INDIGENISATION OF SPACE MATERIALS

DATA SHEETS OF INDIGENIZED MATERIALS

STEERING COMMITTEE ON INDIGENISATION OF SPACE MATERIALS
INDIAN SPACE RESEARCH ORGANISATION
DEPARTMENT OF SPACE

February 2017

FOREWORD

Materials are vital for our national space program. Availability of space qualified materials are essential for the success of our projects. Indigenisation of Space Materials (ISM) programme was conceived and implemented with the primary objective of facilitating uninterrupted flow of materials for Indian space programmes. The task before ISM has been enormous as space technology uses a variety of materials to meet the complex service requirements. The programme has paid rich dividends as about 225 materials (both metallic and non-metallic) have been developed for the national space program. The efforts put in by the ISM team in co-ordinating and steering the activities across ISRO centres, national R&D institutions and industry for scaling up the material production is highly commendable.

It is heartening to note that the recently developed Hafnium sponge and metal which successfully met the technical specifications for use in Space also qualified for more stringent application-requirements of other advanced technology sectors in the country. Special knitting technology which was optimized earlier for realizing mesh for large aperture unfurlable space antenna is recently supplemented by the indigenous development of φ 30 μ gold plated molybdenum yarn of which the mesh is made of. State-of-the-art electronic materials play a vital role in the miniaturization of various systems and sub-systems for space applications. Towards this objective, the development of ceramic-based DR and Patch Antenna with higher dielectric constant, Kovar alloy, SILVAR composite and Alumina substrates for electronic packaging augers very well for our space programme. Realization of superalloy based complex LH_2 exhaust unit for cryo engine through 3-D additive manufacturing technology is a highly noteworthy development. It is time that similar indigenisation efforts are taken up for making available the latest high temperature materials for ISRO's on-the-anvil programmes like RLV-TD and Scramjet engines leading to TSTO.

The present Data sheet Issue-10 comprising space materials developed under ISM programme includes 35 items which have been realized since the release of last issue in October, 2014. I sincerely hope that this compendium will be effectively utilized by the ISRO scientists and designers for various missions.

Formidable challenges are ahead for the material scientists. I am sure that ISM will continue the same pace of development and meet the demand of indigenous materials for emerging programmes of ISRO.

(Dr. K. Sivan)
Director-VSSC

From the desk of Chairman, Steering Committee, ISM

Originated with the mandate to facilitate development and supply of indigenous materials, Indigenisation of Space Materials (ISM) programme has largely kept pace with meeting the requirements of ISRO. With focus on materials for cryogenic engine in the formative years of ISM, a good degree of indigenous capability both in metallic and non-metallic materials, is achieved for solid and liquid stages of launch vehicles and structural elements of satellites. Functional materials and systems such as special magnets for inertial navigation systems, Li-ion cells of various capacities, bimetallic components, Iridium Catalyst, a variety of adhesives and rubber products, Molybdenum mesh for unfurable space antenna, porous structures for thermal management system, solid film lubricants, ferrous and non-ferrous fasteners, a range of products for thermal protection systems etc. have been realized under the programme.

The ISM programme has been also addressing to the needs of emerging programmes of ISRO. Past few years have witnessed a number of development activities for semi-cryo engine, Reusable Launch Vehicle (RLV-TD), Air Breathing Propulsion (ABPP) and space and ground segments of IRNSS and GEOSAT programmes. They include propellant grade kerosene, 18 types of complex-shaped investment castings in special stainless steel, superalloys, titanium alloys and aluminium alloys, powder metallurgy based face seals, silica tiles, a gamut of high temperature and water proofing coatings, nitrile rubber based elastomeric products, electronic ceramics and device packages, etc.

The Steering Committee is extremely happy to record that Hafnium Sponge Plant commissioned at C-MET, Hyderabad has successfully met the qualification requirements and the indigenized sponge is also serving the critical needs of other advanced technology sectors such as atomic energy and defence.

The present 10th Issue of the Data Sheets comprises materials which are indigenized during last about two years. Apart from encompassing the variety of materials for launch vehicles and satellites, it also brings out the harnessing of state-of-the-art processing techniques such as hot isostatic pressing, solid state diffusion bonding, microwave sintering, 3D printing, etc. for realizing performance-critical materials and components.

We express our sincere thanks to Chairman, ISRO for his constant encouragement and keen interest in ISM programme, to Director, VSSC for his guidance and also for agreeing to write the Foreword to the compendium and to all ISRO Centre Directors for the support to activities. We expect that ISRO scientific community makes best use of these indigenous developments included in the Issue-10 like earlier.

Dr. S.C. Sharma
Chairman-SCISM
Deputy Director-PCM

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100 Ah LITHIUM-ION CELLS

INTRODUCTION

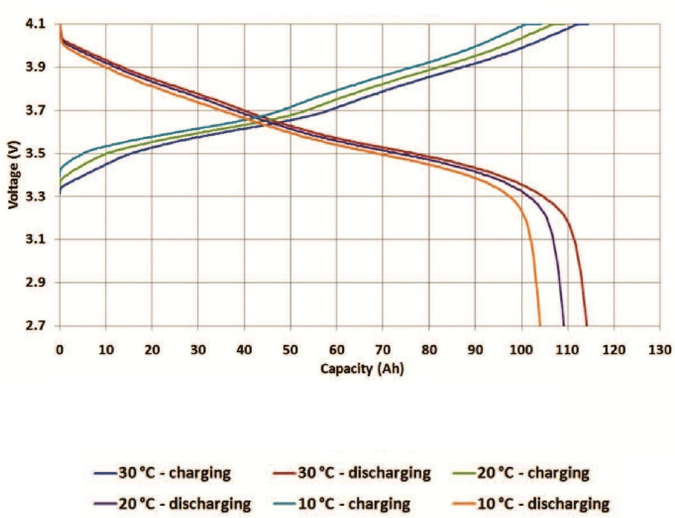
Lithium ion cells form the third generation of power source for satellites. Presently, indigenous 50 Ah Lithium-ion cells are qualified for satellite applications. In order to meet the increasing power demands of satellites like I4K, I6K bus, 100 Ah Lithium ion cells are developed. Currently, ISRO's spacecrafts are powered by imported Lithium ion cells.

DESCRIPTION OF PROCESS/PRODUCT

Name Plate capacity Nominal voltage	100 Ah
Voltage	3.6 V
Positive electrode	Lithium Nickel Cobalt Aluminium Oxide
Negative electrode	Graphite
Cell Case &Lid	Aluminium alloy
Terminal seal	Ceramic to metal
Separator	Polymeric separator
Electrolyte	Lithium salt dissolved in organic solvents
Cell Dimensions	130 x 208 x 50 mm (W x H x T) approx.
Cell mass	~ 2700 g
Internal resistance	< 1 m Ω
Energy density	≥ 150 Wh/kg
Operating temperature	10 °C to 30 °C
Cycle life	> 1500 cycles at 80% DOD
Calendar life	> 15 years
Vibration	25g in Sine mode, 17.25g_{rms} in Random mode and 8g transportation mode
Leak rate	Better than 10^{-8} mbar L/s
Safety features	Rupture disc and Shutdown separator

TYPICAL PROPERTIES ACHIEVED

Performance characteristics of 100 Ah Lithium-ion cell @ different temperatures



APPLICATIONS

For powering satellites with high power requirements and the technology can be tuned for societal applications.

ADVANTAGES

Currently, ISRO's spacecrafts are powered by imported Lithium ion cells. VSSC has developed the technology for 50 Ah Lithium ion cells which can be paralleled to increase the capacity but foot print and battery weight will increase causing reduction in payload in satellites. Development of 100 Ah Lithium ion cell will help us to cater to the future high power requirements of satellites thereby

eliminating the dependence on foreign agency for the technology while bringing in significant cost reduction. This technology can be tuned to meet the power requirements of electric vehicles also. These cells also use indigenously developed Ceramic-to-metal seals thereby reducing the cost of the component to 1/10th.

5 Ah LITHIUM-ION CELLS

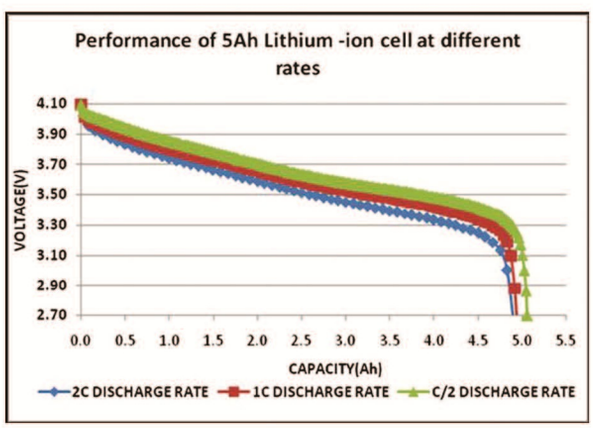
INTRODUCTION

5 Ah Lithium ion cells with Plastic compression seals are developed for Launch vehicle applications for powering Electro Mechanical Actuators. Silver Zinc cells used in Launch Vehicles will be replaced with Li-ion cells.

DESCRIPTION OF PRODUCT

Name Plate capacity Nominal voltage	5 Ah
Voltage	3.6 V
Positive electrode	Lithium Nickel Cobalt Aluminium Oxide
Negative electrode	Graphite
Cell Case &Lid	Aluminium alloy
Terminal seal	Plastic compression seal
Separator	Polymeric separator
Electrolyte	Lithium salt dissolved in organic solvents
Cell Dimensions	65 x 92 x 17 mm (W x H x T) approx.
Cell mass	160 g
Internal resistance	< 15 m Ω
Energy density	> 120 Wh/kg
Operating temperature	10 °C to 30 °C
Vibration	15g in Sine mode, $5g_{rms}$ in Random mode
Leak rate	Better than 10^{-6} mbar L/s
Safety features	Rupture disc and Shutdown separator

TYPICAL PROPERTIES ACHIEVED



APPLICATIONS

Power source for powering various systems in Launch vehicles.

