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# COMMUNICATION AND DISSEMINATION OF TRADITIONAL KNOWLEDGE

## A Scientific Outlook

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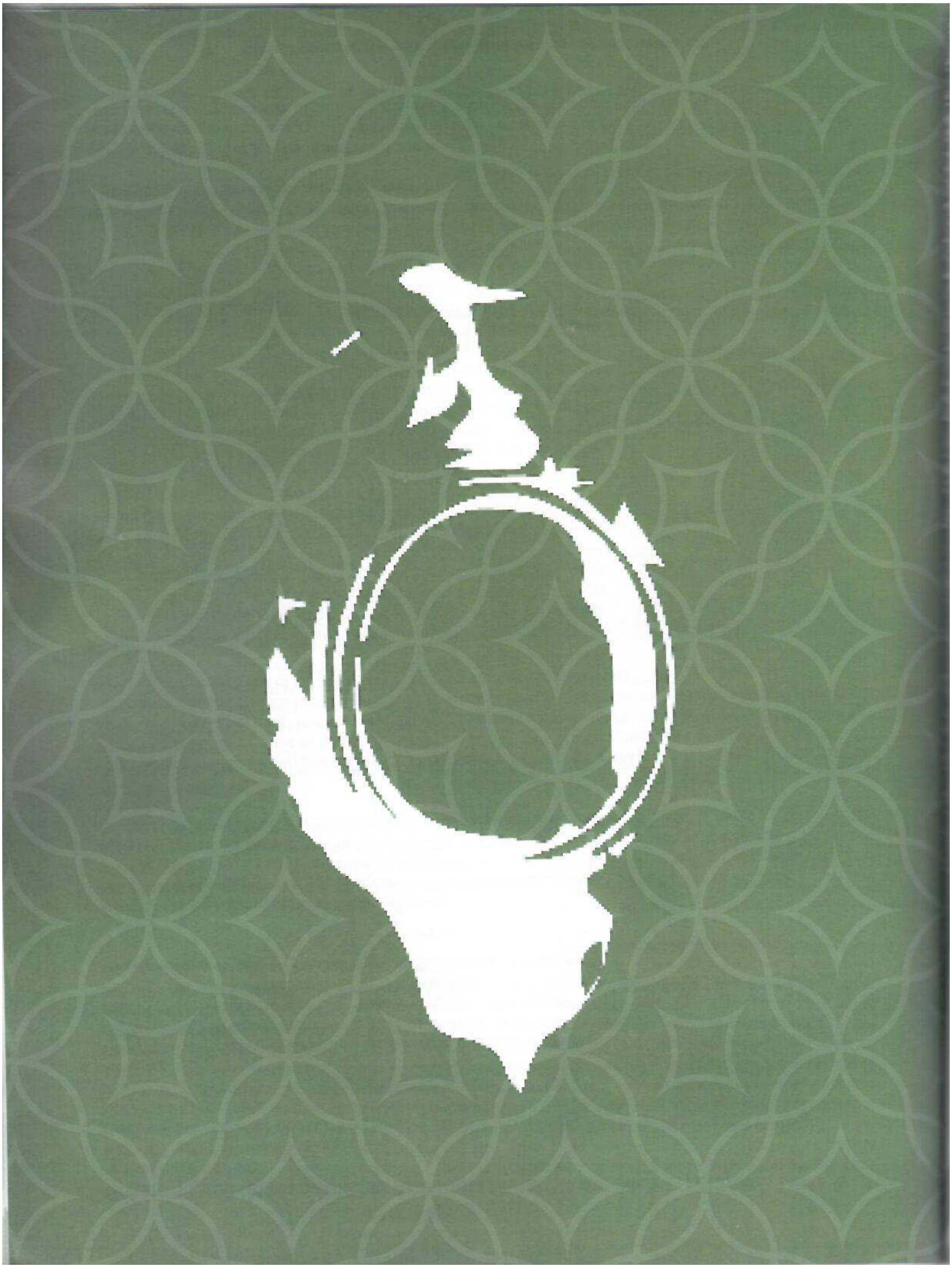

# Scientific Validation of Skilled Aranmula Metal Mirror Craft Tradition

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**Summary**

*This paper discusses methodologies for scientific validation of traditional knowledge from a case study of the traditional craft of metal mirror making from Aranmula in Kerala in southern India, which was found to be made of a sophisticated process with a rare reflective high-tin delta bronze alloy. The usefulness and application of archaeometallurgical investigations, ethnoarchaeological and technical studies on foundry practices, and manufacturing processes for establishing scientific validation is discussed.*

### A case for technical studies for scientific validation

The Indian subcontinent has a rich legacy of traditional knowledge systems and craft survivals including in the realm of metallurgical practices. The exploration of traditional knowledge for validation of scientifically sound aspects is important not only in terms of the history of science and technology but also for recognising their intrinsic value in terms of modern science and technological perspectives and for according a place in terms of contemporary relevance.

Whereas metal mirror-making practices seem to have died out elsewhere in the world, a remarkable crafts survival, which was zealously guarded by hereditary families, is still prevalent in Aranmula Kerala in southern India. What is remarkable is that the metal mirror, solely produced by traditional techniques, has one of the highest qualities of reflectance that could be achieved (Fig 1). This is accomplished by optimising the presence of a specular high-tin bronze alloy matching that of the intermetallic delta bronze compound of around 32% tin.

