INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
34100 TRIESTE (ITALY) · P.O.B. 586 · MIRAMARE · STRADA COSTIERA 11 · TELEPHONE: 2240-1
CABLE: CENTRATOM · TELEX 460392 · I

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WORKSHOP ON SPACE PHYSICS:
"Materials in Micorgravity"
27 February - 17 March 1989

"Introduction to Vapour Growth"

E. KALDIS
ETH
Zurich, Switzerland

Please note: These are preliminary notes intended for internal distribution only.

Materials Research in Microgravity

A case study: **VAPOUR GROWTH** of

« α-HgI_2, a Room Temperature Semiconductor Detector, for x- and γ-Rays »

E. Kaldis

Laboratorium für Festkörperphysik ETH

CH-Zurich 8093, Switzerland

Microgravity → experimental tool for Materials Research

particularly → Growth of Perfect Crystals

Crystals grow from a fluid "nutrient" phase.

→ under gravity
uncontrolled thermal convection
↓
growth irregularities → defects

→ Microgravity very important
with increasing demand for highly perfect crystals in electronics

Basic Crystal growth methods

nutrient phase

- liquid
  - low T. solution growth
  - high T. " " (flux), LPE
  - } On purpose, foreign molecules present ⊕
- melt
  - Solidification
  - Bridgmann
  - Chzochralski
  - } ⊖
- vapour
  - Sublimation ⊖
  - Chem. Transport
  - Epitaxy: VPE, MBE, MOCVD, AE
  - } ⊕

Vapour Growth of α-HgI_2

Most suitable method vapour growth.

Solution growth : Incorporation of solvent (due to layer structure and channels,

melt growth : Not possible → T=130°C Structural Phase Transition

red modification
tetragonal $P4_2/nmc$
↓
yellow modification
orthorhombic $Cmc2_1$

whereas $T_{m.p} = 256°$.

Microgravity Relevance for Vapour Growth of α-HgI_2

State of the art on earth : Large crystals (≤ 500g), but increase of perfection necessary

α-HgI_2 : molecular crystal, very easy to deform
→ deformation under own weight by 1g.

Low vapour growth pressure: 0.1 Torr
↓
Not appreciable thermal convection
↓
solutal convection introduced by impurities? PURITY!
Current opinion: microconvective effects (not possible to calculate) INDUCE DEFECTS

→ Increased perfection of small crystals in µg (NASA exper.)
→ Diffusive Growth dominating

Model Substance for very large PERFECT crystals at low T (<130°C)

Vapor growth of bulk crystals

Stagnation due to underdeveloped **technology.**

Lack of in situ observation and monitoring of important growth parameters.

Growth of very large crystals (1kg and more) introduces a series of additional difficulties which have not been recognized in the past.

Historical development: The existing studies of bulk crystal growth did not last for applications → tendency to layers and thin films

Today, with the advent and maturity of MBE MOCVD etc the perfection of the substrate tends to become the main problem.

Example: CdTe substrate for the family of $Hg_{1-x}Cd_xTe(Se)$, $Hg_{1-x}Sn\,Te(Se)$ etc compounds.

For compounds not suitable for melt growth **bulk vapor growth of large crystals for substrates becomes important.**

Vapour Growth of α-HgI_2 under Microgravity

a very complex interdisciplinary project

List of contents of these lectures

1. Introduction
2. Material properties for detectors. Applications
3. Impurities
4. Nonstoichiometry
5. Kinetics of Growth at the vapour-solid interface
6. Mass transport via the vapour phase (influence of impurities, microgravity etc)
7. Preparation of a GET AWAY SPECIAL (GAS space experiment) to measure the mass transport rate, diffusion coefficients etc
8. Development of an advanced growth facility for space experimentation
9. Vapour Growth of α-HgI_2 in the past. Space Experim
10. Present results on growth rate. Questions about the growth mechanism
11. Possible future developments: High T, organic materials

α-HgI_2 research at ETH-Zurich

Dr. T. Kobayashi (JAPAN) 1979-82

Dr. M. Piechotka (POLAND) since 1983

Prof. M. Isshiki (JAPAN) 1988-9

Dr. R. Revathi (INDIA) 1987-8

Dr. G. Wetzel (West GERMANY) since 1988

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