ADVANTAGES

Currently, ISRO's launch vehicles are powered by Silver-Zinc cells. Lithium-ion cells have higher operating voltage than Silver-Zinc cells which reduces the number of cells in a battery and high energy density and longer wet life. These features will help in reducing the weight of batteries in launch vehicles which in turn will translate into enhanced payload capability. Launch pad operations will be minimized due to longer wet life. The indigenous development of this technology will also reduce the dependency on foreign vendors for supplying cells

in future. These cells also use in-house developed plastic compression seals which have also brought about significant cost reduction.

HAFNIUM SPONGE FOR C-103 ALLOY FOR LIQUID ENGINE NOZZLES

DESCRIPTION

Launch vehicles and satellites of ISRO use NIOBHAT-101 alloy for the combustion chamber and nozzles of liquid engines. Hafnium is one of the critical compositional elements used in this alloy which renders the capability of withstanding high temperatures with superior thermo mechanical properties.

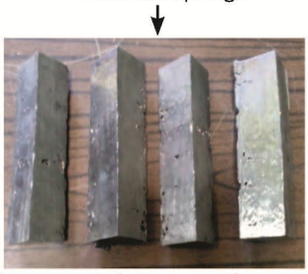
Hafnium metal also finds critical applications in nuclear field. Due to its strategic relevance, Hafnium metal is not easily available in the international markets. ISRO in association with C-MET took up the development, scale-up and production of this metal to meet the requirements of ISRO. The production plant set up at C-MET, Hyderabad has the capability of producing 320 kg of Hafnium sponge per year.

DEVELOPMENT MODE

Hf sponge is derived from Zirconium (Zr) Raffinate after a series of complex processing steps which include Zr removal, Solvent Extraction, Calcination, Carbo Chlorination, Kroll Reduction and Magnesium Separation. Complexity of the whole process can be judged by the fact that one liter of Raffinate yields only about one gram of Hf sponge.

A Hafnium Sponge Production Plant at C-MET is successfully commissioned.

Hafnium sponge



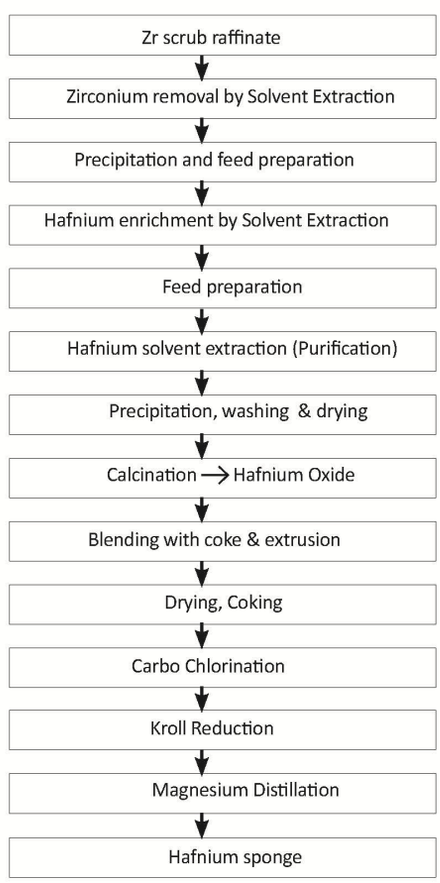
Hafnium metal

First batch of 25 kg of sponge was obtained from the qualification trials of the commissioned plant. Subsequently Hafnium Sponge is supplied to M/s MIDHANI. EB melting trials have been successfully completed.

SPECIFICATION

Sl. No.	Elements	Target Specs. (in ppm)	Achieved Specs.
1	Zr	<15000	7500
2	Fe	<3000	1290
3	Cr	<500	340
4	C	<10	10
5	Ni	<50	10
6	O	<3000	2012

PROCESING STEPS



HOT ISOSTATIC PRESSING (HIPING) TECHNOLOGY FOR INVESTMENT CAST PRODUCTS

INTRODUCTION

Investment cast products are used in cryo/semi-cryo engines. During manufacturing, defects are inevitable at some locations due to their complex shapes. Casting with defects at severe locations may be rejected & it makes delay in delivery schedule. Developing Hot Iso-static pressing technology is beneficial for salvage the castings.

HIP applies high pressure and temperature to the material inside the closed pressure vessel which helps to remove the inner defects of products such as shrinkage cavity, shrinkage filamentary etc.

DESCRIPTION OF PROCESS

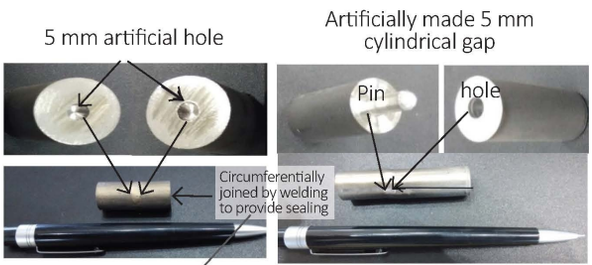
Artificial cast defects were created on materials and HIPing process carried out based on the systematic study. Healing mechanism was studied after HIPing. X-ray radiography and micro structural analysis using optical metallography and scanning electron microscopy were carried out and defects were healed fully.

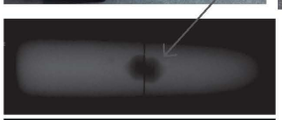
APPLICATIONS

Defect healing of different types (more than 20 types) of Investment cast products made up of different materials used in Cryo/Semi-cryo engine

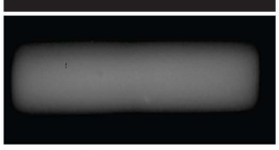
ADVANTAGES

This process improves the reliability of cast products by healing defects used cryo/semi-cryo engines.

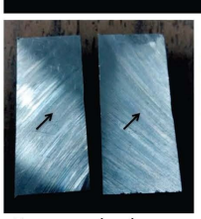




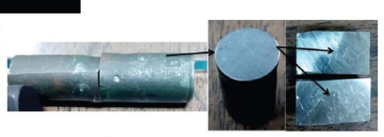
X-ray radiography before HIPing shows the defects



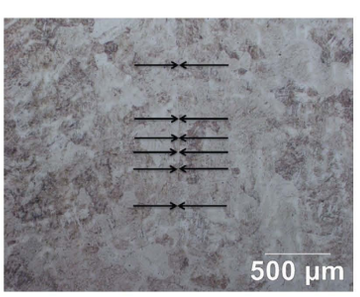
X-ray radiography after HIPing shows full removal of defects



Cut sample shows removal of defects at center after HIPing



Cut sample shows removal of cylindrical gap of 5mm



Joined interface of healed area in-between two mating surfaces

SOLID STATE JOINING TECHNIQUES FOR TITANIUM ALLOY TO STAINLESS STEEL

INTRODUCTION

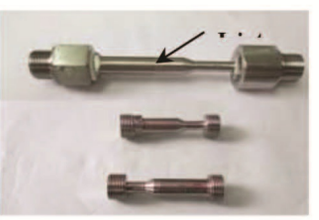
Launch vehicle and spacecraft uses dissimilar metal joints of titanium and stainless steel in propellant and pressurant tankages. It is proposed to develop these joints through diffusion bonding or explosive welding techniques to achieve better mechanical properties at ambient and cryogenic temperatures. Initially explosive bonding route was attempted. Bonding of lower thickness of Ti6Al4V (upto 8mm thick) was only possible due to narrow range of explosive parameters and high explosive content required for thicker plates. Bonded joints were characterised through metallography and mechanical properties evaluation.

Requirement was for developed CP Ti + SS304 transition tube of size: 6mm dia x 1 mm Wall thickness X 80mm Length, identified as transition joint between Carbon Overwrapped Pressure Vessels (COPV) Helium gas pressurant tank for satellite application. Due to higher length (80mm) of tubes, diffusion bonding route was attempted.

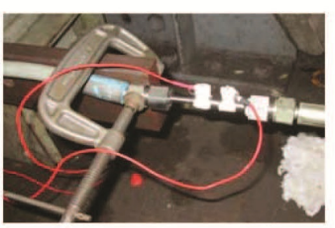
TYPICAL PROPERTIES ACHIEVED

Optimized bonding parameters resulted in achieving stipulated tensile strength of 200MPa minimum. Further, actual transition tube machined out from this which has successfully undergone preliminary qualification tests viz., Helium leak test

Diffusion bonded commercially pure (CP)-70 titanium alloy and stainless steel rod



Transition Tubes



Transition Tube under Proof pressure test

(spec: < 10X10-5 mbarlitsec-1), MEOP pressure: 250bar; PPT pressure: 400bar; tube subjected to highest pressure of 550bar and structural integrity confirmation though post He leak test

APPLICATIONS

Titanium alloy/ stainless steel transition joint components are used as end adaptors of gas bottles in cryogenic stages of Launch Vehicle (Ti5Al2.5Sn-ELI+SS321 and Ti6Al4V-ELI alloy+SS321) and Satellite pressurant tankages (CP Ti+ SS304).

ADVANTAGES

Indigenously developed tubes can replace presently imported tubes.

EXHAUST UNIT INVESTMENT CASTING IN ICNI-4314-706C SUPERALLOY FOR TURBO PUMP OF CUS ENGINE

DESCRIPTION

Exhaust Unit investment cast component is used in Turbopump of CUS engine of GSLV MkII. As the name suggests, this casting is used in exhaust region of the turbo pump where temperature is high (~500 Deg C). Foremost challenge in development of this component in superalloy ICNi-4314-706C was melting & casting of the alloy under vacuum condition in VIM furnace. Pouring has to be done with minimum turbulence. Challenges in the development of this intricate and critical component involved casting design, die design and fabrication, design of appropriate gating system for realizing sound casting etc. The investment casting technology for these components were successfully established. These components are now being regularly supplied to the project by FTD/MMG.

