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Experiments for Electromagnetic Levitation in Microgravity

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Containerless Processing is a promising research tool for investigating the properties of undercooled melts and their solidification. For conducting samples RF-electromagnetic levitation offers the possibility to obtain large undercoolings by avoiding heterogeneous nucleation at container walls.

On earth, however, strong magnetic fields are needed to compensate the gravitational force which imposes a lower limit on the available temperatures and on the accessible undercooling range. Under microgravity conditions the magnetic positioning fields can be minimized and hence, undercooling becomes feasible under ultra high vacuum conditions and lower temperatures become accessible.

In contrast to other undercooling and solidification techniques, electromagnetic levitation allows for diagnostic measurements during the early steps of nucleation and phase selection. Experiments cover a wide field of research topics: nucleation, directional solidification at a high velocities, generation of metastable phases, evolution of microstructures, properties of undercooled liquids. Examples from these classes including experiments selected for the IML-2 mission will be discussed with emphasis of technical requirements. An overview will be given on the German TEMPUS (Electromagnetic levitation facility) program.

EXPERIMENTS FOR ELECTROMAGNETIC LEVITATION IN MICROGRAVITY

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Workshop on Containerless Experimentation in Microgravity
Pasadena, January 17 - 19, 1990

Experiments for Electromagnetic Levitation in Microgravity

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INTRODUCTION

- o General Aspects of Electromagnetic Levitation Techniques
  - Advantages of Experiments under Microgravity
- o Experiment Classes and Scientific Objectives
- o Scientific Hardware Requirements
- o TEMPUS Development Program

ADVANTAGES OF ELECTROMAGNETIC LEVITATION

- Contactless Positioning
- Contactless Heating
- *in situ* – Diagnostics
- Bulk Samples
- High Temperatures (up to 2500°C)
- Pure Environment

Limitation

- Conducting Sample

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ADVANTAGES OF ELECTROMAGNETIC LEVITATION UNDER MICROGRAVITY

- Less R.F. power necessary for positioning
- Separation of positioning and heating
- Investigation of low melting metals
- UHV environment
- No shape deformation
- Reduced magnetic damping
- Stirring effects will be considerably weaker

Experiment Classes

1. Undercooling and Nucleation
2. Non - Equilibrium Solidification
3. Metastable Phases
4. Thermophysical Properties of Undercooled Melts

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Scientific Objectives

1. Undercooling and Nucleation

- max. undercoolings
- "hypercooling"
- nucleation frequencies
- heterogenous and homogeneus nucleation
- nucleation control
- effects of microgravity environment on undercooling experiments

2. Non - Equilibrium Solidification

- measurements of solidification velocities
- directional dendritic and eutectic solidification
- solute trapping and segregation free solidification
- microstructure evolution
- coarsening and ripening effects

Scientific Objectives

3. Metastable Phases

- generation of metastable phases
- metastable phase diagrams
- phase selection processes
- formation of quasicrystaliine phases
- metallic glass research
- thermodynamics of metastable phases

4. Thermophysical Properties

- surface tension
- viscosity
- specific heat

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Experiment Hardware Requirements

Generic Requirements

Pure Environment	UHV $\leq 10^{-8}$ mbar, pure inert gases
Two Frequency Generators	two coil system tunable input power 0-100%
Stable Sample Positioning	stable against 10^{-2} g_0 damped rotations and oscillations
Evaporation Shielding	

Specific Requirements

	Nucleation	Growth	Metastable Phases	Properties
Pyrometry	≤ 1 μs; < 2570 C	≤ 1 μs; = 90	≤ 1 s; ≥ 400 C	#
Power Modulation				10 W/s
Nucleation Trigger		#	#	
Video System		≤ 500 Hz		≤ 200 Hz; top and side view
Quenching Device		#	#	

TEMPUS DEVELOPMENT PROGRAM

STEP O:	- Pre-Developments	Since 1983	DLR Inst. for Space Simulation
STEP 1:	- Laboratory-type Model	3/86 - 11/87	Contractor: Dornier
	o KC-135 Tests	11/1987, 5/1988	
	o coil development	-1989	
	o ground support program (TEXUS)	1988	
	o temperature diagnostics (contamination study)	1989/1990	
	o user support program (IML-2)	1990 - 1993	
STEP 2:	- TEXUS-Model	5/1987 - 6/1989	
	Facility Test / Scientific Experiment		
	First Mission	4/1989	
	- Spacelab Model Phase B	6/1988 - 3/1990	
STEP 3:	- Spacelab Model Phase C/D	4/1990 - 1/1992	
	o First Mission : IML-2	Jan. 1993	

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Experiments for TEMPUS on IML-2

PI	Affiliation	Title
Bayuzick	Vanderbilt Univ.	"Effects on Nucleation by Containerless Processing in Low Gravity"
Flemings	MIT	"Alloy Undercooling Experiments"
Szekely	MIT	"Measurements of the Viscosity of the Undercooled Melts Under the Conditions of Microgravity and Supporting MHD Calculations"
Johnson	California Inst. of Technology	"Metallic Glass Research in Space"
Egry	Inst. for Space Simulation, DLR	"Viscosity and Surface Tension of Undercooled Melts"
Herlach	Inst. for Space Simulation, DLR	"Non-Equilibrium Solidification of Largely Undercooled Melts"
Urban	Inst. for Solid State Research, KFA Jülich	"Structure and Solidification of Largely Undercooled Melts of Quasicrystal-Forming Alloys
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