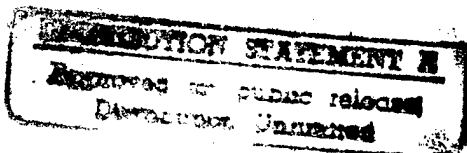


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Inventor Deborah Haught
Inna G. Talmy

NOTICE

The above identified patent application is available for licensing. Requests for information should be addressed to:

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DEPARTMENT OF THE NAVY
CODE OCCC3
ARLINGTON VA 22217-5660



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2 CERAMIC MATERIAL

3 BACKGROUND OF THE INVENTION

4 This invention relates to ceramics and more particularly to
5 aluminosilicate ceramics.

6 Future classes of advanced tactical missiles will require
7 new ceramic materials for radomes to meet the stringent
8 requirements arising from greater speeds (up to Mach 8) and
9 longer flight times. The critical need is to develop ceramic
10 materials stable up to at least 1400°C with low and thermally
11 stable dielectric constant (ϵ) and loss tangent, low coefficient
12 of thermal expansion (CTE), and high thermal shock and rain
13 erosion resistance. Presently used slip cast fused silica
14 (SCFS) has excellent dielectric and thermal properties for
15 radomes, but the relatively low strength and rain erosion
16 resistance of this material limit its future application. For
17 this reason, research conducted on radome materials is directed
18 both toward improvement of the mechanical properties of SCFS
19 and development of new candidate ceramics.

20 SUMMARY OF THE INVENTION

21 Accordingly, an object of this invention is to provide a
22 ceramic material which has a thermally stable, low dielectric
23 constant.

24 Another object of this invention is to provide a new
25 ceramic material with a dielectric constant that only slightly
26 changes with increasing temperature.
27
28

1 A further object of this invention is to provide a ceramic
2 material which maintains its chemical composition and
3 crystalline modification even at high temperatures.

4 Yet another object of this invention is to provide a
5 ceramic material that is transparent to electromagnetic waves
6 and has stable dielectric properties at high temperatures.

7 A still a further object of this invention is to provide a
8 ceramic material suitable for high temperature dielectric
9 applications such as missile radomes.

10 It is also an object of this invention to provide a ceramic
11 material suitable for substrates for electronic components.

12 These and other objects of this invention are accomplished
13 by providing:

14 a material which is ceramics based on monoclinic
15 $BaO \cdot Al_2O_3 \cdot 2SiO_2$; or ceramics based on monoclinic $SrO \cdot Al_2O_3 \cdot 2SiO_2$;
16 or ceramics based on monoclinic, solid solution of from more
17 than zero to less than 100 mole percent of $SrO \cdot Al_2O_3 \cdot 2SiO_2$ with
18 $BaO \cdot Al_2O_3 \cdot 2SiO_2$ being the remainder, and a method of making this
19 ceramic material.

20 This material can be used in radomes.

21 BRIEF DESCRIPTION OF THE DRAWINGS

22 FIG. 1 is a phase diagram for the
23 $SrO \cdot Al_2O_3 \cdot 2SiO_2 / BaO \cdot Al_2O_3 \cdot 2SiO_2$ system where the materials were
24 prepared directly from oxides and salts as raw materials.

25 FIG. 2 is a phase diagram for the
26 $SrO \cdot Al_2O_3 \cdot 2SiO_2 / BaO \cdot Al_2O_3 \cdot 2SiO_2$ system where the materials were
27

28

1 prepared from previously synthesized monoclinic $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$
2 and monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ powders;

3
4 FIG. 3 is a graph showing the dependency of the relative
5 density on composition and firing temperature for ceramics
6 based on the $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2/\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ system;

7
8 FIG. 4 is a graph showing the dependency of bending
9 strength on composition and firing temperature for ceramics
10 based on $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2/\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$, system; and

11
12 FIG. 5 is a graph showing the changes in dielectric
13 constant with temperature for ceramics based on monoclinic
14 $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$, monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$, and a 25 mole percent
15 $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2/75$ mole percent $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ monoclinic solid
16 solution.