DEVELOPMENT MODE

Investment casting technology for Exhaust Unit Castings was successfully developed by FTD of MMG/MME, VSSC in association with M/s MIDHANI, Hyderabad. These components were qualified by thorough testing of chemical composition, radiographic quality, DP check, dimensional inspection and mechanical properties. Leak test as qualification step has been implemented for these castings.

QUALIFICATION TEST RESULTS

1. Chemical Composition

Element	Specified	Achieved
Nickel	42-45	43.71-43.92
Chromium	13-15	14.44-14.58
Molybdenum	1.0-2.0	1.45-1.50
Niobium	2.3-2.8	2.43-2.57
Titanium	1.5-2.0	1.67-1.73
Aluminium	0.2-1.0	0.60-0.63
Vanadium	0.1-0.5	0.22
Carbon	0.03-0.07	0.047-0.055
Manganese	0.5 max	0.22
Silicon	0.5 max	0.39
Sulphur	0.01 max	0.002
Phosphorous	0.01max	0.007
Copper	0.03 max	0.01
Iron	Balance	Balance

2. Mechanical Properties

Properties	Specified (min.)	Achieved
UTS (MPa)	784	940-990
YS (MPa)	588	762-804
Elongation %	5	7-14
% RA	5	21-37
Stress rupture at 540 MPa, 650°C	0.5 hrs	1.6-12.0

ADVANTAGES

Available through indigenous source only.

ELASTOMERIC PRODUCTS BASED ON LOW HARDNESS NITRILE RUBBER

INTRODUCTION

Rubber products find application in various sub systems/ components used in the Semi Cryo Engine. These products are processed from different rubber compositions depending on their properties and working environment. Low hardness Nitrile rubber based composition was developed successfully meeting the project requirement. This composition is used in the moulding of elastomeric vessel for start fuel tank of engine.

PROCESSING

Indigenization of the rubber products was done as follows:

a. Development of product : An Elastomeric vessel was realised using the specially designed mould in an electrically heated hydraulic compression moulding machine on the basis of data generated by rheological study of the developed rubber compound.

b. Characterisation: The mechanical properties were evaluated as per ASTM D 412–87 using universal testing machine "INSTRON". Shore-A hardness tester was used for measuring the hardness. ODR (Oscillating Disc Rheometer) was used for generating the rheological parameters of low hardness Nitrile rubber compound.

PROPERTIES

The properties were evaluated at ASTM slab level

MECHANICAL & PHYSICAL PROPERTIES

Tensile strength, ksc	190
Elongation at break, %	700
Hardness (Shore A)	58-59
Compression set (%); 70^{0}C; 22 hrs.	18
Density, g/cc	1.19

APPLICATIONS

The moulded rubber product based on low hardness Nitrile rubber compound and its brief use is tabulated below:

Products	Uses
Elastomeric Vessel 	To be used as Isrosene expulsion system for start fuel tank of Semi Cryo Engine

ADVANTAGES

These products are developed as substitute for the product defined in Jasmine project report as per details available. Compatibility with Isrosene and other functional requirements have been addressed during development to meet the project requirement.

SCNM 2043-BASED RUBBER COMPONENTS

INTRODUCTION

Rubber products find application in various sub systems/ components used in the Semi Cryo Engine. These products are processed from different rubber compositions depending on their properties and working environment. This composition is used in the moulding of O-rings for various sub-systems in engine.

Development of product: Sealing materials like O-rings were realised in specially designed mould in an electrically heated hydraulic compression moulding machine on the basis of data generated by rheological study of SCNM 2043 compound.

Characterisation: The mechanical properties were evaluated as per ASTM D 412–87 using universal testing machine "INSTRON". Shore-A hardness tester was used for measuring the hardness. ODR (Oscillating Disc Rheometer) was used for generating the rheological parameters of SCNM 2043 compound.

PROPERTIES

The properties were evaluated at ASTM slab level

Mechanical & Physical properties:

Tensile strength, ksc	170
Elongation at break,%	280
Hardness(Shore A)	74-76
Compression set (%); 200°C; 22 hrs.	10
Density, g/cc	1.90

APPLICATIONS

The moulded rubber products based on SCNM 2043 and its brief use is tabulated below:

Products	Uses
O-rings 	To seal the various interfaces of the subsystems in Semi Cryo Engine

ADVANTAGES

These Products are developed as substitute for the product defined in Jasmine project report as per details available, specifically for high temperature application. Compatibility with Isrosene and other functional requirements have been addressed during development to meet the project requirement.

SYNTHESIS OF SEMICONDUCTOR GRADE HYDROCHLORIC ACID

INTRODUCTION

High-purity electronic grade HCl is used in the manufacturing process of semiconductors. The purity of hydrochloric acid used in wafer cleaning operations has a direct impact on device yield and reliability. The SEMI (Semiconductor Equipment and Materials International) specifications for maximum permitted levels of metallic and non-metallic impurities in concentrated acids should be in parts per billion (ppb) levels.

The major factor affecting the purity of acids are the method adopted for purification, contamination from the storage vessel, environment contamination, and sample to sample cross contamination.

There are various methods for the purification of acids and among these techniques, sub boiling distillation is recognized as the reliable method.

ANALYTICAL RESULTS OF SG HCl

Parameter	Results	Spec (max)
Assay (%)	20.7	20.3 - 21.0
Arsenic (ppb)	ND	5
Iron (ppb)	ND	50
Sodium (ppb)	0.2	50
Lead (ppb)	ND	50
Sulphate (ppb)	60	200
Sulphite (ppm)	ND	2
Free chlorides (ppb)	ND	50
Residue on ignition (ppm)	0.6	1
Residue after evaporation (ppm)	1.4	2

APPLICATIONS

Semi conductor grade hydrochloric acids are widely using as cleaning and etching agent in semiconductor industry.

ADVANTAGE

Ultrapure acids and solvents required for various applications at SCL, Chandigarh is currently met by importing these materials. By in-house realization of this material, cost reduction can be achieved.

HEAT PIPE FOR THERMAL MANAGEMENT SYSTEM OF SATELLITES

DESCRIPTION

Heat pipes are widely used for thermal management in satellites. These have intricate fins for increasing the surface area for effective heat transfer. Alloy used for fabrication of heat pipes is aluminium alloy AA6063. This alloy is compatible with ammonia fluid used in these heat pipes for heat transfer. At present all the requirements are being met through import. Present effort is to produce these heat pipes through indigenous route and one particular configuration is selected for present development.

CHALLENGES

Deep-Grooved structure of heat pipe is a challenging task for the manufacturers. There are 28 fins of 1.3 mm depth and 0.39 mm thickness. These dimensions are very difficult to produce and many industries were not ready to take up this difficult task. Achieving of mechanicals properties with optimization of extrusion parameters has to be done. Due to complexity of fins, development of heat pipes meeting stringent dimensional tolerances is very challenging.

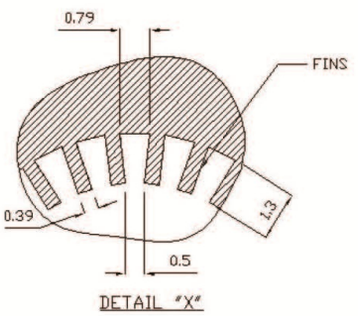
DEVELOPMENT MODE

Extrusion is the only possible method of making the grooved structure of this kind. Process established for production of these heat pipes and same has been qualified by testing the dimension and mechanical properties and also qualified by burst test.

QUALIFICATION TEST RESULTS

1. **Dimension [critical only]**

Specified	Achieved (typ)
0.79	0.72 / 0.78
1.30	1.30 / 1.46
0.50	0.52 / 0.55
0.39	0.35 / 0.40

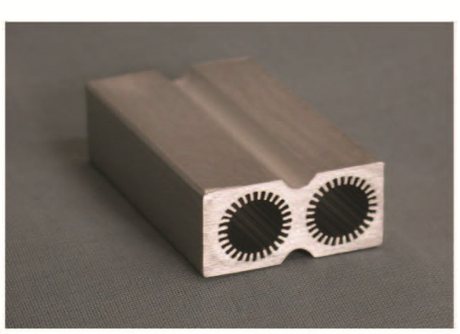


Critical dimensions of a heat pipe

2. Mechanical Properties

Properties	Specified	Achieved
UTS (MPa)	205	243-252
0.2%YS (MPa)	170	190-216
Elongation %	8	14.1-15.6

3. Pressure Test: Burst test was successfully completed on the indigenously realized heat pipe at 215 bar at ISAC, Bangalore.



ADVANTAGES

Cost saving approx Rs. 20000 per heat pipe of 6 m length.

ALUMINIUM ALLOY IMPELLER THROUGH CASTING ROUTE

DESCRIPTION

Impeller is a complex shaped component in Aluminium alloys and is being made by machining from a solid block/rod. Cover and body parts of the impeller are then welded to obtain integral piece. Extensive CNC machining is required to obtain desired vane profile. Casting has been exploited for realization of complex shaped components in various alloys. This complex shaped impeller components can be realized through casting route. It not only reduces machining load and material wastage but also eliminates welding needs. In present work this impeller casting has been developed as integral component. It has been subjected to various testing and is qualified as per specification to be assembled in the semi cryogenic engine.

DEVELOPMENT

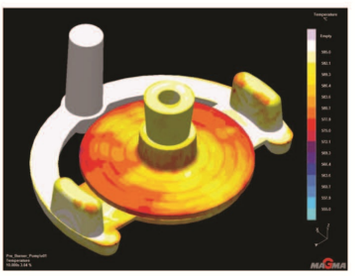
Investment casting technology for Pre-burner impeller was successfully developed.

This component was qualified by thorough testing of chemical composition, radiographic quality, DP check, dimensional inspection and mechanical properties.

