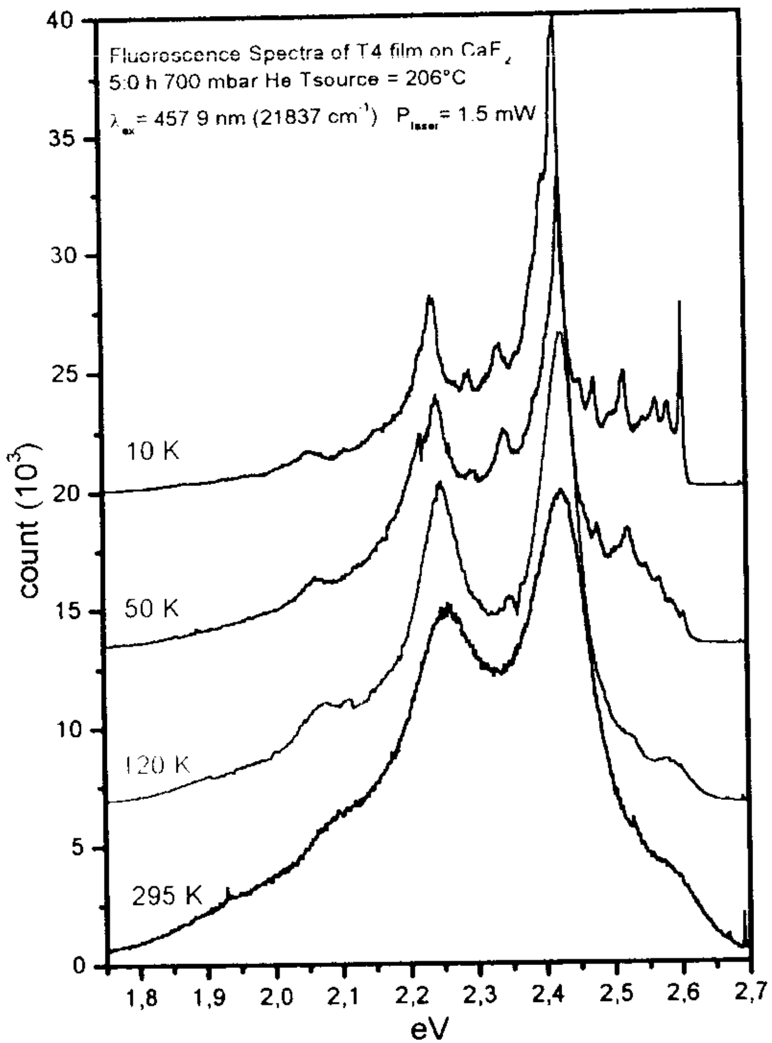
HSB Grown films:
Fluorescence from T4 as a Function of Temperature