17 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

18 The ceramic materials of this invention are prepared from
19 fine powders of pure monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ and pure
20 monoclinic $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$. The powders preferably have a
21 surface area of from about 3 to about 6 m^2/g and more preferably
22 from 4 to 5.5 m^2/g . The ceramic materials produced include pure
23 monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$, pure monoclinic $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$, and
24 monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2/\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ solid solutions
25 prepared from intimate mixtures of the pure monoclinic
26 $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ and pure monoclinic $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ powders in the
27 desired proportions.

28 Specifically excluded from this invention are the hexagonal
crystalline form of $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ and the hexagonal crystalline
form of $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$. Hexagonal $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ transforms

1 reversibly into low temperature orthorhombic crystalline form
2 at 300°C. This transformation is accompanied by significant
3 volume changes which can weaken or damage the ceramic
4 structures. Because of this fact, hexagonal $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ is
5 of no practical use as a ceramic material for high temperature,
6 especially, thermal cycling applications.

7
8 FIG. 1 is a phase diagram for the
9 $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2/\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ system where the materials are
10 prepared directly from oxides and salts (BaCO_3 , Al_2O_3 , SiO_2 , and
11 SrCO_3 powders). The hexagonal form of the
12 $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2/\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ is difficult to avoid in the
13 preferred ranges of composition when this method is used. In
14 contrast, FIG. 2 is a phase diagram for the
15 $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2/\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ system where the materials are
16 prepared from fine powders of monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ and
17 monoclinic $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$. As can be seen, the hexagonal form
18 of the $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2/\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ solid solutions is easily
19 avoided using this method.

20 The ceramics based on solid solutions containing from more
21 than zero to less than 100 mole percent of monoclinic
22 $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ with the remainder being monoclinic
23 $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ are more sinterable, are denser, and have greater
24 bending strength than do the ceramic materials formed from
25 either monoclinic $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ powder or monoclinic
26 $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ powder alone when fired at optimum temperatures
27 (see FIG. 3 and FIG. 4). Within that broad range, narrower,
28 preferred ranges are selected to emphasize certain desirable

1 properties. Ceramic based on monoclinic solid solutions having
2 from 15 to 35 and preferably from 20 to 30 mole percent of
3 monoclinic $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ with the remainder being monoclinic
4 $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ have the greatest bending strength when fired at
5 optimum temperature for producing the densest material (see
6 FIG. 4).

7
8 The most preferred solid solution compositions are those
9 which are most useful for radomes. These compositions fall in
10 the range of preferably from more than zero to 15, and more
11 preferably from 5 to 10 mole percent of monoclinic
12 $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ with the remainder being monoclinic
13 $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$. Ceramics based on monoclinic solid solutions of
14 $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ and $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ in these ranges of composition
15 have higher density and bending strength than monoclinic
16 $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ alone (see FIG. 3 and FIG. 4). Moreover these
17 solid solutions are stable in the monoclinic crystalline form
18 at temperatures above 1590°C whereas pure $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ is not.
19 For example, at 1600°C pure $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ transforms from the
20 monoclinic to the hexagonal crystal form. In contrast, a solid
21 solution containing 10 mole percent monoclinic $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$
22 and 90 mole percent monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ is stable in the
23 monoclinic form at 1700°C . This means that the material may be
24 used for radomes operating at higher temperatures. FIG. 5 and
25 Table 1 show that the dielectric constant of a ceramic based on
26 monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ changes less significantly with
27 increasing temperature than does a ceramic based on monoclinic
28

1 SrO•Al₂O₃•2SiO₂, and ceramics based on solid solutions of these
2 two falling proportionally in between.

3
4 When these materials are to be used in the manufacture of
5 radomes, care must be taken not to introduce impurities. Thus
6 natural materials such as kaolin or clay or technical grade
7 purity chemicals containing significant amounts of impurities
8 should not be used. Moreover, additives such as B₂O₃, LiF,
9 Cr₂O₃, CaF₂, ZrSiO₃, etc., which promote the formation of
10 monoclinic BaO•Al₂O₃•2SiO₂, must also be avoided. Impurities can
11 distort the electromagnetic signals passing through the radome.