Aluminum alloy Impeller made through investment casting process

RESULTS

1. Gating System



2. Chemical Composition

Element	Specified	Achieved
Copper	0.30 max	0.08
Iron	0.60 max	0.14
Silicon	8.00 – 10.50	8.90
Magnesium	0.17 -0.30	0.19
Manganese	0.20 – 0.50	0.24
Titanium	0.15 max	0.04
Zinc	0.20 max	0.01
Cobalt	0.10 max	0.01
Aluminium	Remainder	

3. Mechanical Properties

Properties	Specified (min.)	Achieved
UTS (MPa)	225	280
Elongation % (GL=5D)	3	3
Hardness (BHN)	70	95

4. Radiographic Inspection

Acceptable as per the specification.

ADVANTAGES

- Low cost.
- Improvement in productivity.

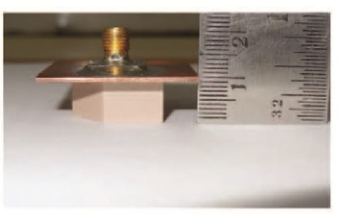
DR & PATCH ANTENNA FOR GSAT & IRNSS GROUND TERMINALS

INTRODUCTION

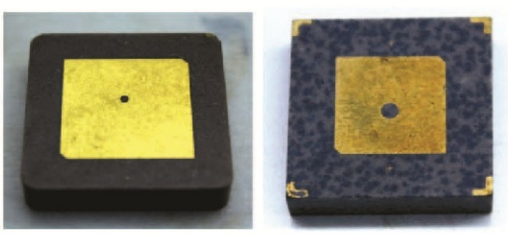
Development of dielectric devices for Space communication systems is a significant and challenging one. These devices significantly reduce the size and weight of systems. The properties of interest to application like dielectric constant or relative permittivity(εr), dielectric loss ($\tan\delta$) etc. are primarily dependent on the crystal structure and defects. The antenna characteristics greatly depend on the substrate thickness, the εr and the $\tan\delta$. The first two parameters determine the resonant length of the circuitry/ components that are etched on it. Hence they form a crucial parameter in the design stage itself. The $\tan\delta$ determines the device insertion loss/power dissipation within the circuit. Tolerances on these parameters are also required to be tight for microwave applications. VSSC and SAC are jointly working on the development and qualification of DRAs and PAs for ground terminal applications. This consists of Antenna Design, Ceramic processing, Machining, Metallization and Testing.

ANTENNA TECHNOLOGY

Design, Realization and Testing of Antennas are carried out at SAC. Inputs like minimum achievable $\tan\delta$, the range of εr for the two types of ceramics and overall maximum thermal drift etc. have been taken into account based on discussions. DRA and PA realized by SAC are shown in photographs.



Typical DRA(2.56GHz) using DK18 ceramic



Typical patch antennas on DK35 ceramics for (left) L-band-1.57GHz and (right) S-band-2.49GHz

Typical Properties Achieved

Specification	DRA (DK18)	PA (DK35)
Dimensions	30mm×13mm	30mm×6mm 15mm×4mm
Density (ρ) of ceramic [g/cm^3]	3.80 – 4.0	4.35 – 4.65
Dielectric constant of ceramic (εr)	20 –21	36.5 – 37.5
Loss factor (tanδ, max) OR Q.f min [THz]	$<4\times10^{-5}$ OR 50	$<8\times10^{-5}$ OR 25
Temp. coeff. of frequency [ppm/°C]	<|10|	<|10|
Quantity	50 no.	60 no.
Frequency of Operation	S-Band	L & S Bands
Power [W CW]	5-10	5-10
Bandwidth (typical)	10 %	10 %
Overall Efficiency (typical)	80 %	80 %

APPLICATIONS

Receiver terminals of GSAT ground segment and IRNSS ground segment.

ADVANTAGES

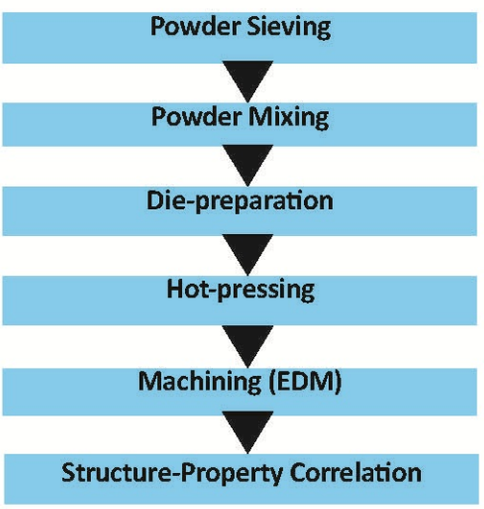
Size and weight reduction of minimum 5 times and not available for import.

Al-Si ALLOY SYSTEM FOR ELECTRONIC PACKAGING APPLICATIONS

INTRODUCTION

Thermal stresses have a significant impact on the performance of various sub-systems of electronic packages of spacecrafts. To minimize this impact, a series of Si-Al alloys were explored as candidate materials for such applications. The selection of Si-Al alloys lies in the fact that they offer superior combination of properties (low CTE, high TC and low density) over conventional materials.

DESCRIPTION



TYPICAL PROPERTIES ACHIEVED

Property	Achieved
Chemical Composition (Wt.%)	Al : 49 – 51 Si: balance
Density (g/cc)	2.39-2.43
Co-efficient of thermal expansion (ppm/K) (0-200 °C)	12.3-12.9
Thermal Conductivity (W/m.K)	91-92
Ultimate Tensile Strength (MPa)	114-145
Ultimate Compressive Strength (MPa)	346-358
Transverse Rupture Strength (MPa)	206-220

APPLICATION

Electronic packaging in space-crafts.

ADVANTAGE

Low Density.

SILVAR: A COMPOSITE FOR MICROWAVE INTEGRATED CIRCUITS (MIC) PACKAGING APPLICATIONS

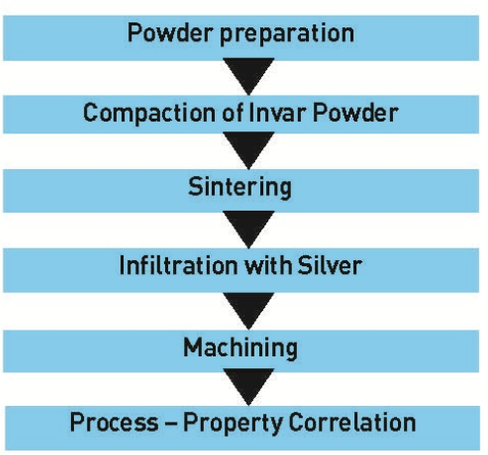
INTRODUCTION

The continuing increase in the electronic package density has resulted in a need for materials with high thermal conductivity. In addition, to minimize thermal stresses that can cause component or solder failure, packaging materials must have coefficients of thermal expansion (CTEs) matching those of ceramic substrates (such as Al_2O_3 , AlN), and semiconductors (Si and GaAs). SILVAR is a unique composite material combination of silver and INVAR. It provides high thermal conductivity and optimum thermal expansion coefficient.

DESCRIPTION

SILVAR have been developed in-house by adopting compaction, sintering & infiltration technique through Powder Metallurgy route. Skelton of Invar with controlled porosity were realized through Compaction and Sintering of Invar Powder followed by infiltration of the Skelton with Silver in order to achieve required property in the composite. Proto type component have been processed based on optimised process parameter.

Detailed process flow chart has been given below



TYPICAL PROPERTIES ACHIEVED

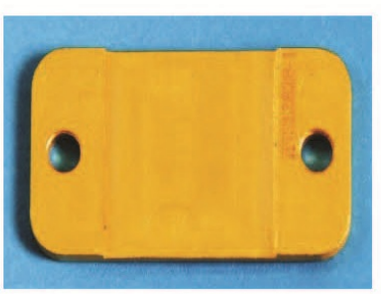
Property	Specified	Achieved
Composition (Wt. %)	Ag: 25 ± 3 Bal : Invar	Ag : 24.2 – 25.8, Invar : Balance
Co-efficient of thermal expansion (ppm/K)	5.5 (min.)	5.7 – 6.1
Thermal Conductivity @ 200°C (W/m.K)	Better than Kovar (17)	45 – 50
Hardness (Vickers – VHN)	-	159 - 164
0.2 % Yield Compressive Strength (MPa)	-	205.8 – 209.6
Ultimate Tensile Strength (MPa)	-	344 – 349
Elongation (%)	-	23 - 25
Density (g/cc)	-	8.44 – 8.48

APPLICATION

SILVAR carrier plates are planned to be used in future Microwave Integrated Circuits (MICs) subsystem for high power applications in GEOSAT class of space-crafts.

ADVANTAGE

Better Thermal conductivity compared to currently used Kovar with optimum co-efficient of thermal expansion.



Gold plated Proto Carrier Plate
Dimn: 24 mm x 13 mm x 1.5 mm

RTCM-321
ROOM TEMPERATURE CURABLE CERAMIC ADHESIVE

INTRODUCTION

Ceramic adhesives are notable for high temperature capabilities and hence, find application for bonding different metal alloys and hence useful for space applications.

DESCRIPTION

RTCM-321 is an indigenously developed room temperature curable ceramic adhesive for bonding applications of different types of metal alloys. It is a silicate based formulation and contains various ceramic fillers. It cures at room temperature and retain the bond integrity to very high temperatures of 900K. This is achieved by the judicious combination of ceramic fillers with similar coefficient of thermal expansion (CTE), so as to avoid large CTE mismatch with the bonding substrates with increase in temperature.

ADVANTAGES

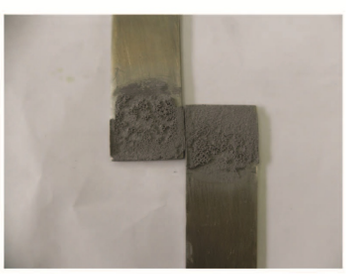
- No organic solvents or polymers used.
- Can withstand a temperature range of RT to 900 K.
- RT curable.
- Can be stored as two different parts-Part A (solvent) and Part B (dry powder).
- Easy to prepare.

