The physical acoustics group at the Jet Propulsion Laboratory has developed a single mode acoustic levitator technique for advanced containerless materials processing. This technique was successfully demonstrated in ground-based studies to temperatures ≈ 1000 °C in a uniform temperature furnace environment and to temperatures > 1500 °C using laser beams to locally heat the sample. At this time, we are evaluating microwaves as a more efficient means than lasers for locally heating a positioned sample. Recent tests of a prototype single mode hybrid microwave/acoustic levitator successfully demonstrated the feasibility of using microwave power as a heating source. The potential advantages of combining acoustic positioning forces and microwave heating for containerless processing investigations will be discussed and results of ground-based acoustic, microwave, and hybrid microwave/acoustic studies will be presented.
CONTAINERLESS EXPERIMENTATION IN MICROGRAVITY WORKSHOP

HIGH TEMPERATURE ACOUSTIC
AND
HYBRID MICROWAVE/ACOUSTIC
LEVITATORS FOR MATERIALS PROCESSING:
PROGRESS REPORT

MARTIN BARMATZ

JPL

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PRESENTATION OUTLINE

• HIGH TEMPERATURE SINGLE MODE ACOUSTIC LEVITATOR
  • ISOTHERMAL ENVIRONMENT (≤ 1000 °C)
  • LASER BEAM HEATING (≈ 1500 °C)
  • VIDEO TAPE

• HYBRID MICROWAVE/ACOUSTIC LEVITATOR
  • ADVANTAGES OF MICROWAVE HEATING
  • DEVELOPMENT PROGRAM
  • TEMPERATURE FEEDBACK CONTROL
  • PROTOTYPE HYBRID
  • POTENTIAL SCIENCE AREAS
MICROWAVE/ACOUSTIC

RESEARCH TEAM

DR. M. BARMATZ - MICROWAVE/ACOUSTIC PHYSICIST

DR. J. WATKINS - MICROWAVE/ACOUSTIC PHYSICIST

MR. J. STONEBURNER - ACOUSTIC PHYSICIST

DR. H. JACKSON - THEORETICAL PHYSICIST

DR. C. SHIPLEY - SCIENTIFIC PROGRAMMER

MR. G. AVENI - ACOUSTIC SCIENTIST

MR. C. HAGENLAGER - PROGRAMMER

MR. R. ZANTESON - MACHINIST
HIGH TEMPERATURE SINGLE MODE ACOUSTIC LEVITATOR

- CYLINDRICAL SINGLE MODE POSITIONER
- FIXED FREQUENCY 20 KHZ DRIVER
- (011) MODE EXCITATION
- ISOThERMAL FURNACE (1000 °C)
- 100 WATT NEODYMIUM-YAG LASER - DUAL BEAM
  - \( \approx 3 \text{ mm DIAMETER SHUTTLE TILE SAMPLE} \)
- NON-CONTACT TEMPERATURE MEASUREMENT
- QUANTUM LOGIC LASER PYROMETER
HIGH TEMPERATURE SINGLE MODE ACOUSTIC LEVITATOR

PIEZOELECTRIC TRANSDUCER

HORN

DRIVER ROD

ADJUSTABLE SCREEN

SAMPLE

CYLINDRICAL QUARTZ TUBE

SAMPLE INSERTION AND RETRIEVAL PORT

VIEWING PORT

ADJUSTABLE PLUNGER

STEPPER MOTOR
 DRIVER POWER VS TEMPERATURE

TEMPERATURE (°C)

DRIVER POWER (WATTS)

- AL (2.8 g/cc)
- HOLLOW GLASS (1.51 g/cc)
- HOLLOW AL (0.84 g/cc)
- SHUTTLE TILE (0.32 g/cc)
- SHUTTLE TILE (0.20 g/cc)
YAG - HeNe PATH