12 The monoclinic BaO•Al₂O₃•2SiO₂ ceramic materials, monoclinic
13 SrO•Al₂O₃•2SiO₂ ceramic materials, and the monoclinic
14 BaO•Al₂O₃•S2iO₂/SrO•Al₂O₃•2SiO₂ solid solution ceramic materials
15 are made from high purity monoclinic BaO•Al₂O₃•2SiO₂ and high
16 purity monoclinic SrO•Al₂O₃•2SiO₂ fine powders. The monoclinic
17 BaO•Al₂O₃•2SiO₂ starting material can be prepared without seed
18 crystals according to example 1. This monoclinic BaO•Al₂O₃•2SiO₂
19 is then used as seed crystals in the much easier process of
20 example 2 to produced more monoclinic BaO•Al₂O₃•2SiO₂. The
21 monoclinic BaO•Al₂O₃•2SiO₂ produced in example 2 can be used as
22 seed crystals for further batches. The monoclinic
23 SrO•Al₂O₃•2SiO₂ can be produced according to the process of
24 example 3. The monoclinic BaO•Al₂O₃•S2iO₂ and the monoclinic
25 SrO•Al₂O₃•2SiO₂ are each ground into very fine powders. These
26 powders will preferably have a surface area of from 3 to 6 m²/g
27 and more preferably of from 4 to 5.5 m²/g.
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1
2 To prepare a ceramic based on monoclinic solid solution of
3 a given composition, the appropriate amounts of monoclinic
4 $BaO \cdot Al_2O_3 \cdot 2SiO_2$ and monoclinic $SrO \cdot Al_2O_3 \cdot 2SiO_2$ powders are
5 intimately mixed (see example 4). Of course, the monoclinic
6 $BaO \cdot Al_2O_3 \cdot 2SiO_2$ powder or the monoclinic $SrO \cdot Al_2O_3 \cdot 2SiO_2$ powder
7 can each be used alone to produce either monoclinic
8 $BaO \cdot Al_2O_3 \cdot 2SiO_2$ ceramics or monoclinic $SrO \cdot Al_2O_3 \cdot 2SiO_2$ ceramics.

9 Next the monoclinic $BaO \cdot Al_2O_3 \cdot 2SiO_2$ powder, or monoclinic
10 $SrO \cdot Al_2O_3 \cdot 2SiO_2$ powder, or mixture of monoclinic $BaO \cdot Al_2O_3 \cdot 2SiO_2$
11 and $SrO \cdot Al_2O_3 \cdot 2SiO_2$ powders are formed into a green body. This
12 is done by conventional methods such as cold pressing, cold
13 isostatic pressing, extrusion, injection molding, or slip
14 casting, etc. In addition to radomes of various shapes, other
15 structures such as component substrates may be formed.

16 The green bodies are then fired at a temperature of
17 preferably from about 1550°C to less than 1590°C and more
18 preferably from 1550°C to 1580°C. Referring to FIGS. 3 and 4
19 it can be seen that relative density and bending strength
20 increase with increasing temperature. Note however that
21 overfiring (1650°C) results in a substantial reduction in these
22 properties. Therefore, care is taken to keep the firing
23 temperature below 1590°C.

24 The general nature of the invention having been set forth,
25 the following examples are presented as specific illustrations
26 thereof. It will be understood that the invention is not
27 limited to these specific examples but is susceptible to
28

1 various modifications that will be recognized by one of
2 ordinary skill in the art.