PROPERTIES

Property	Value
Lap Shear Strength (LSS) at RT	2-3 MPa
Lap shear strength at 830K	2-3 MPa
Mode of adhesion failure	Cohesive/mixed adhesive

APPLICATIONS

RTCM-321 will find applications as high temperature adhesive for bonding metallic structures. Currently, it is planned to use for bonding of brackets on to CE 20 nozzle divergent (material ICSS 1218 321) and the joints have to withstand maximum operational temperature of 830 K. These brackets are used for wire harnessing from the nozzle divergent area.



SS321 metal coupons after LSS testing

HIGH TEMPERATURE RESISTANT SILICONE POTTING COMPOUND, SILPOT 5052

INTRODUCTION

SILPOT 5052 is a silicone polymer based coating capable of withstanding high temperature environment, i.e, 400°C for continuous exposure, possessing excellent electrical insulation properties (>100 MOhms) as well as low outgassing properties to meet space requirements. Further, the coating can withstand low temperature environment as low as -100°C and exhibits good adhesion to different substrates such as metals and fiber glass. Advanced applications of the material include those in space technology where it protects the fiber glass insulation as well as the metallic body of the thruster bobbins in the anode unit of stationary plasma thruster for the electric propulsion programme in satellites. In the anode unit of Stationary Plasma Thruster, high temperature solenoid coils are used as part of magnetic circuits. To provide electrical insulation, high temperature encapsulation compound, SILPOT 5052 is needed. It is an eco-friendly coating as it contains no organic solvents nor any low volatiles and possess high water repellency.

DESCRIPTION

SILPOT 5052 is a two-part addition curable silicone polymer based formulation.

SILPOT 5052 is processed by compounding fillers with the Part A polymer in a three roll mill followed by catalyst addition in an internal mixer. Part A is then blended with Part B and applied on the substrate. It is then cured.

PROPERTIES

	Properties	Results
1.	Colour	Red
2.	Ti (temperature for 5% weight loss) by TGA (under N2 atm. at a heating rate of 10° C/min.)	≥350 °C
3.	Glass transition temperature	-96°C
3.	Insulation Resistance at 1000 V (Ω)	≥ 10^9 (material level)
4.	TML	<1%
5.	CVCM	<0.1%

APPLICATIONS

SILPOT 5052 is applied over the fiber glass windings on the thruster bobbins in the anode unit of stationary plasma thruster to provide electrical insulation to the bobbin as well as to protect the fiberglass insulation from high temperature produced due to the ionization of Xenon gas (max. 400°C).

SILPOT 5052 coated bobbins for stationary plasma thruster

ADVANTAGES

The technology brings in self-reliance in the area and considerable cost benefit.

HIGH STRENGTH LOW ALLOY (HSLA) 35NCD16 STEEL

INTRODUCTION

35NCD16 is a medium carbon high strength low alloy steel containing Ni, Cr & Mo. Alloy is having good strength with toughness which makes it a potential candidate for fasteners.

Alloy in heat treated condition is widely being used for fabrication of shear bolts in launch vehicles. Activity was taken up to realize AFNOR 35NCD16 materials from indigenous sources thereby lead time and cost can be brought down.

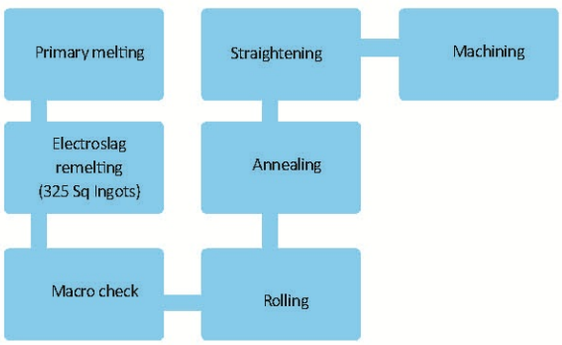
DESCRIPTION

Alloy is processed through Electric Arc Furnace (EAF) melting followed by Electro Slag Re-melting (ESR) technology to achieve superior cleanliness. ESR ingots were then subjected to hot forging operations to convert into intermediate sizes for rolling. Hot rolling was carried out to realize rods of Dia 20mm. Ultrasonic testing as per AMS 2630B Class A was carried out on all rods at the final supply condition.

ADVANTAGES

35NCD16 material successfully indigenized.

- Processed through ESR route giving better properties and superior cleanliness.
- Cost saving to the tune of ~ 40%.



PROPERTIES ACHIEVED

	C (%)	Ni (%)	Cr (%)	Mo (%)
Spec	0.3-0.4	3.5-4.2	1.6-2	0.25-0.6
Actual	0.36	3.93-3.95	1.83-1.85	0.29-0.3

	0.2%PS (MPa)	UTS (MPa)	%El (50mm GL)	Impact srength (J/cm^2)
Spec	1030 Min	1230-1380	8 Min	50
Actual	1059-1169	1242-1266	12-14	67-86

APPLICATIONS

Fabrication of shear bolts for Light alloy structures (PSLV / GSLV / LVM3).

Ti6Al4V FASTENERS

INTRODUCTION

Ti6Al4V material is known for its high specific strength and corrosion resistance. The fasteners of size range M2-M10 have been successfully indigenized and inducted into the flight program.

DESCRIPTION

The fasteners pertaining to 900MPa (annealed) and 1100MPa (solution treated and aged) property classes have been realized at M/s Ankit Fasteners, Bangalore with different surface treatment variants as given below:

Al IVD and Chromatized

- Anodized
- Al IVD and MoS2 coated
- Bare Ti6Al4V

CHEMICAL COMPOSITION

Element	wt.% min.	wt.% max.
Al	5.50	6.75
V	3.50	4.50
Fe	-	0.30
C		0.10
O_2		0.20
N_2		0.05
H_2		0.0125
Y		0.005
Res. (each)		0.10
Res. (total)		0.40
Ti	Balance	

MECHANICAL PROPERTIES

Property Class	UTS MPa	YS MPa	%El 4D	%RA
900 MPa	900 min.	825 min.	10 min.	25 min.

KOVAR ALLOY

INTRODUCTION

This alloy is being used by Satellite Application Centre as microwave carrier plate for communication payloads. Indigenous development and characterization of the alloy was carried out to establish indigenous technology and study the alloy behaviour. Melting was done through vacuum induction melting (VIM) process. Forging and rolling parameters were selected to obtain desired section of product. Further, heat treatment (annealing) was conducted. Sheets of 1.5mm and 3 mm thickness and plates of 12 mm thickness was realized.

DESCRIPTION

Mainly process control in melting to achieve the desired chemistry through use of purer raw material, hot working under desired workability range with required reduction and heat treatment at suitable temperature are important to achieve the properties in the alloy.

PROPERTIES

Chemical composition of Kovar alloy is given in Table 1. Mechanical properties and physical properties are presented in Table 2.

Table 1: Chemical composition of alloy

Elements	C	Mn	Si	Cr	Co	Fe	Ni
Specified	0.04 max	0.5 max	0.2 max	0.2 max	17 nom	53 nom	29 nom
Obtained	0.007	0.36	0.13	0.01	17.3	>53	28.7
<0.1 Mg, Zr, Ti (each), Al:0.002, Cu:0.01, Al+Mg+Zr+Ti <0.2							

Table 2: Mechanical properties of alloy

Properties	0.2% roof stress (MPa)	UTS (MPa)	% El (on 4d)	Hardness (HRB)
Specified	-	570 max	25 min	85 max
Annealed	343-349	497-501	33-36	81

GRAIN SIZE : ASTM No. 5 & 6

Microstructure: equiaxed austenitic grain with annealing twins

CTE (30-100^{0}C): 5.3-5.8X10^{-6}/^{0}C

APPLICATION

Microwave carrier plate for communication payloads.

ADVANTAGE

Self reliance in special materials and products.

ADTEK H 74
THERMALLY CONDUCTIVE ADHESIVE

INTRODUCTION

Adtek H74 is a thermally conductive and electrically insulating heat curable epoxy designed for multiple applications. It can find application in hybrid circuit assembly including die-attach, substrate attach, lid-seal, heat dissipation, hermetic sealing and also for sealing opto- packaging in general.

DESCRIPTION

It is an epoxy based alumina filled adhesive system curable at high temperature. This thixotropic paste can be dispersed, screen printed or manually applied. It is a two component system possessing high glass transition temperature, thermal conductivity and electrically insulating properties. Epoxy resin blended with reactive diluents function as the resin part, which is further blended with alumina and boron nitride constitutes to formulate Part A of the adhesive composition. Part B is mixture of aliphatic amines.

Epoxy resin and reactive diluents blended and pre-dried to remove all traces of moisture. Part A is prepared by blending the dried epoxy resin pre-mix and fillers along with coupling agent using a suitable mixing mechanism. Part B is a mixture of aliphatic amines.

PROPERTIES

Properties		Results
Pot life at Ambient temp.		142 minutes
Mix ratio (part A:part B) by weight		100 : 5
Thermal conductivity (W/mK)		1.1
Glass Transition Temperature (^{0}C)		123
Out Gassing properties	TML-WVR CVCM	<1% <0.1%
Cure Schedule		70 ^{0}C [for 3-hours]
Density (g/cc)		1.84
Lap shear strength (ksc)		118, 119, 120
Electrical insulation		1.3 X 10 ^{15} Ωcm

APPLICATION

The adhesive finds application as a heat sink in electronic packages in satellite and launch vehicle and for camera holding assembly potting in launch vehicle.

ADVANTAGES

The technology brings in self reliance in the area and considerable cost benefit.

SCNM 80 NBR-BASED RUBBER COMPONENTS

INTRODUCTION

Rubber products find application in various sub systems/ components used in the Semi Cryo Engine. These products are processed from different rubber compositions depending on their properties and working environment. SCNM 80 NBR (High Hardness Nitrile Rubber) is one such composition which is an equivalent of Jasmine composition IRP9089/9087/1004 developed successfully meeting the project requirement. This composition is used in the moulding of O-rings, rubber rings, Collars (lift off seals) and the in-situ vulcanisation of metal valves.