- = YAG LASER BEAM
- = HeNe LASER BEAM
- = BOTH BEAMS CO-ALLIGNED

/ = MIRROR
/ = BEAM-SPLITTER

- = LENS

YAG LASER

MOTORIZED BEAM-SPLITTER

BEAM COLLIMATOR

SAMPLE

COMPUTERIZED STEERING MIRRORS

METER

COMPUTERIZED STEERING MIRRORS
OUARTZ CHAMBER - FURNACE INSULATION / LEN_ COOLING PORT

SAMPLE

OPTICAL PATH

CLOSE FOCUS LENS

LEN_ COOLING PORT

BEAM SPLITTER

CCD VIDEO CAMERA

LASER PYROMETER

1000 DEG FURNACE

OPTICAL PATH OF PAN AND TILT TABLE
MICROWAVE/AcouSTic HYBRID LEVITATOR

MICROWAVE HEATING ADVANTAGES

- EFFICIENT POWER CONVERSION COMPARED TO LASERS AND ARC LAMPS

- SMALL, LIGHT WEIGHT POWER SYSTEM

- VOLUMETRIC SAMPLE HEATING IS POSSIBLE

- SAMPLE POSITIONING IS NOT CRITICAL

- FAST CONTROLLABLE HEATING OF SAMPLE QUICK RESPONSE TIME

- COLD CHAMBER WALLS ⇒ QUICK CONTROLLABLE COOLING - TEMPERATURE CONTROLLED PROCESSING

- SELECTIVE HEATING OF SAMPLE COMPONENTS

- POSITIONING OF HOT AND COLD SAMPLES SIMULTANEOUSLY (DROP COALESCENCE)
MICROWAVE/ACOUSTIC HYBRID LEVITATOR

DEVELOPMENT PROGRAM

- EVALUATE MICROWAVE HEATING CONCEPT APPLIED TO CONTAINERLESS PROCESSING
  - MODEL - ABSORPTION OF A SPHERE
  - MODEL - TEMPERATURE PROFILE WITHIN SPHERE - INVERTED TEMPERATURE PROFILE (HOTTEST IN CENTER)
  - TEMPERATURE FEEDBACK CONTROL
  - MATERIALS CHARACTERIZATION - DIELECTRIC CONSTANT
    - GLASSES (LEAD BORATE - 900 °C)
    - CERAMICS (ZEOLITE - > 1100 °C)
- DEMONSTRATE HYBRID LEVITATOR CONCEPT
  - PROTOTYPE - 20 KHZ (ACOUSTIC) LEVITATION - 10 WATTS (MICROWAVE)
  - HIGH POWER HYBRID - 1KW MICROWAVE SOURCE
TEMPERATURE CONTROL OF ALUMINA SILICATE

MICROWAVE HEATING - 20 WATTS
TM (010) MODE

Prop = 140
Int = 7
Diff = 1
MICROWAVE / ACOUSTIC HYBRID LEVITATOR

PIEZOELECTRIC DRIVER - SINGLE MODE POSITIONER

MICROPHONE PROBE TUBE

1.25" Dia. ACOUSTIC DRIVER ROD

CONTACT FINGERS

CAVITY TOP PLATE

CYLINDRICAL CAVITY

VIEWING WINDOW

SUPPORT SCREEN

SAMPLE INSERTION PORT

SAMPLE

ZnSe WINDOW

PLUNGER

MICROWAVE COUPLERS

CAVITY BOTTOM PLATE

IR TEMP DETECTOR
MICROWAVE/ACOUSTIC HYBRID LEVITATOR

POTENTIAL SCIENCE AREAS

• TEMPERATURE CONTROLLED PROCESSING
  • QUICK HEATING AND COOLING
  • PHASE TRANSFORMATION STUDIES
  • GLASS AND CERAMIC MATERIALS SYNTHESIS
  • TEMPERATURE MODULATION STUDIES

• ENHANCED MATERIALS PROCESSING DUE TO INVERTED TEMPERATURE PROFILE
  • UNIQUE ANNEALING OR ZONE REFINING

• NON-CONTACT THERMOPHYSICAL PROPERTIES MEASUREMENTS
  • SPECIFIC HEAT, DIELECTRIC PROPERTIES