PRAKĀŚA STAMBHANĀBHIDA LAUHA OF MAHARṢI BHARADVĀJA

(A novel IR transparent material of range 5000 to 1400 cm⁻¹)

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This paper deals with the description and preparation of *'Prakāśa Stambhanābhida Lauha'*—a novel non-hygroscopic *i.r.* transparent material having a range from 5000 to $1400 cm^{-1}$ (or 2 to 7 μ)—as described in *Aṃśu Bodhinī* of Maharshi Bharadvaja with a commentary by Bodhananda. The composition of constituent raw materials were mixed together in the ratio as described in the text and melted at a temperature of 265 *kakṣya* on an ancient temperature scale (about 940°) and then rapidly poured into a dye to produce a new material which is a non-hygroscopic non-opalent greenish yellow calcium glass. It will be important to note that it is novel in the sense that most of the known infra red transparent materials used for prisms and windows for cells are highly hygroscopic in nature such as LiF (upto 6μ) CaF_2 (2 to 8.5μ), NaCl (upto 15μ) etc. and they need dry air environment for their working:

Key Words : Novel infra-red transparent material, *Prakāśa Stambhanābhida Lauha.*

INTRODUCTION

Dhvānta Pramāpaka Yantra of *Maharṣi Bhardvaja* (Spectrometer/ monochromator)[1] includes a description of some materials along with *Prakāśa Stambhanābhida Lauha* in short. A project was taken up to study these materials. As a part of this project, this material was prepared in our laboratory and characterised it.

This material has been originally described in *Aṃśu Bodhinī* on page 76 [2] which is as follows:

(a) स्तम्भनामुखलोहेषु पश्चात्द्वादशकस्य च ।

क्रमात्तवचरारव्य लोडहस्याष्ट भागांशकं तथा ।

भूचक्रसुरमित्रादिक्षारपंचकमेवच ।

अयस्कान्तस्य चत्वारि षड्भागोरुरुकस्य च ।

एतान्संमैवय विधिवत् तत्तद्भागानुसारतः ।

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(b) पश्चाद्भ्रामणिकमूषामुखमध्ये प्रपूर्य च ।
पंचषष्ट्युत्तरद्विशतकक्ष्योष्ण प्रमाणतः ।

(c) गालयित्वाऽतिवेगेन यंत्रास्ये संपूरयेत् ।
एतद्भवेत्कृतकलोहः प्रकाशस्तम्भनाभिदः ।

Prose form :

(a) पश्चात् स्तम्भनाभिद लोहेषु खचराख्यलोहस्य अष्टभागांशकं तथा भूचक्रसुरमित्रादिक्षार
पंचकम्, अयस्कान्तस्यचत्वारि च रुरुकस्यषड्भागः एतान् तत् भागानुसारतः
विधिवत् संमेल्य

(b) पश्चात् भ्रामणिकमूषामुखमध्ये प्रपूर्य पंचषष्ट्युत्तरद्विशतकक्ष्योष्ण प्रमाणतः गालयित्वा

(c) यंत्रास्ये अतिवेगेन प्रपूरयेत् तदा प्रकाशस्तंभनाभिदः एतत्कृतकलोहः भवेत् ।

Note: For the English version of the above quotation to be meaningful, we first consider the four constituent materials cited above *viz.*, (1) *khacara* (2) *bhūcakra - suramitrādi kṣāra*, (3) *ayaskānta* and (4) *ruruka* and try to identify the corresponding materials known to the modern scientific world.

(a-1) The first amongst them *khacara* (a traveller in space) may be considered as the most prominent star - sun - for our planet earth. Here we are concerned with the representative material of sun which is in according to Indian mythology is *sphaṭika* (quartz or silica - SiO_2)

(a-2) The next material is *bhūcakra* or *suramitrādi*. The first term *bhūcakra* indicates a material composed of earth having a spiral over the surface. The other synonym *suramitra* (a friend of Hindu dieties) which may be considered as *Viṣṇu* and the corresponding representative material *śāligrāma*. In fact *śāligrama* [3] is a fossil from Spiti shale of Jurassic age, belonging to Phylum Cephalopoda (Amnonoidea), with the chemical composition as calcium carbonate ($CaCO_3$). The text suggests the use of the *kṣāra* of this material. The calcination product of this material, therefore, is lime or calcium oxide (CaO).

(a-3) The third material is *ayaskānta*, means a material which attracts iron, obviously the material is the ore magnetite ((lodestone) or magnetic oxide having the chemical composition Fe_3O_4.