PRODUCT DEVELOPMENT & CHARCTERIZATION

The development of different sealing materials like O-rings, rubber rings, collars and in-situ vulcanisation of metal valves were done in specially designed mould in an electrically heated hydraulic compression moulding machine

Characterisation: The mechanical properties were evaluated as per ASTM D 412–87 using universal testing machine "INSTRON". Shore-A hardness tester was used for measuring the hardness. ODR (Oscillating Disc Rheometer) was used for generating the rheological parameters of SCNM 80 NBR compound.

PROPERTIES

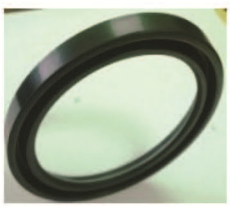
The properties were evaluated at ASTM slab level

Mechanical & Physical properties:

Tensile strength, ksc	140
Elongation at break,%	450
Hardness(Shore A)	76-77
Compression set (%); 70^0C; 22 hrs.	18
Density, g/cc	1.20

APPLICATIONS

The moulded rubber products based on SCNM 80 NBR and its brief use is tabulated below:

Products	Uses
O-rings	To seal the various interfaces of the subsystems in Semi Cryo Engine
Collars 	To minimise the leakage of Isrosene towards the liquid Oxygen pump before start of engine and after shut down of engine
Rubber rings 	Used in breather valve V-9 of control component in engine

ADVANTAGES

These products are developed as substitute for the product defined in Jasmine project report as per details available. Compatibility with Isrosene and other functional requirements have been addressed during development to meet the project requirement.

CYANATE ESTER FILM ADHESIVE, CEF-120

INTRODUCTION

Cyanate esters encompass several desirable attributes including low dielectric constant and dissipation factor, good RF transparency, low moisture absorption and good thermal stability rendering them the material of choice in high-performance antenna as well as PCB applications. The CEF-120 cyanate ester film adhesive has been formulated to use in specific applications where low moisture absorption and low dielectric constant/ low loss are of utmost importance. Due to the cyanate ester resin system's inherent low shrinkage during cure, bonded structures will be subjected to lower inherent stress and will therefore remain dimensionally more stable during thermal cycling. CEF-120 film adhesive also displays low outgassing properties.

DESCRIPTION

CEF-120 is developed as a substitute for the imported cyanate ester based film adhesive EX 1516. It is cast from a blend of cyanate esters and other additives in a specified composition which can be cured **easily.** CEF-120 is available as an unsupported film adhesive with areal density of 70 grams per square meter (GSM). The film adhesive is extensively used for the fabrication of DGR antenna and Patch array antenna. Shelf life of CEF-120 is 1 year when stored below -18°C.

PROPERTIES

Sl No	Properties	Specification
1	Appearance	Pale yellow
2	TML-WVR (%)	< 1
3	CVCM (%)	< 0.1
4	LSS @ RT (Al to Al) (MPa)	10-13
5	Areal density (g/m^2 (GSM))	70

APPLICATIONS

Cyanate ester film adhesive is extensively used in fabrication of multi-layer printed antenna (patch array antenna) and bonding applications in Duel gridded reflector antenna (DGR) such as face skin with Kevlar honeycomb, Rib of DGR and Intercostal ring of DGR.

Duel gridded reflector antenna

ADVANTAGES

This is the indigenized vesion of the imported counterpart EX 1516 cyanate ester film adhesive.

SINGLE PART RUBBER BASED PHENOLIC ADHESIVE-CPRA

INTRODUCTION

CPRA is a single part, Chloroprene-Phenolic Rubber Adhesive formulation-CPRA single component elastomer-metal adhesive system that possess good adhesive properties in terms of peel strength and lap shear strength and that can be applied with minimal metal surface preparation to a variety of metal/ elastomeric and composite surfaces. It is proposed to replace the multi component-multi part adhesive system (RCN5-PCR1) which is currently used for bonding vulcanized neoprene bellow to the metallic heat shield, in the heat shield separation system of PSLV/GSLV.

DESCRIPTION

CPRA is a one-coat polychloroprene based contact adhesive formulation developed for bonding elastomeric materials to metal, composites, leather etc. which find potential applications in aerospace, automobile, upholstery and in construction applications. These adhesives are applied on the substrates, dried and mated under only enough pressure to result in good contact. Most of the adhesives that are commercially available or reported in literature are based on two part adhesive formulation comprising of a primer and an overcoat and require extensive pretreatment of the metal surfaces to be bonded.

ADVANTAGES

- Replaces the multi component multi part rubber metal adhesive.
- Simpler formulation and room temperature processable.
- Low cost.
- Inventory issues are simplified.
- Does not require excessive pretreatment of the metal surface.
- Excellent adhesive properties between various dissimilar substrates.
- Finds application in aerospace, automobile, textile and leather industry.

PROPERTIES

Table 1: Adhesive property between various substrates

Substrate 1	Substrate 2	180° Peel Strength Kg/cm	Lap Shear strength Kg/cm^2
SS	Nylon reinforced neoprene	8-12	18-25
Al	Neoprene/Nitrile	2-5	18 -22
CFRP	Neoprene/nitrile	4-6	10-18
CFRP	Nylon reinforced neoprene/ nitrile	2-5	15-20

PROCESSING

CPRA is processed by milling the neoprene rubber and fillers and metal oxide in a three roll mill followed by its dissolution in appropriate mixture of hydrocarbon solvent and a tackifying phenolic resin.

APPLICATIONS

CPRA will be used for joining the bellows and the loose flaps to the end adaptors of the zip cord jettisoning system of heat shield separation system in PSLV, GSLV and GSLV Mk III.

Fig 1: Bonded specimens a) Lap shear strength and b) Peel strength between reinforced rubber and metal

ANTI-CORROSION PASTE (POLYCHROME)

INTRODUCTION

Galvanic corrosion occurs when two dissimilar metals are in physical or electrical contact and it is a serious concern for metallic structures in launch vehicles. The metallic joint between 15CDV6/35NCD16 and AA2014 is most common in PSLV/GSLV and is highly prone to corrosion by galvanic route. PSCD has developed an anti-corrosion paste (polychrome) to prevent galvanic corrosion between 15CDV6/35NCD16 and AA2014.

DESCRIPTION

The developed paste (polychrome) is a soft coating which is non-solvent based and does not set or cure. It is a fine paste with fineness in the range of 5-7 (Hegman scale). It can resist both galvanic and electrolytic corrosions between 15CDV6/35NCD16-AA 2014 metallic couples. The coating is stable up to 100°C without flow. The coating possesses very low solubility (<1 ppm) in water and aq. sodium chloride solution. This coating also withstands salt spray fog/ galvanic corrosion tests up to 360h.

PROPERTIES

Sl. No	Properties	Specification
1	Appearance	Yellow paste
2	Fineness (Hegman no.)	6-8
3	Volatile content (wt.%)	<1.0
4	Salt spray test for 360h	No sign of corrosion

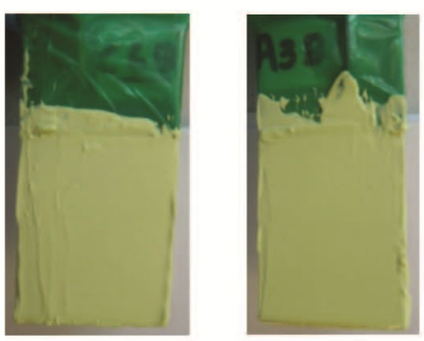


Fig1. Polychrome coated on 15CDV6 and AA2014 substrates

APPLICATIONS

The wet paste finds applications at the metallic joints between 15CDV6/35NCD16 and AA2014 in PSLV/GSLV which are highly prone to galvanic corrosion.

ADVANTAGES

This is the indigenized equivalent of Mastinox D40/ JC5A.

EPOXY FILM ADHESIVE EFA-4335-LD (MELT CAST)

INTRODUCTION

The special type of film adhesives with low dielectric properties are extensively used for fabrication of antenna for satellite using Rohacell Foam and RT Duroid. It offers high strength and good bonding to both metals and composite systems. Specially it withstands the environmental testing for satellite.

DESCRIPTION OF PROCESS/PRODUCT

The system consists of speciality epoxy resin and additives for low dielectric and rheological flow characteristics. Fillers also improve the strength and latent curing agent for controlled curing. EFA 4335-LD (melt cast) is stored below -18°C and in this storage conditions it has a shelf life of minimum 1 year.

TYPICAL PROPERTIES ACHIEVED

Appearance	Gray film
Specific weight (GSM)	75±10
Lap shear strength (Al/Al) at 25°C (kgf/cm^2)	≥ 150
TML-WVR (%)	≤ 1.0
CVCM (%)	≤ 0.1

APPLICATIONS

EFA 4335-LD (Melt Cast) finds extensive applications in the fabrication of antenna.

ADVANTAGES

The cost of the product is reduced and it is 1/5th of imported.

Patch array antenna fabricated using EFA 4335 LD

ADTEK H 21 D
ELECTRICALLY CONDUCTING ADHESIVE

INTRODUCTION

Electrically conductive adhesives are widely used in satellites and launch vehicles for chip bonding in microelectronic and optoelectronic devices. The system may also find application in general demands as electrically conductive adhesive.

DESCRIPTION

It is an two part, heat curable, modified epoxy based filled high temperature curable adhesive having long pot life (service life) of 15 hours. Part A and Part B are filled adequately. consistency is brought to paste like for application in small cavities. Part B is a blend of imidazoles.

PROCESSING

Epoxy resin and reactive diluents blended and dried at elevated temperature to remove the humidity contamination. Pre dried silver flakes are mixed with the resin blend and amine blend separately using a suitable mixing mechanism to achieve the desired consistency.