3
4 EXAMPLE 1

5 Preparation of monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ without seed
6 crystals

7
8 A uniform, stoichiometric, raw powder mixture of BaCO_3 ,
9 Al_2O_3 , and SiO_2 gel was prepared by the sequential addition of
10 BaCO_3 powder and tetraethylorthosilicate (Silbond 40 from
11 Stauffer Chemical Co.) in ethanol to a NH_4OH -stabilized Al_2O_3
12 (0.3 micron) suspension (pH 11). Ammonia served as a catalyst
13 for the hydrolysis of the tetraethylorthosilicate. The mixture
14 was continuously stirred until the hydrolysis was completed and
15 then vacuum dried at 65-70°C. The resulting powdered mixture
16 was uniform and did not contain any agglomerates. The powder
17 was pressed into pellets at 100 MPa and then fired at 1500°C
18 for about 150 hours. The product was monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$.
19 It was ground to a particle size less than 60 microns for use
20 as seeds in example 2.

21
22 EXAMPLE 2

23 Preparation of monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ using monoclinic
24 seeds

25
26 Into a uniform, stoichiometric, raw powder mixture of
27 BaCO_3 , Al_2O_3 (0.3 microns), and SiO_2 gel prepare as described in
28 example 1, was added the monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ seed crystals

1 (less than 60 microns in size) prepared in example 1. Batches
2 containing 1, 3, 5, and 10 percent by weight of the monoclinic
3 $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ seed crystals were prepared and then fired at
4 1250-1500°C for 5 hours. The addition of monoclinic seeds
5 highly intensified the formation of monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$.
6 Even the presence of 1 percent seeds significantly promoted the
7 phase transformation from hexagonal to monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$
8 at 1250°C. Total phase transformation was accomplished by the
9 addition of at least 5 percent by weight of the monoclinic
10 $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ seed crystals. This was demonstrated by the
11 batches containing 5 and 10 percent by weight of the seed
12 crystals. Note that the completely transformed, 100 percent
13 monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ product can be ground to particles
14 less than 60 microns in size and used as seed crystals for
15 subsequent batches. In other words, the arduous process of
16 example 1 is needed only to prepare an initial batch of
17 monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$.
18

19 EXAMPLE 3

20 Preparation of monoclinic $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$

21
22 A uniform, stoichiometric, raw powder mixture of SrCO_3 ,
23 Al_2O_3 , and SiO_2 gel was prepared by the sequential addition of
24 SrCO_3 powder and tetraethylorthosilicate (Silbond 40 from
25 Stauffer Chemical Co.) in ethanol to a NH_4OH -stabilized Al_2O_3
26 (0.3 micron) suspension (pH 11). Ammonia served as a catalyst
27 for the hydrolysis of the tetraethylorthosilicate. The mixture
28

1 was continuously stirred until the hydrolysis was completed and
2 then was vacuum dried at 65-70°C. The resulting dry raw
3 powders were uniform and did not contain any agglomerates. The
4 raw powder mixture was pressed into pellets at 100 MPa and then
5 fired at 1050-1400°C for 5 hours. X-ray diffractograms showed
6 that the reaction was practically completed at 1300°C and the
7 product consisted only of monoclinic $\text{SrO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$.
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2 EXAMPLE 4

3 Previously synthesized monoclinic $\text{BaO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ (BAS) and
4 monoclinic $\text{SrO}\cdot\text{Al}_2\text{O}_3\cdot 2\text{SiO}_2$ (SAS) were used as starting powders
5 for the preparation of ceramics in the BAS-SAS system. The
6 powders were ground in an attritor using ZrO_2 grinding media to
7 surface area up to $5\text{m}^2/\text{g}$. Specimens having the following
8 compositions were prepared:

9 mole percent

10 BAS SAS

11 100 0

12 98 2

13 90 10

14 75 25

15 50 50

16 25 75

17 10 90

18 5 95

19 2 98

20 0 100

21 All specimens were pressed at 100 MPa. Specimens of each of
22 the compositions were fired at 1500°C , 1550°C , 1600°C and
23 1650°C with a holding time of 5 hours at each of those
24 temperatures.