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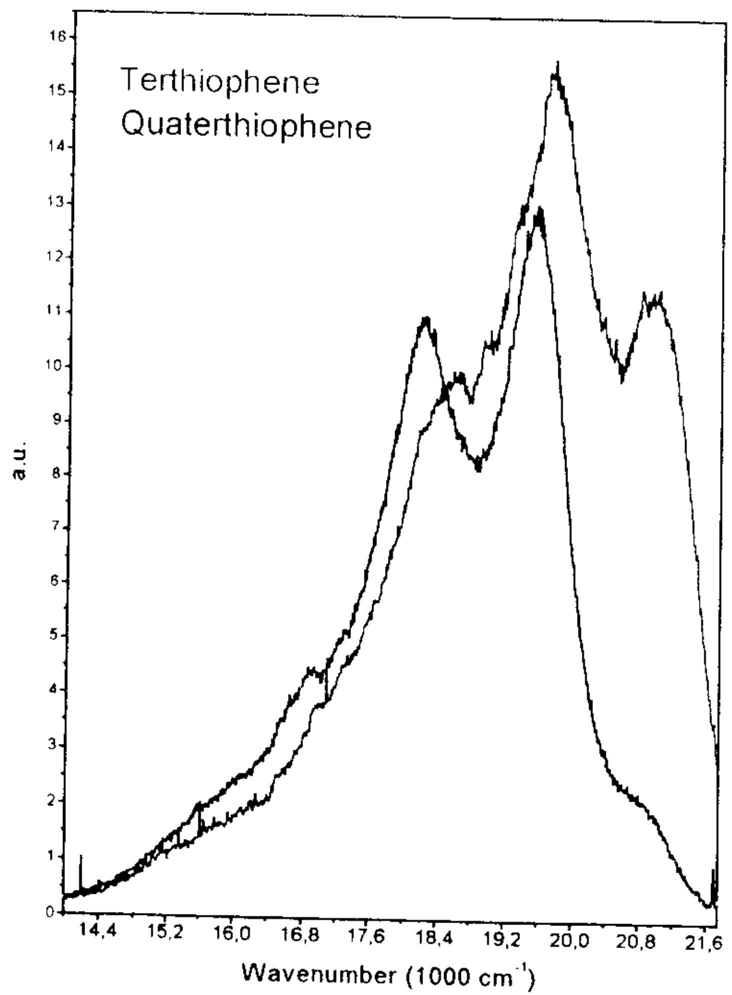
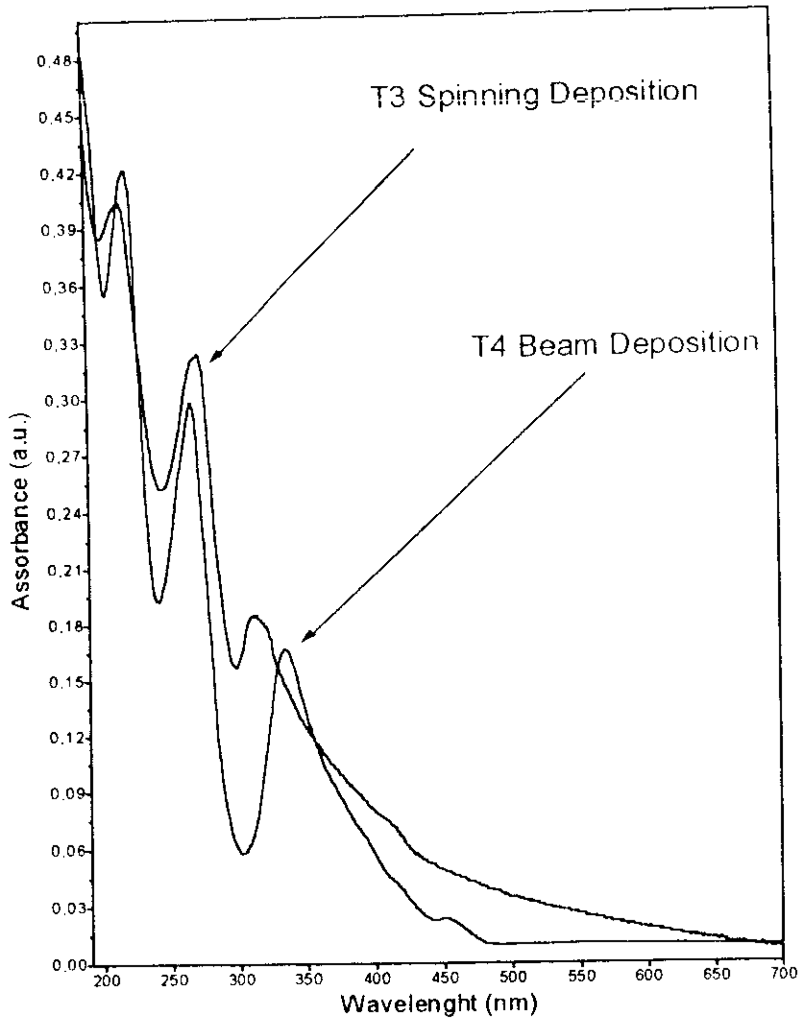
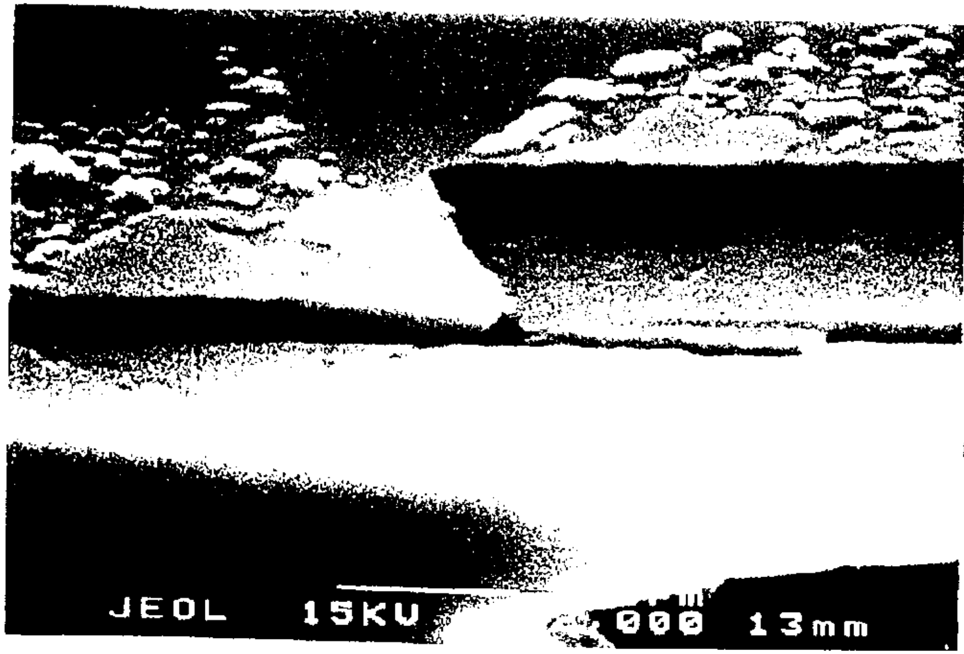
T3 versus T4 Fluorescence
-The T4 film is Obtained from HSB
- The T3 from Spinning



T3 versus T4 Absorbance



SEM Micrograph of Films of T4 grown by HSB: seeding in He



T4-Film about250 nm thick Grown by HSB

Thin T4 Film with Island FormationGrown by HSB (low Pressure Source

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Conclusions and Perspectives

- *We have built an highly efficient and reliable source for hyperthermal supersonic beams for Fullerene and oligo-polymers.*
- *The fullerene source produces the beam of neutrals in the ground electronic state with the highest achievable kinetic energy: very promising applications.*
- *The processes involving vibrational cooling and acceleration of super-hot clusters can be studied directly.*
- *The Synthesis of films of oligo-polymers can be studied in well defined conditions with full control of the molecular degrees of freedom.*
- *An UHV apparatus combining PACIS and HSB sources will allow to study co-deposition and funtionalization processes.*

ES: - OLIGO-THIOPHENES + C_{60} → ELECTRON TRANSFER + NLO PHOTOVOLTAIC ...

- ORGANIC + METAL CLUSTERS → "PHYSICAL" FUNCTIONALIZA...