INORGANIC COMPOSITES FOR SPACE APPLICATIONS

by

Dr. J. W. Malmendier
Corning Glass Works
Corning, New York 14830

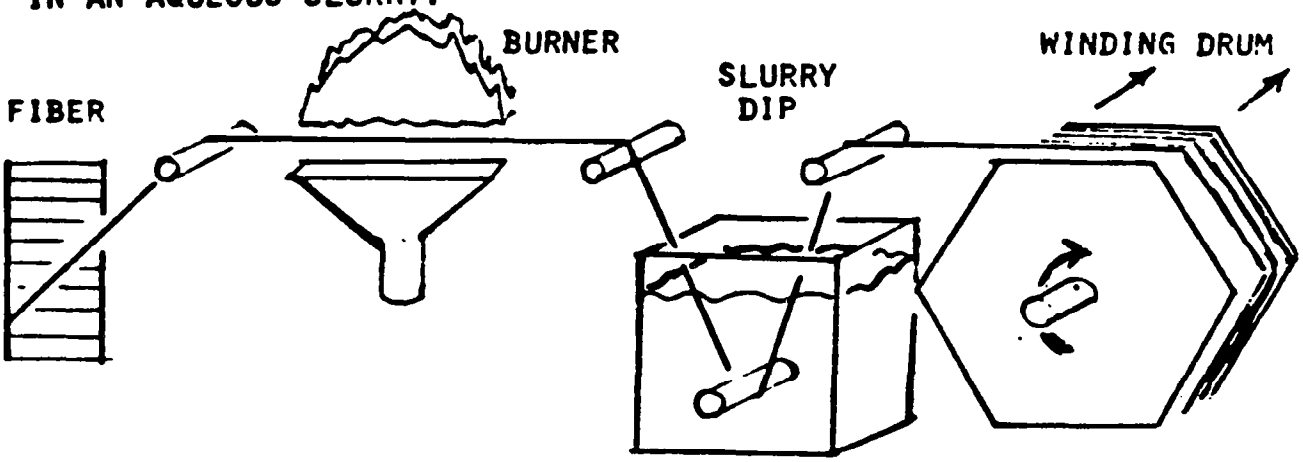
ABSTRACT

Corning Glass Works has conducted internal studies and has had cooperative programs with other organizations for the development of inorganic composite materials. Some of these composites are well suited for space applications. An overview of the results of the work are presented herein.

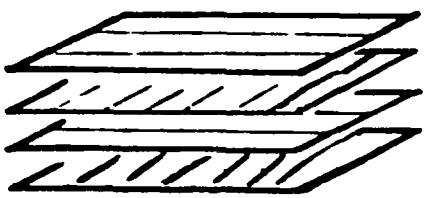
The composites do not contain any organic materials, and therefore, are not subject to degradation by ultraviolet radiation, volatilization of constituents, or embrittlement at low temperatures. The corning composites consist of glass, glass-ceramics or ceramic matrices, reinforced by refractory whiskers or fibers. Such composites have the low thermal expansion, refractoriness, chemical stability and other desirable properties usually associated with the matrix materials. However, the composites also have a degree of toughness which is extraordinary for refractory inorganic materials.

COMPOSITE PROCESS

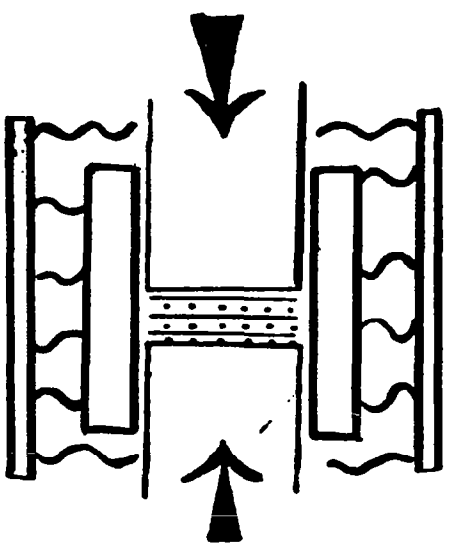
A. PREPREG - INFILTRATE FIBER YARNS WITH POWDERED GLASS SUSPENDED IN AN AQUEOUS SLURRY.