25 The dependence of relative density on composition and
26 firing temperature is shown in FIG. 3. The specimens based on
27 pure BAS were completely densified (open porosity close to
28 zero) at 1600°C , and those based on pure SAS at 1550°C . The

1 addition of SAS to BAS sharply enhanced densification at 1500°-
2 1550°C and only slightly at 1600°C. The addition of BAS to SAS
3 in amounts up to 10 mole percent promotes densification at
4 1500°C. Materials containing up to 25 mole percent BAS had the
5 best sinterability in the system and were completely densified
6 at 1550°C. The decrease in density for specimens sintered at
7 1650°C is due to overfiring. Pure BAS fired at 1650°C consisted
8 of only the hexagonal modification. The addition of 2 mole
9 percent SAS significantly inhibited the hexagonal-to-monoclinic
10 transformation, and 5 mole percent SAS practically stabilized
11 the monoclinic form. Stabilization of the monoclinic
12 modification of BAS with the addition of SAS decreases the
13 sensitivity of BAS to sintering temperatures close to 1600°C
14 and increases the service temperature.

15
16 The microstructure of ceramics in the system was studied by
17 SEM of polished specimens thermally etched at 1450°C for 2
18 hours. All the specimens had fine grained structure with
19 maximum grain size of about 5 microns.

20 Bending strength was measured in 3-point bending (2.54 mm
21 span) using 4 x 4 x 40 mm bars. The bending strength of
22 specimens of intermediate compositions fired at optimum
23 sintering temperature was higher than that of the end members
24 (FIG. 4). The highest strength of about 130 MPa was shown by
25 specimens containing 75 mole percent BAS and 25 mole percent
26 SAS (75BAS/25SAS), compared to about 80 and 100 MPa for SAS and
27 BAS, respectively. The drop in strength for specimens fired at
28 1650°C is due to overfiring.

1 Thermal expansion was measured with a differential
2 dilatometer at temperatures up to 1500°C using dense 25 mm long
3 specimens and a sapphire reference. The coefficient of thermal
4 expansion (CTE) of BAS was 4.56×10^{-6} /degree and of SAS was
5 4.92×10^{-6} /degree, in the 100-1500°C range, with linear
6 dependence on temperature.

7 The dielectric properties of BAS, SAS, and 75BAS/25SAS
8 ceramics were measured up to 1200°C at 35 GHz. The dielectric
9 data are summarized in Table 1 and FIG. 5. The loss tangent
10 for the samples was very low despite noticeable levels of ZrO₂
11 impurities (up to 0.85% ZrO₂ from grinding media). At 1200°C,
12 the loss tangent of BAS is 40×10^{-4} and SAS is 50×10^{-4} , which
13 for all practical applications is negligible. The 75BAS/25SAS
14 specimen showed approximately 2 to 3 times higher loss tangent
15 in the whole temperature range.

16 The relative increase in dielectric constant with
17 temperature is smallest for BAS and largest for SAS ceramics
18 despite the fact that the room temperature value for SAS is
19 smallest. The results for the 75BAS/25SAS material fall
20 between the end members according to its relative composition
21 ratio.
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DIELECTRIC PROPERTIES OF CERAMICS IN THE SYSTEM



AT 35 GHz AS A FUNCTION OF TEMPERATURE

MATERIAL	TEMPERATURE (°C)	DIELECTRIC CONSTANT	THERMAL CHANGES OF %	DIELECTRIC	
				LOSS	$\tan \delta$
$BaO \cdot Al_2O_3 \cdot 2SiO_2$	RT	6.55	-	8×10^{-4}	
	500	6.73	2.8	-	
	800	6.84	4.4	-	
	1000	6.92	5.7	25×10^{-4}	
	1200	7.00	6.8	40×10^{-4}	
$95BaO \cdot Al_2O_3 \cdot 2SiO_2$ $5SrO \cdot Al_2O_3 \cdot 2SiO_2$	RT	7.04	-	17×10^{-4}	
	500	7.25	3.0	19×10^{-4}	
	800	7.37	4.7	29×10^{-4}	
	1000	7.46	5.9	42×10^{-4}	
	1200	7.54	7.1	60×10^{-4}	
$75BaO \cdot Al_2O_3 \cdot 2SiO_2$ $25SrO \cdot Al_2O_3 \cdot 2SiO_2$	RT	6.88	-	25×10^{-4}	
	500	7.11	3.3	-	
	800	7.24	5.2	-	
	1000	7.33	6.5	43×10^{-4}	
	1200	7.40	7.6	65×10^{-4}	
$SrO \cdot Al_2O_3 \cdot 2SiO_2$	RT	6.16	-	11×10^{-4}	
	500	6.44	4.6	-	
	800	6.58	6.8	-	
	1000	6.68	8.4	30×10^{-4}	
	1200	6.77	9.9	50×10^{-4}	