(a-4) The last material is *ruruka*. *Ruru* stands for young deer and therefore, *ruruka* means the material obtainable from young deer. It could represent the bone-ash from the bones of a young deer. Bone-ash is one of the chief constituents in glass making. Bone-ash is mainly tricalcium phosphate ($Ca_3P_2O_8$). In the ancient period there were plenty of deers in Indian forests and their description is very common in Indian mythological texts.

With the above interpretation, the prose form of the *śloka* under discussion can be expressed in the following form in English Version:

(a) "Then 8 parts of *khacara lauha* (silica - SiO_2), the twelfth in the serial number in the group of radiation absorbing materials, 5 parts of *bhūcakra-suramitrādi*

kṣāra (lime - CaO), 4 parts of ayaskānta (magnetic oxide - Fe_3O_4) and six parts of ruruka (bone-ash - $Ca_3P_2O_8$) are mixed in the proportion as given above.

(b) These are then melted together in bhrāmaṇika mūṣā (rotating crucible) at the temperature 265 kakṣya of the ancient temperature scale (about 940°, see discussion below), and then

(c) it is rapidly poured into the yantrāsye (dye), and

(d) in this way prakāśa stambhanābhida lauha (light absorbing/heat transmitting material) is prepared".

DISCUSSION

2(a) This part gives us the bhāga—the proportion in which the materials are to be mixed together. As the first step to commence the discussion, the term bhāga must be by weight, then only 8, 5, 4 and 6 parts (bhāgas) respectively may become meaningful.

In "Metrology and Coinage in Ancient India and Contemporary World" [4], one of the authors of this paper has described Āyamānī Lauha Śāṇa (A.L. Śāṇa) of 48 māṣa, a weight unit equivalent to muṣṭi unit of Caraka Saṃhitā and also identified it with weight 'H' belonging to the first series of the weights discovered at Indus Valley by John Marshall. The weight of this muṣṭi is given as 54.24 gms.

It is the general practice that when one has to prepare or manufacture a certain base material by mixing various constituent raw materials in certain given proportions, the manufacturer's unit of the weight should be a little more, so that after finish, the product is of the standard weight to cover the manufacturing losses of the constituent materials. If one tenth loss of the material be the expectation, then the manufacturer's weight unit (say, manufacturer's 'muṣṭi') will be such that its 9/10 must be the standard weight of one muṣṭi. This means the manufacturer's weight unit approximately will become 60.267 gms as—

$$(60.267 \times 9)/10 = 54.24 \text{ gms.}$$

which is the weight of standard 'muṣṭi' unit as given above. Thus here we may take a bhāga/bhagāṃśa as one manufacturer's muṣṭi equivalent to a weight of 60.267 gms or approximately 60.3 gms and hence 8, 5, 4 and 6 bhāgāṃśa (parts) may be attributed with proper approximate weights as shown in table 1.

In the following table 1, column (1) gives the constituent material with its identified chemical composition, column (2) the proportion, column (3) corresponding weight, column (4) the molecular weight of the constituent molecule, column (5) estimated number of the molecules with rounded integer and the last column (6) the constituent molecule with its probable number present in the final product with its relative percentage forming prakāśa-stambhanābhida lauha, which leads for the empirical formula for this product.

Table 1: An interpretation of the composition of
prakāśa-stambhanābhida lauha.

Material with its identified chemical composition with the percentage of occurence in the ore.	The proportion as in the text	Corresponding weight = 60.3 X proportion in gms	Molecular weight	Estimated number of molecules with rounded integer	Number of molecules with relative percentage
1. *Khacara lauha* (Silica SiO_2 100%)	8	482.4	60.3	8 ~ 8	8($SiO2$) 37%
2. *Bhucakrasura-mitrādikṣāra* (Lime CaO 93%)	5	301.5	56.1	5.37 ~ 5	5(CaO) 21.5%
3. *Ayaskānta* (Lodestone Fe_3O_4 96%)	4	241.2	231.4	1.04 ~ 1	Fe_3O_4 17.7%
4. *Ruruka* (Deer bone ash $Ca_3P_2O_8$ 86%)	6	361.8	310.3	1.17 ~ 1	$Ca_3P_2O_8$ 23.8%

From Table 1, it is evident that the empirical formula of the final product may be given as $5 (CaO.SiO_2) (Fe_3O_4) (Ca_3P_2O_8)$.

This emperical formula suggests that this fused material is a lime glass containing dissolved colouring agents as ferreso - ferric silicates and forming a clear emulsion with tricalcium phosphate. Thus we may also say that this batch of glass known as *prakāśa stambhanābhida lauha* has silica, lime, lodestone and phosphate, where their percentages are 37, 21.5, 17.7 and 23.8 respectively.