PROPERTIES

Properties		Results
Thermal conductivity (W/mK)		1.5-1.6
Volume Resistivity (Ohm-cm)		$\leq 9x10^3$
Lap Shear Strength (KSC)		100 minimum
Pot Life (hours)		15
Out Gassing properties	TML-WVR CVCM	<1% <0.1%

ADVANTAGES

The technology brings in self reliance in the area and considerable cost benefit.

ADBOND 56C
ELECTRICALLY CONDUCTING ADHESIVE

INTRODUCTION

Electrically and thermally conductive adhesives are widely used in satellite for the application in satellite thermal management and insert bonding in solar panels. The system may also find application in general demands an electrically conductive adhesive.

DESCRIPTION

Adbond 56C is a modified epoxy based filled room temperature curable adhesive. Low viscous epoxy resin blended with reactive diluents constitutes the resin part.

PROPERTIES

Properties		Results
Thermal conductivity (W/mK)		3.2-3.8
Volume Resistivity (Ohm-cm)		$\leq 9 \times 10^{-4}$
Lap Shear Strength (KSC)		40 minimum
Pot Life (minutes)		45
Out Gassing properties	TML-WVR	<1%
	CVCM	<0.1%

APPLICATION

The adhesive is used for insert fixing in solar panels of satellites and in satellite thermal management systems. The adhesive can also find applications in electronic packages where high level of electrical conductivity is a desired criteria.

ADVANTAGES

The technology brings in self-reliance in the area and considerable cost benefit.

VERY LOW HARDNESS SILICONE ELASTOMER SHEET FOMSIL 1015

INTRODUCTION

FOMSIL 1015 is a two-part addition cure silicone elastomer with shore-A hardness of 10-20, which is developed for arresting the vibration of the parts inside the FBGA interrogation analyser of fibre optic sensor based measurement system (FOMS) for structural strain measurements in launch vehicles. This low hardness unfilled silicone sheet can be used as vibration isolation sheet in electronic packages and in similar areas.

DESCRIPTION

FOMSIL 1015 is a two-part addition cure silicone elastomer.

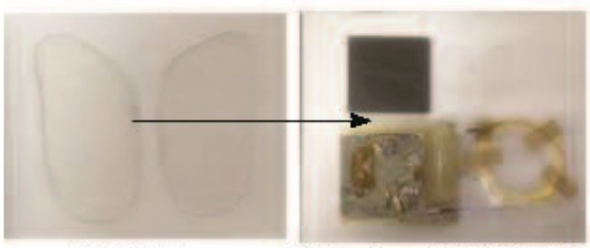
PROPERTIES

	Properties	Specification
1.	Hardness, Shore A at 25°C	10-20
2	Tensile strength at RT, ksc	3.0-4.0
3	Elongation at RT, %	140-215
4	Modulus at 100% elongation (ksc)	2.5-3.0

APPLICATIONS

It was used in the fibre optic sensor based measurement system (FOMS) for structural strain measurements in GSLV F05 mission. To arrest the vibration of the parts inside interrogation analyzer, FBGA (brought-out module) used inside FOMS, a silicone elastomer sheet with low shore-A hardness is required which is further sealed with a metal cover. Designer level vibration test (upto 13.5grms) was carried out using FOMSIL-1015 and performance improvement was observed in the system.

This low hardness elastomer sheet can be used in vibration isolation applications in electronic packages and other allied areas



FOMSIL-1015 FOMS package with FOMSIL 1015

ADVANTAGES

The technology brings in self reliance in the area and considerable cost benefit.

RTV SINGLE PART SILICONE ADHESIVE, PYROSIL 10M

INTRODUCTION

Pyrosil 10M is a room temperature curable, high temperature resistant single part adhesive. It is designed for use in the separation and destruct systems of PSLV and GSLV. It can be used as a bonding agent for bonding extruded silicone rubber to lead sheath of flexible linear shaped charges (FLSC).

DESCRIPTION

Pyrosil 10M is a single part silicone based adhesive in which the resin, filler and the moisture sensitive curing components are premixed in dehumidified condition and stored in ready-to-use squeeze tubes. It is room temperature curable and does not require any external source of heat for curing. It is a non-solvent system. It has good thermal stability and good water-repellent characteristics. This adhesive is specifically designed for applications where it should withstand both low and high service temperature environments. The adhesive can be easily squeezed out from the tube and can be applied to various substrates like metals, composites, polymers and rubberized fabrics.

PROPERTIES

Sl. No.	Properties	Values
1	Density, g/cc	1.03 -1.04
2	Tensile Strength at RT, ksc	9-12
3	Elongation at RT, %	250 - 320
4	Hardness, Shore A	27-30
5	Modulus at RT , kg/cm^2	4-5
6	LSS Al-Al at RT, ksc	12-17
7	LSS on lead to silicone rubber at RT, ksc	0.5-0.7
8	Pot life	>45 minutes
9.	Tack free time	6 hrs

APPLICATIONS

PYROSIL 10M is a single part silicone based adhesive proposed for use in the separation and destruct systems of PSLV and GSLV. It can also be used as a bonding agent for bonding silicone sealant to lead sheath of flexible linear shaped charges (FLSC) and also as an adhesive for bonding extruded silicone rubber to FLSC.

It can also find application as a general purpose high strength RTV silicone adhesive.

ADVANTAGES

The technology brings in self-reliance in the area and considerable cost benefit.

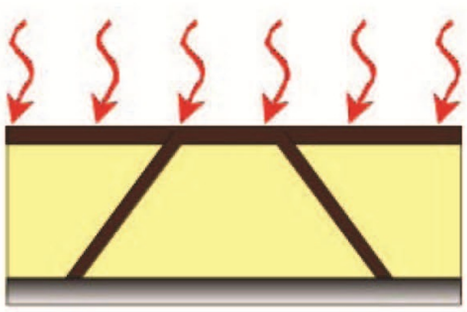
CMC BASED INTEGRATED TPS FOR WINDWARD REGION OF RLVS

INTRODUCTION

CMC based TPS materials are potential candidates for hot structure development of hypersonic flight systems. These systems require hot-structures that are lighter in weight and require less maintenance. The concept of integrated thermal protection systems has gained much importance towards the development of integrated multifunctional air frame structures that eliminate fragile external thermal-protection systems and incorporate the insulating function within the structure.

DESCRIPTION

The design approach is the truss core sandwich concept in which the entire mechanical load is taken care by the external wall structure and the thermal loads by the internal insulation layers. The combined structure could withstand a temperature of 1500°C and is able to withstand mechanical/ thermal loads. The temperature capability can be increased to above 2000°C by providing suitable high temperature coatings and/or by using ultra high temperature composites (UHTC) as the external structural components.

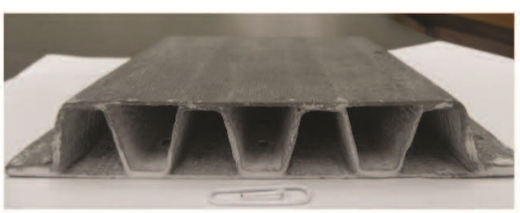


Schematic of truss core sandwich concept

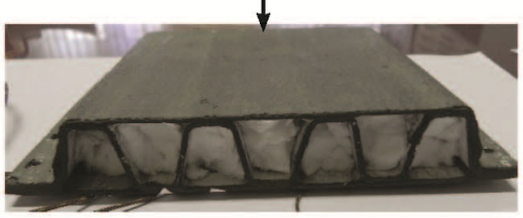
ADVANTAGES

- Eliminates fragile external thermal protection systems
- Water proofing not required
- Larger unit size
- More durable (reduced inspection and repair)
- Low cost
- Withstands temperatures as high as 1800 K in oxidizing environment

CHARACTERIZATION



CMC based stiffened panel construction by precursor route



CMC based stiffened panel construction after filling with insulator

CMC based stiffened panel was tested in 6 MW PWT facility, at a heat flux of 10-12 W/cm^2 for 92 sec. The back wall temperature was ~100°C. The qualification will be carried out as per the project requirement.

CMC based stiffened panel after testing

POLY URETHANE BASED GREY CONDUCTIVE COATING - PUGCC 50

INTRODUCTION

Polyurethane based Grey conductive coating (PUGCC 50) is a urethane based room temperature curing antistatic coating that has been developed for the advanced composite cryo insulation. Its function is to prevent static charge build up. It is the outermost layer of the composite cryogenic insulation system. This coating is a two part polyurethane based system and is applied over the urethane based heat shielding coating. It replaces the existing silicone based antistatic coating GCC-50 over cryo tank insulation. Performance of PUGCC 50 during the launch environment is by way of avoiding any electrical surface discharge build up due to air friction. In the launch pad environment, it mitigates the static electricity on the tank by conducting through the grounded lines. It also adds to the insulation process, by reducing the heat in leak in the cryogenic stage.

DESCRIPTION

The development, characterization and qualification of PUGCC 50 has been completed after a series of tests along with the new composite insulation system. PUGCC 50 has been flight proven in GSLV F 05. As a urethane system, it has excellent adhesion towards PU based heat shielding coating and imparts good antistatic properties.

PROPERTIES

Appearance	Grey
Surface resistivity (ohms/sq.)	$\leq 10^6$
IR emissivity	>0.80
Solar absorptivity	>0.85
Adhesion (cross-hatch test, %)	>0.95

APPLICATIONS

PUGCC 50 is a urethane based antistatic coating and outermost layer of LOX and LH_2 tank insulation

MAJOR BENEFITS/ADVANTAGES

This coating has good adhesion towards newly developed urethane based heat shielding coating.

PUGCC 50 applied over CUS -07

OXIDATION RESISTANT HIGH TEMPERATURE COATING

INTRODUCTION

C/C composites are used as the thermostructural material for nosecap of reusable launch vehicles (RLV-TD) and leading edges of air breathing engines. Eventhough they have high mechanical strength they are easily prone to oxidation above temperatures of 500°C in presence of air. Thus, SiC coating is applied on these structures to prevent oxidation in high temperature environments.