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2 Obviously numerous modifications and variations of the
3 present invention are possible in light of the above teachings.
4 It is therefore to be understood that
5 the invention may be practiced otherwise than
6 as specifically described herein.
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2 Navy Case No. 71,959

3
4 CERAMIC MATERIAL

5 ABSTRACT OF THE DISCLOSURE

6 A ceramic material which is (1) ceramics based on
7 monoclinic $\text{BaO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$; (2) ceramics based on monoclinic
8 $\text{SrO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$; or (3) ceramics based on monoclinic solid
9 solution of $\text{BaO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ and $\text{SrO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$.
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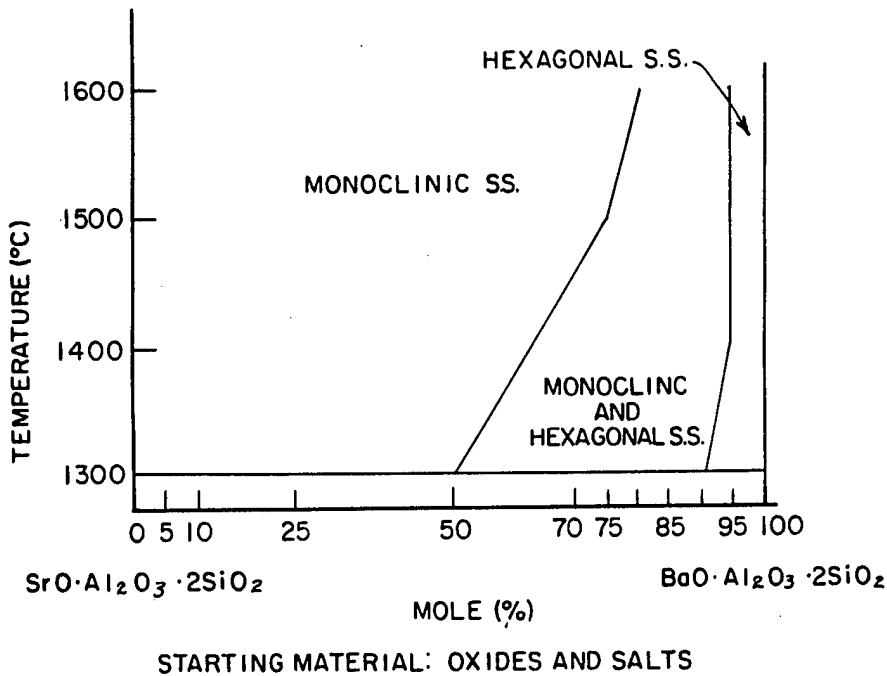