(b) This part of the text needs attention on the following three points: (i) the use of a rotating crucible along with the choice of the particular constituent materials, (ii) the use of lodestone as colouring agent in place of the other iron oxide ores, and (iii) what should be the approximate value of ancient unit of temperature *kakṣya* in terms of Celsius scale of temperature? Let us discuss them in the above said order.

(i) The action of the rotating crucible appears to be equivalent to stirring the mass during melting and in refining processes without plunging a stirrer from outside into the mass [5]. Here it is important to note that in this era, for the first time in the United States of America, a rapid method has been introduced by J.W. Morey (1919), whereby the stirring is performed during melting and refining process and commenced as soon as the glass is present in sufficient amount to fill half the pot. It is claimed that by so doing melting is expedited and pot attack is diminished.

Further it is well known that the action of lime with silica commences at about 800°c [6], though the phase diagram shows the eutectic point at 1436°c, between silica and meta calcium silicate (CaO, SiO_2)[7], where the mixture has the composition 63% SiO_2, and 37% CaO. In fact this batch has the same composition in so for as silica and lime are concerned. Lime thus aids in lowering the melting point.

(ii) The choice of lodestone as a source of ferreso - ferric oxide inspite of any other iron oxide source, which might have been known to ancient workers, is to have colouring effect shared by both the forms of iron silicates, *viz.*, the ferrous and ferric silicates. It is well known that the colour due to iron depends upon whether the metal is in the ferrous or ferric condition (silicate).[8]

Dralle[9] gives the colour of ferrous silicate as bluish green. The range of the colours varying from this, through green and greenish yellow to yellow as the proportion of ferric to ferrous salt increases. With small qantities of iron, the ferrous silicate colour is the more prominant, but the ferric salt gives the more pronounced effect, when the iron content is large.

Thus we find that the ancients might have been aware of the above effect, and have chosen lodestone as one of the in-put substances for this batch to have simultaneous effects of both the iron salts. Further in order not to change the ferreso-ferric oxide into ferric oxide in the presence of oxygen, the temperature of the molten mass should not exceed 1300°[10].

(iii) In fact for melting this mixture has to be raised to a temperature 265 *kakṣya* on the scale of temperature of the ancients and also that the temperature should not exceed 1300° in order to retain the ferreso-ferric character of the iron salt. Hence, one *kakṣya* must be less than 4.9°. Further, in order to initiate the chemical activities of lime and silica, the initial temperature must be more than 800° i.e., one *kakṣya* must be greater than 3°. Therefore, the *kakṣya* may be mathematically expressed as

$$3°c < \text{one } kakṣya < 4.9°c$$

According to Vedic Numerical Code[11], *kakṣya* (ka - kṣa - ya) stands for a number 101 i.e., *kakṣya* is 101th part of the some standard temperature difference forming a scale of temperature. Let us assume this is the boiling point of mercury, which is 357° and that leads to one *kakṣya* as 3.54°.

Again it is interesting to note that I *liṅka* = 21.24°c, as 50 *liṅka* is the melting point of gold (1062°c)[12]. Correlating these two we find that 1 *liṅka* is just six times the temperature unit *kakṣya* at 3.54°. Therefore, we may say that

1 *kakṣya* = 3.54°c   101 *kakṣya* = boiling point of Hg = 357°c

6 *kakṣya* = 21.24° = 1 *liṅka*   50 *liṅka* = melting point of Au = 1062°

and therefore the temperature of this batch of glass has to be raised to a temperature of 265 *kakṣya*, i.e., 265 X 3.54 = 940°c (approx.), for fusion of this mixture.

(c) In this process of glass making, rapid pouring of molten mass into a dye is of great importance. This does not allow the molten tricalcium phosphate to separate and to form fine globules suspended in the bulk glass and thus it avoids the opalescence that would have appeared. In the modern era, the addition of phosphate salt is only limited to opal glasses. In this connection the following quotation from the book of Glass Technology[13] is most relevent.

> "In fact the first opal glasses produced were 'bone glasses' in which bone ash was used for producing the effect. .... The cause of the opacity of phosphate glass is that at low temperatures two liquid phases (in this case one being the solution of ferreso-ferric silicates into the metacalcium and the other being the molten tricalcium phosphate) of different composition separate. The smaller one taking the form of fine globules of calcium phosphate is suspended in the main bulk of the molten glass. With increase in temperature, the two phases become miscible and a clear liquid results. Hence, if phosphate glass is heated strongly and rapidly chilled, no opalescence is obtained but if the clear liquid is allowed to stand for some time at a lower temperature (i.e., not very far above the melting point) the two phases again separate and the milkiness reappears".