DESCRIPTION

SiC coating through preceramic route is an indigenously developed high temperature oxidation resistant coating for carbonaceous substrates. It is a phenolic resin based formulation and contains various ceramic fillers which gets converted to SiC at 1500°C. SiC ceramic is having excellent oxidation resistance, and good compatibility with C/C composites and glassy silica layer will be formed on the coating surface when the coating is exposed to air at high temperatures.

ADVANTAGES

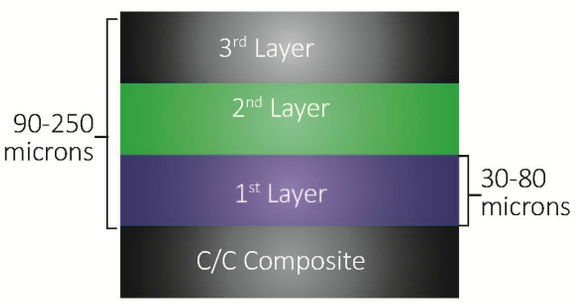
- low cost
- coating of complex shapes
- lower capital investments
- ease of repair of damaged areas

SiC coated C/C SLE

SiC coated 4D C/C BLS after hot test

SiC coated C/C nosecap

The multilayer coating developed is a three layer system consisting of a SiC layer applied to the hardware by spraying. SiC coating has been successfully completed on C/C nosecap for RLV-TD and on boundary layer splitter and strut leading edge for ABPP. The schematic representation of the coating approach is given below:



PROPERTIES

Property	Value
Viscosity (cps)	700-1200
Thickness (micron)	Can be varied from 50-800
Curing temperature	175°C for 2 hrs
Size of the hardware/ specimen to be coated and coating technique	Unlimited/spray or brush
Absorptivity	0.87
Emmissivity	0.9
C.T.E(/°C)	At RT: 2 and 800°C: 4.5
Thermal Conductivity (W/ mK)	RT: 2.0
Specific heat (cal/g/°C) at 50°C	0.27
Kinetic heating simulation test (KHS)	Withstood a maximum heat flux of 36W/cm^2 for 1036 secs.
Arc jet test	Tested at different heat fluxes ranging from 48 W/cm^2 for 80 secs. to 460 W/cm^2 for 7 secs.
Reusability test (KHS)	Tested 5 times for reusability at 36 W/cm^2 for a duration of 1036 secs.

ULTRA LOW EXPANSION GLASS-CERAMIC (ULEGC) FOR ISRO RING LASER GYROSCOPE

INTRODUCTION

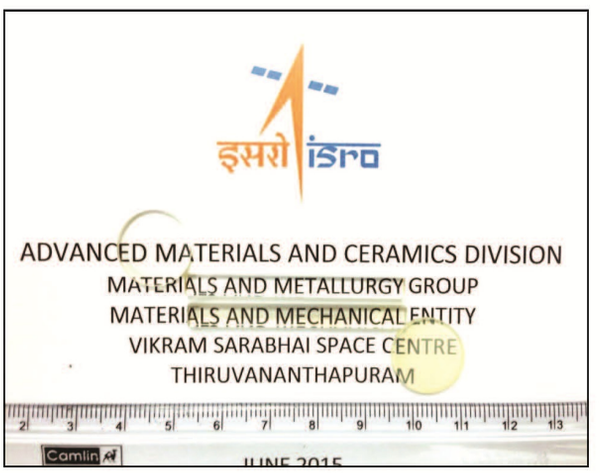
Ultra low expansion glass-ceramics (ULEGCs) are polycrystalline material produced from controlled crystallization of lithium alumino silicate glass. Near zero expansion characteristic is attributed to the tuned nanocrystallinity wherein Negative Thermal Expansion (NTE) of crystals compensates Positive Thermal expansion of the residual glass matrix.

DESCRIPTION

Present indigenization effort involves conventional glass forming technique and conventional two stage ceramization procedure. Commercial grade composition has been used for realization.

TYPICAL PROPERTIES ACHIEVED

Properties	ULEGC
Density (g/cm^3)	2.44
CTE, (10^{-6} /°C) 0 - 50°C	-0.03 to -0.08
CTE, (10^{-6} /°C) -60 to 60°C	-0.1
Transparency in Visible range	>85%
Thermal Conductivity	1.3-1.4
Elastic reduced modulus (GPa) (Nanoindentation: 10mN load, 4mN loading rate)	82.84
Indentation Hardness (GPa) (Nanoindentation: 10mN load, 4mN loading rate)	10.10



APPLICATION

Due to the very high dimensional stability, thermal shock resistance, mechanical strength and polishability, ULEGCs are widely used in Ring Laser Gyroscope (RLG) , Satellite mirror blanks, mounting units of electro-optic systems etc. ISRO imports these materials for its all strategic applications. IISU uses Astrositall® as the dynamically stable platform in the manufacture of ISRO Ring Laser Gyroscope (ILG).

ADVANTAGE

'Astrositall®', 'Zerodur®', Clearzerm are commercially available ULEGCs. Indigenisation and realization of this material is very important for complete indigenization of ILG technology. Technology developed can also be used for realization of large satellite mirror blanks.

3D PRINTING TECHNOLOGY

INTRODUCTION

3D printing is the latest advancement in materials processing domain to process near net complex shapes with intricate profiles in a faster lead time. Complex shaped proto-type of exhaust unit was realized in alloy IN718, in order to evaluate the suitability of this technology for launch vehicle components. The proto-type met all the metrological and NDT requirements. Coupon level mechanical properties were also evaluated.

DESCRIPTION

High purity imported raw material (pre-alloyed spherical IN-718 powder) selectively laser sintered and heat treated as per AMS 5662.

Microstructural features of 3D printed IN-718 across different printing directions

TYPICAL PROPERTIES ACHIEVED [IN 718]

Attribute	UTS (MPa)	YS (MPa)	%TE
X direction	1441-1478	1250-1283	13-16
Y direction	1480-1509	1288-1317	14-16
Z direction	1388-1416	1225-1285	13-20
Wrought[@]	1275-1400	1030-1167	12-21

[@] Mat.Sci.Eng. A,383,(2004),201-212

3D printed proto-type realized in 718 alloy

TEMPERATURE-COMPENSATED ALUMINA (COMAL) FOR MIC SUBSTRATE APPLICATIONS

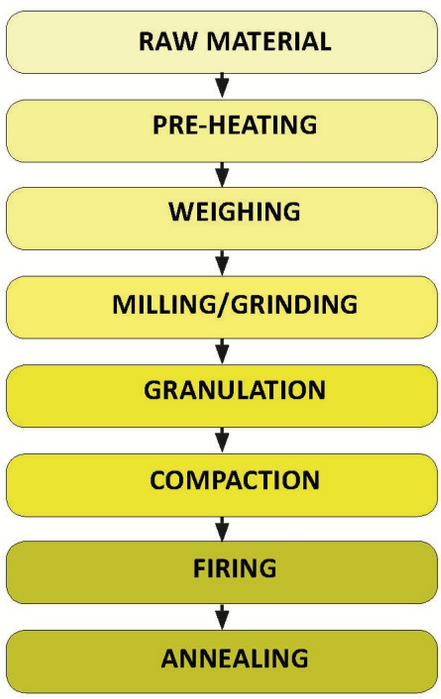
INTRODUCTION

Alumina substrates are widely used in all integrated circuits. Currently, different varieties of these are being imported from various sources.

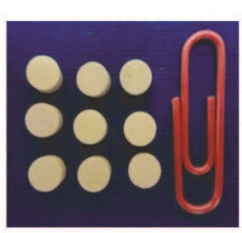
The properties like dielectric loss vary with purity (99.6-99.9%) and also based on the additives used. The firing temperature as well as the thermal coefficients can be reduced by adding suitable additives to alumina. VSSC has developed such a composition (ComAl) to reduce the temperature-coefficient of dielectric constant (τε) of Al_2O_3 by half and can be sintered into full density at appropriate temperature.

The electrical properties of alumina are not seriously affected by this process.

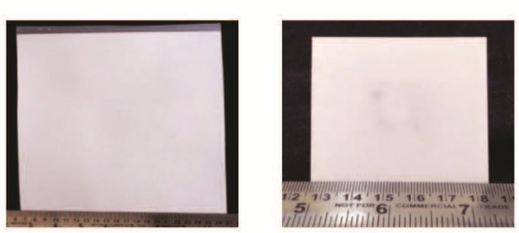
ComAl can replace alumina in a number of applications like MIC and HMC substrates, supports for dielectric resonators (DRs), high-frequency DRs, dielectric antennas, IC package etc.



Sintered substrate (28×28×2.5mm) for HMC



Supports for DRs in S-band Filter



Typical green tape (6.5" square) for IC package and sintered thin sheet(150μ) for MIC substrate (courtesy: NAL)

TYPICAL PROPERTIES ACHIEVED

Specification	Bulk	Thin sheet
Dimensions	No limit	<1mm thickness
Density (ρ) of ceramic [g/cm^3]	3.80 – 4.0	3.80 – 4.0
Dielectric constant of ceramic (εr)	11.5— 12.0	10.8—12
Loss factor (tanδ, max) @ 10GHz	7.0— 7.5 ($\times10^{-5}$)	2.0 — 2.5 ($\times10^{-4}$)
Temp. coeff. of εr [ppm/°C] (measured from frequency drift)	<|20|	<|50|
Coeff. Thermal expansion ($\times10^{-6}$)	7.0—7.8	7.0— 7.8
Thermal conductivity (W/mK)	25— 30	--
Breakdown voltage (kV/mm)	8 – 10	--

APPLICATIONS

ComAl can replace alumina in MIC and HMC substrates, supports for dielectric resonators (DRs), high-frequency DRs, dielectric antennas, IC package etc.

ADVANTAGES

Size and weight reduction, temperature-stability.