FIG. 1

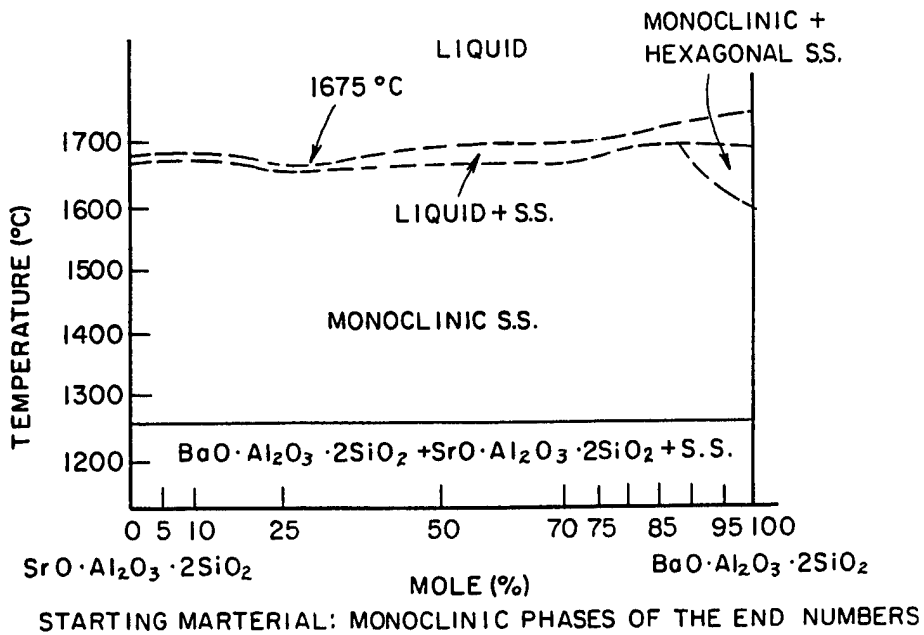


FIG. 2

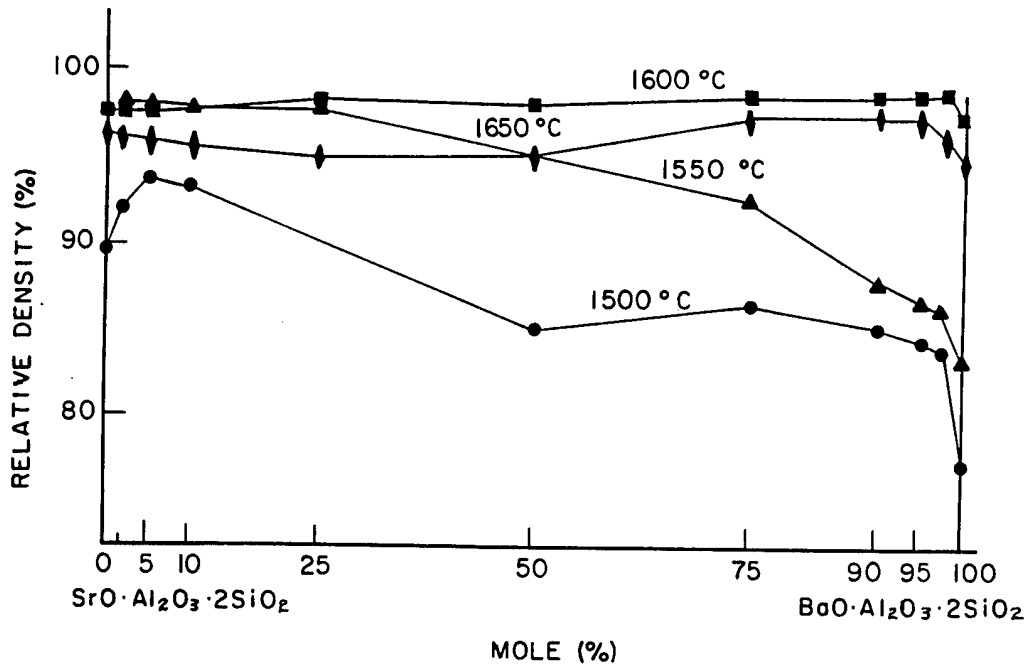