B. LAY-UP - CUT PREPREG TO DESIRED SHAPE AND STACK IN BEST ORIENTATION FOR USE.



C. HOT PRESS - CONSOLIDATE IN GRAPHITE MOLD USING ENOUGH PRESSURE TO ACHIEVE MECHANICAL COMPACTION AND ASSIST SINTERING.



FIBER/WHISKER REINFORCED COMPOSITES
VS.
MONOLITHIC CERAMICS

ADVANTAGES

- HIGHER FRACTURE TOUGHNESS AND RELIABILITY
- HIGHER DESIGN STRENGTHS AND OPERATING TEMPERATURES (EFFICIENCY)
- HIGHER DIMENSIONAL STABILITY
- LOWER FABRICATION TEMPERATURES

UNIQUENESS OF GLASS-CERAMIC APPROACH

COMBINATION OF

- LOW-FABRICATION TEMPERATURE ($T \leq 1400°C$)
  - MINIMIZE THE FIBER DEGRADATION
- REFRACTORINESS
  - TYPICALLY 200-400°C INCREASE IN USE TEMPERATURE

ORIGIN OF FRACTURE TOUGHNESS

- INTERFACIAL REACTION OF C/SiC WITH SILICATES
  - FIBER STRENGTH
  - BOND STRENGTH

BOND STRENGTH	FRACTURE MECHANISM	STRENGTH AND TOUGHNESS
"TOO WEAK"	NO REINFORCEMENT	BRITTLE AND WEAK
"TOO STRONG"	CRACKS RUN ACROSS THE INTERFACE	BRITTLE AND WEAK
"INTERMEDIATE"	INTERFACIAL DEBONDING CRACK DEFLECTIONS FIBER PULL-OUTS	TOUGH (FIBROUS) AND STRONG

TYPICAL SiC FRC* VS. SiC MONOLITHIC CERAMIC

MATRIX	LAS III	BMAS II	EXP.(1)	MONOLITHIC α-SiC (CARBORUNDUM)
DENSITY (G/CC)	2.5	2.7	2.7	3.1
YOUNG'S MOD. (MSI)	17	20	20	59
MOR (KSI) 25°C	135	150	140	65
FRACTURE TOUGHNESS K_{1C} (KSI $\sqrt{IN}$)	15-25	10-15	10-15	4
FRACTURE ENERGY (KJ/M^2)	3-4.5	--	--	0.025
THERMAL EXPANSION ($10^{-6}/°C$, 25-900°C)	2.2	3.5	4.0	4.5
MAX. USE TEMP. (°C)	1150	1250	1350	1450

*30-35 V/O FIBER, UNIAXIAL REINFORCEMENT

APPLICATIONS

- HIGH TEMPERATURE TO 1300°C

  JET ENGINE COMPONENTS (VANES, BLADES, AFTER-BURNER FLAP)

  ADVANCED GAS TURBINE

  POWER TURBINE, GASIFIER AND POWER TURBINE BACKPLATES

  ADIABATIC DIESEL ENGINE

  CYLINDER TOP AND LINING

- LOW TEMPERATURE TO -200°C (CARBON/GLASS)