(d) In this part of the text, the end product is called as '*prakāśa stambhanābhida lauha*' (visible light absorbing material). In the light of the above discussions it appears that this material is a solution of ferresoferric silicate in metacalcium silicate and uniformally mixed with tricalcium phosphate in their liquid phases to produce a clear liquid and then chilled to a solid mass. According to the Sanskrit text this material should be able to absorb visible light and will transmit the infrared radiation through it.

LABORATORY PREPARATION OF STAMBHANĀBHIDA LAUHA

After fixing the composition of the glass as the above, it was decided to prepare the same by substituting deer bone ash with ortho-phosphoric acid. Silica glass was used as the source for SiO_2. It was ground and 150 mesh powder was employed. AR grade calcium carbonate was used for generating calcia. High purity magnetite (>99.9%) produced from $FeO(OH)$ at the National Metallurgical Laboratory was employed. Each batch was of 100 gms. All ingredients in the desired proportions were thoroughly mixed. As a result of several experiments, it was found that only recrystallised alumina crucible can withstand attack by the mixture at elevated temperatures. The mixture was charged into the alumina crucible which, in turn, was provided with a graphite susceptor for induction heating. Rate of heating was very slow upto 300°c followed by intermediate rate of heating upto 1600°c, basically to achieve a greater homogeneity of the melt and the formation of ferric oxide could be stopped by instantaneously quenching the melt for high temperature as its formation kinetically requires some time. At this temperature

the ingredients formed a clear liquid. The liquid was then chill cast into a copper mould to yield the final glassy mass.

Samples in the form of thin slices were cut from the main block for the purpose of carrying out the optical transmission studies.

TEST FOR TRANSMITTANCE

The spectrophotometer of Nicolet Instrument Corporation, using KBr as the material for prism and windows having transmission range upto 25μ, was used to record the transmittance of this material (*Prakāśastambhanābhida Lauha*).

The non-hygroscopicity of the material was confirmed in the process of carrying out its optical transmission test. As mentioned, thin slices were cut and these were exposed in open atmosphere for a long time. The transluscent nature of the slices was still preserved.

Fig. 1 shows this spectrum. It is obvious that this material shows a transmittance of nearly 0.5% at and above 5000cm^{-1} (2μ) and steadily rises to 9.72% at about 2200cm^{-1} (4.55 μ) and then falls to zero nearly upto 1400cm^{-1} (7μ).
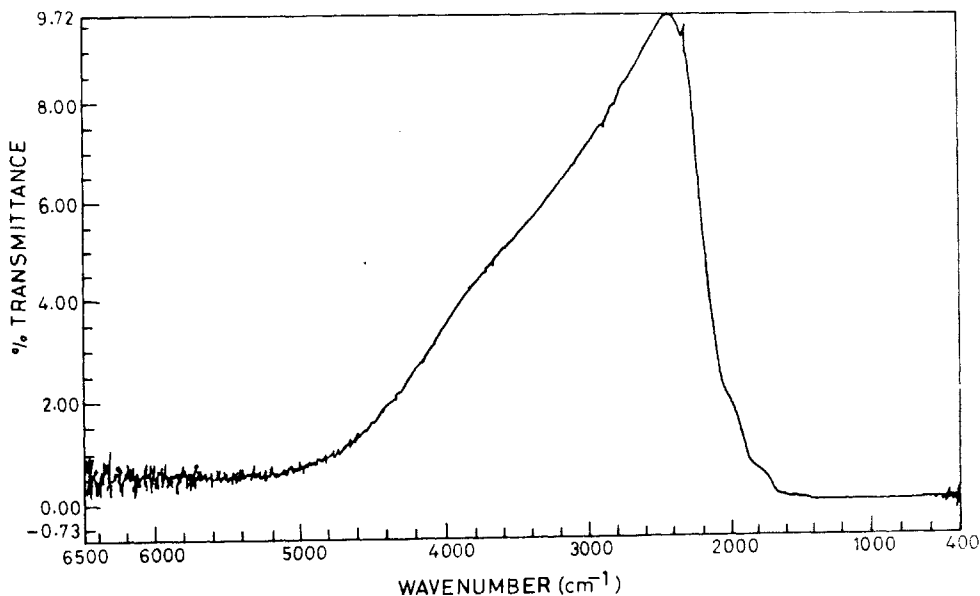
INFERENCE

This material may be well compared with a transmittance of CaF_2 with a range of 5000 to 1175cm^{-1} (2 to 8.5μ) with the salient difference that this material is perfectly non-hygroscopic, while CaF_2 is highly hygroscopic. For studies of infra-red spectra or signals this material may prove ideal in the range of 5000cm^{-1} to 2000cm^{-1} (2 to 5μ) and may be used as window and prism material without the danger of the presence of water vapour into the atmosphere.

ACKNOWLEDGEMENT

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