FIG. 3

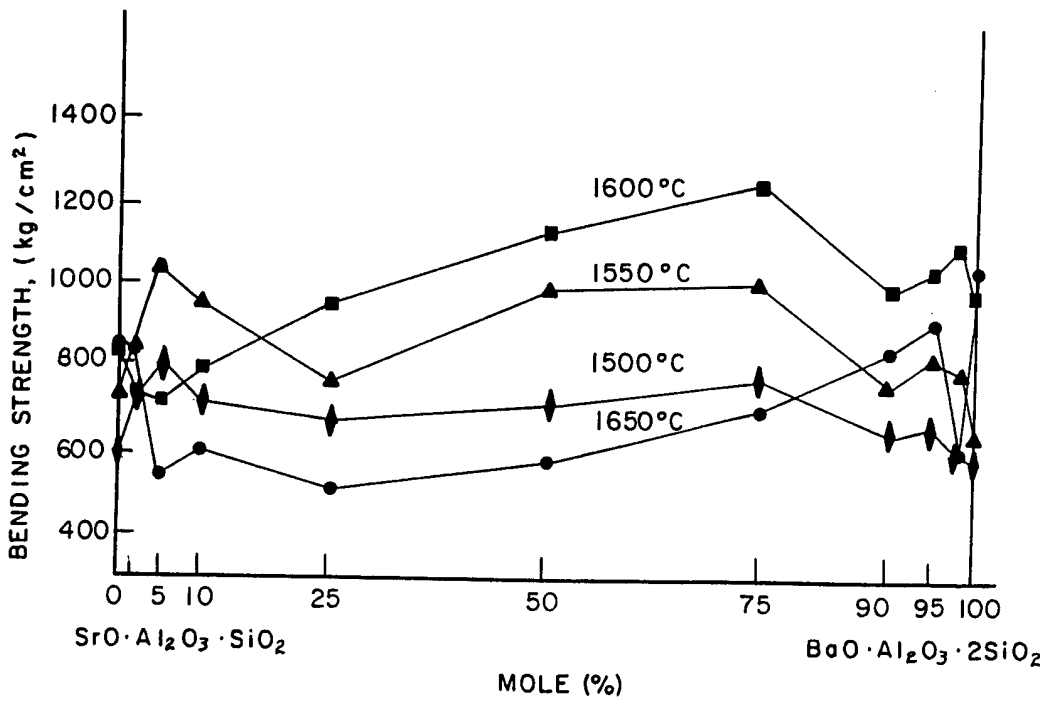


FIG. 4

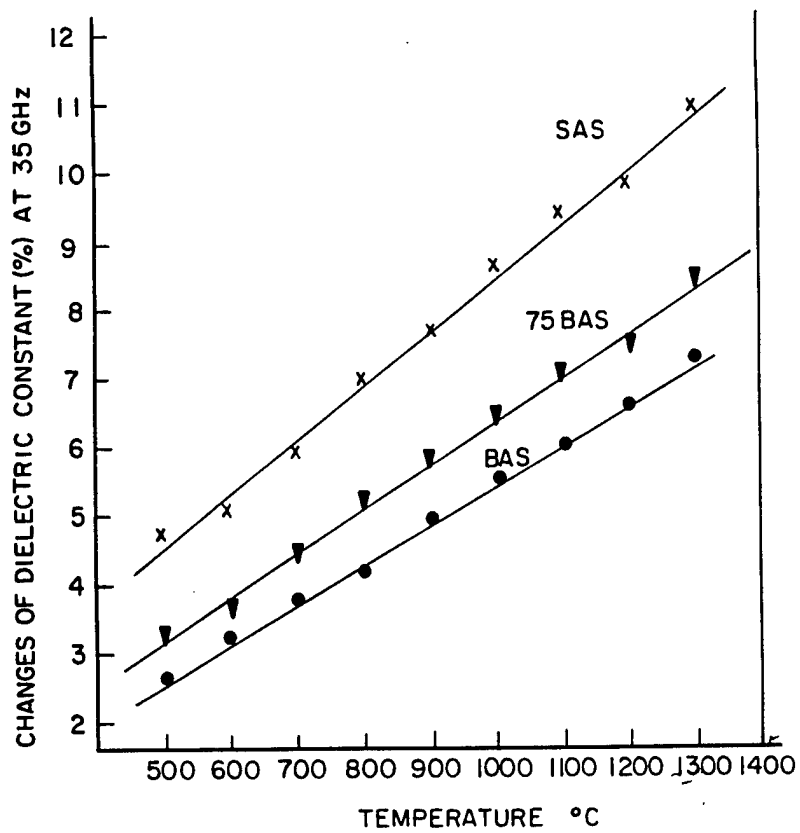


FIG. 5