  SPACE STRUCTURE FOR LASER AND COMMUNICATION MIRRORS

  - DIMENSIONAL STABILITY, THERMAL SHOCK RESISTANCE, NO UV RADIATION DAMAGE, NO MOISTURE ABSORPTION, ZERO EXPANSION

SYNTHETIC MICA MATERIALS

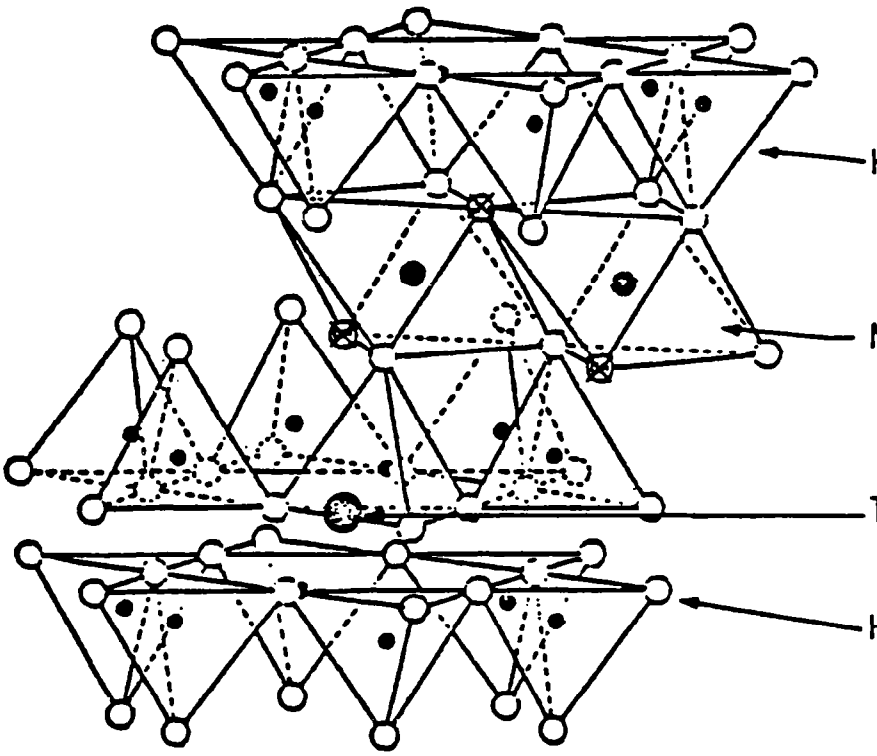
CORNING GLASS WORKS

CORNING SYNTHETIC MICA MATERIALS ARE A FAMILY OF PRODUCTS FORMED FROM FLUOROMICA GLASS-CERAMICS BY A PATENTED PROCESS. THE GLASS-CERAMIC IS REACTED WITH WATER (OR OTHER POLAR LIQUIDS), YIELDING VERY SMALL PLATELETS OF EXCEPTIONALLY HIGH ASPECT RATIO. THIS UNUSUAL MORPHOLOGY AND CERTAIN ION-EXCHANGE PROCESSES PRODUCE MATERIALS WITH THE UNIQUE PROPERTIES DESCRIBED IN THE FOLLOWING PAGES.

SYNTHETIC MICA PRODUCTS ARE PRESENTLY AVAILABLE FROM CORNING'S LABORATORIES, WHERE THEY ARE PRODUCED IN LIMITED QUANTITIES. PRODUCTION FACILITIES ARE BEING PLANNED IN ACCORDANCE WITH MARKET REQUIREMENTS.

MICA STRUCTURE

CONSISTS OF OCTAHEDRAL SHEET SANDWICHED BETWEEN TWO TETRAHEDRAL SHEETS ALSO SHOWN ARE THE SITES FOR F OR OH (■)



HEXAGONAL SHEET OF Si-O TETRAHEDRONS

Mg-O OCTAHEDRONS IN AN OCTAHEDRAL SHEET

THE INTERLAYER CATION (X)

HEXAGONAL SHEET OF Si-O TETRAHEDRONS OF THE NEXT STRUCTURAL UNIT

GENERALIZED STRUCTURAL FORMULA $X_{0-1}\ Y_{2-3}\ Z_4\ O_{10}\ (F, OH)_2$

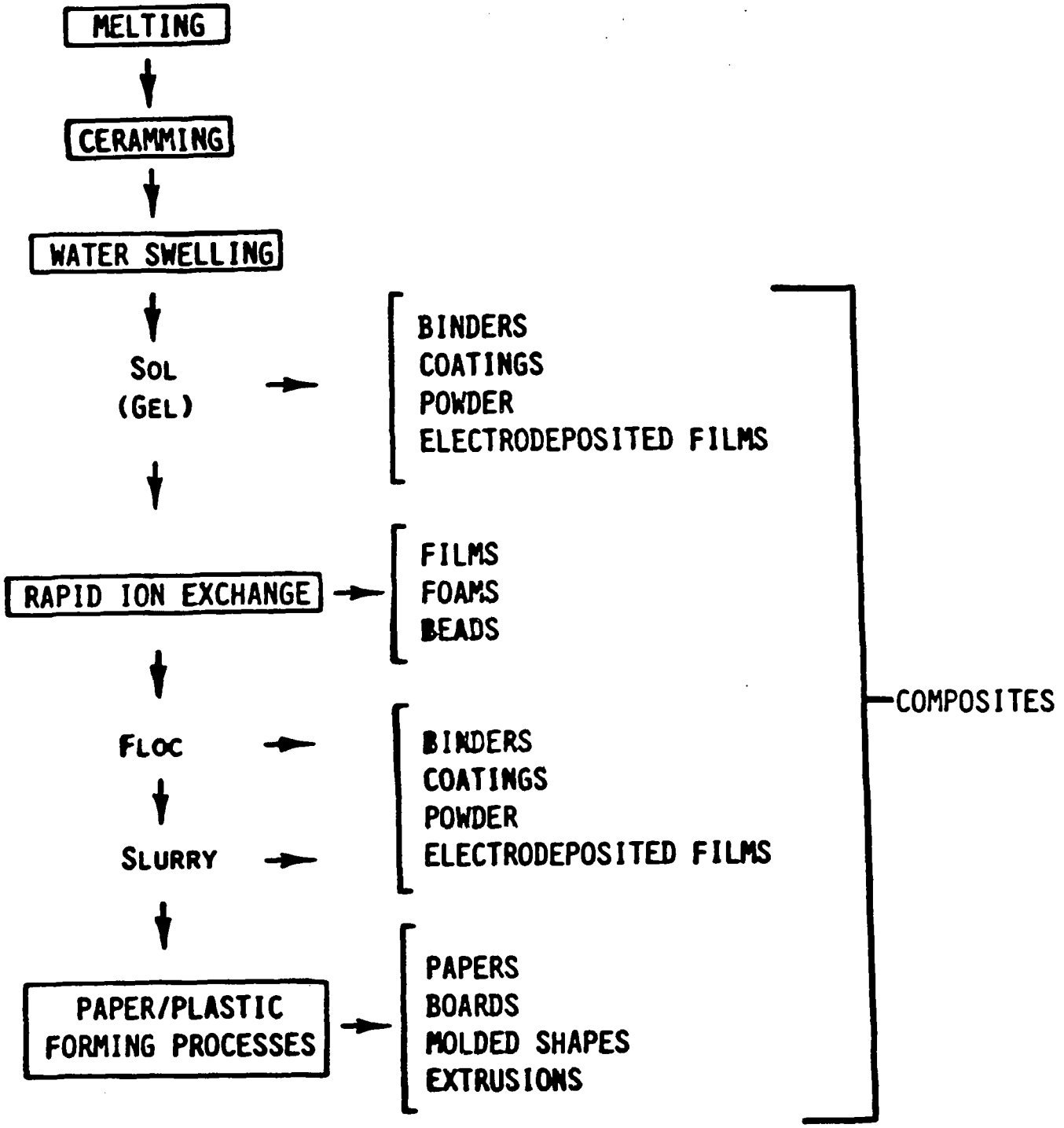
CATIONS TYPICALLY:

INTERLAYER: X = Li, Na, K, Ca, Sr, Ba, Pb, NH_4, Rb, Cs

OCTAHEDRAL: Y = Mg, Al, Li, Mn, Fe, Zn, Cu, Ni, Co

TETRAHEDRAL: Z = Si, Al, B, P, Ge, Be

BASIC PROCESS & PRODUCTS



PARTICULATE FORMS OF CORNING'S SYNTHETIC MICA MATERIALS

GEL (SOL) - A COLLOIDAL SUSPENSION OF SYNTHETIC MICA PLATELETS IN A POLAR LIQUID.

FLOC - FINE AGGLOMERATES OF SYNTHETIC MICA PLATELETS, MADE BY EXTRUDING GEL THROUGH PIN-HOLE ORIFICES INTO AN ION EXCHANGE SOLUTION.

SLURRY - USUALLY AN AQUEOUS DISPERSION OF ION-EXCHANGED SYNTHETIC MICA PLATELETS. NON-AQUEOUS SUSPENSIONS CAN ALSO BE FORMED.

SPRAY DRIED PARTICULATES - GEL, FLOC, OR SLURRY SPRAY DRIED. ADDITIVES SUCH AS COUPLING AGENTS CAN BE INCORPORATED.

MONOLITHIC FORMS OF CORNING'S SYNTHETIC MICA MATERIALS

FILM - CONTINUOUS THIN FILMS FORMED BY EXTRUDING GEL THROUGH A SLOT ORIFICE INTO AN ION EXCHANGE SOLUTION.

PAPER - CONTINUOUS SHEET FORMED BY DEPOSITING SLURRY (ION EXCHANGED GEL) ON CONVENTIONAL PAPER MAKING EQUIPMENT.

BOARD - THICK SHEET PRODUCED FROM FLOC OR SLURRY BY DEPOSITION, MOLDING, PRESSING, EXTRUSION OR LIKE PROCESSES.

FOAM - LIGHTWEIGHT MATERIALS PRODUCED BY SIMULTANEOUS ION-EXCHANGE AND FROTHING.

BEADS - HOLLOW, SOLID OR POROUS; FORMED BY VARIATIONS OF THE EXTRUSION AND FOAM PROCESSES.

Corning Glass Works

SYNTHETIC MICA MATERIALS

UNIQUE CHARACTERISTICS

- HIGH USE TEMPERATURE
- GOOD DIELECTRIC PROPERTIES
- RESISTS STRONG ALKALIES AND ACIDS
- CAN FORM COMPOSITES WITH ORGANIC AND/OR OTHER INORGANIC MATERIALS
- VARIETY OF PARTICULATE AND MONOLITHIC FORMS
- NON-TOXIC