The methodologies and use of archaeometallurgical investigations in the validation of traditional knowledge are traced through a study of surviving mirror-making foundries. Such endeavours can also be important in terms of awarding patents and indeed the Aranmula mirror has also been awarded a Geographical Indicator Patent in 2004-2005. This gives intellectual property rights that identify the Aranmula metal mirror as having distinctive properties and vintage associated with its geographical location; thereby helping to protect it as a local product.

Fig 1 *Valkannadi* metal mirror from Aranmula

The investigations undertaken were two fold. On the one hand, the composition of the metal alloy was characterised using metallographic examination and compositional analysis using Scanning Electron Microscopy, and Electron Probe Microanalysis, and other techniques. On the other hand, the study of the pryotechnological processes and foundry methods used was undertaken from investigations on refractory moulds and casting crucibles and so on, as well as the novel thermal camera investigations to document the foundry processes and casting methodologies. Attempts were also made to trace the trajectory of mirror-making in Indian antiquity which helped to underscore its distinctive nature as indigenous knowledge. The usefulness of published scientific research, such as those made by the author in the Encyclopedia of Non-Western Science (Springer) (Srinivasan 2008), Journal of Historical Metallurgy (Srinivasan and Glover 1995), and Materials Research Society Proceedings (Srinivasan and Glover 1997) in validating traditional knowledge of metal mirror making at Aranmula is also noteworthy.

### Cultural significance of Aranmula and metal mirror

Aranmula is an important cultural centre and temple town on the banks of the Pampa River in Kerala. The name Aranmula refers to six pieces of bamboo. It is well known for the Aranmula Parthasarathy temple which is one of 108 *'Divya Desams'* or temples of Vishnu said to have been venerated by the medieval Alwar poet saints of the Tamil Bhakti canon. The wooden tiered-roof Kerala-style temple overlooking the Pampa River is dedicated to Lord Krishna as Parthasarathy or Arjuna's charioteer in the epic the Mahabharata. The Aranmula *Valkannadi* (*kannadi*: mirror in Malayam and Tamil; *val*: tail in Malayalam and Tamil) refers to the specific kind of mirror with a tang made at Aranmula for holding in the hand. As told by the late Janardhan Achary to the author, master craftsman from a hereditary family of mirror makers, the craftspeople are said to have migrated from Sankarankoil in Tamil Nadu in Tirunelveli district (Srinivasan and Glover 1995). The traditional weddings of the matrilineal Nair community of Kerala included the *ashtamangalyam* comprising eight auspicious articles as part of the wedding trousseau the brides, which included the *Valkannadi* mirror (*valkannadi* in Tamil and Malayalam). The maiden or *darpanika* admiring herself in a mirror is a popular theme in medieval sculpture from across the country ranging from Khajuraho in Madhya Pradesh to Hoysala sculpture in Karnataka. A 9th century Chola Ardhanarishwara deity of the conjoined male and female principles of Siva and Parvati from Aditurai in Tanjavur shows Parvati prominently holding a mirror. Thus, the mirror had significance not just for adornment but also for worship.

**Technical investigations on Aranmula metal mirror making**

The author has been undertaking archaeometallurgical research on the Aranmula mirror since 1990 with samples collected from the workshops of late Gopalakrishna Achary, late Janardhan Achary, and Gopukumar Achary (Srinivasan and Glover 1995, Srinivasan and Glover 2007, Srinivasan 2008). Such sustained studies across multiple foundries have been useful in understanding the standardisation of practices and reproducibility with respect to scientific validation.

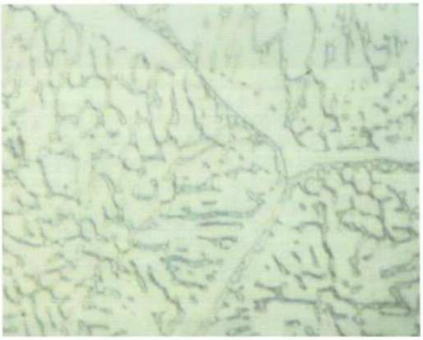

Fig. 2 Microstructure of metal mirror from Aranmula, showing a typical structure of binary unleaded delta high-tin bronze (32-33% tin bronze) with a whitish matrix of delta compound phase, which gives the reflective properties and some minor amounts of bluish alpha plus delta eutectoid phase.

These studies indicated that the mirrors were uniquely made by skillfully optimising the presence of a highly reflective specular composition of bronze of around 32-33% (Fig. 2), as confirmed through both Scanning electron microscopy and EPMA analysis which yields a hard, silvery and reflective alloy which can be highly polished to get the best mirror effect. The copper-tin phase diagram indicates that between a narrow composition range of about 32-33% tin alloyed to copper, the delta phase intermetallic phase of 32.6% tin ($Cu_{31}Sn_8$) is predominantly formed in the matrix. Apart from the silvery colour which would yield good reflectance, the delta bronze alloy is very hard, even harder than steel as found by the author (Vickers hardness of 500 VPN as against steel of 400 VPN), and hence it can take a high polish without distortion giving the best possible mirror image. Due to the close match with the composition of the delta phase, these mirrors have been described as made of delta bronze by the author (Srinivasan 2007, 2008).


Fig 3. Section of crucible-cum-mould showing very thin space within 2 piece mould within which the delta bronze alloy would be cast to get a thinner casting to reduce heterogeneities

Using low-cost methods and organic materials, an innovative closed-crucible-cum mould casting process was used to cast the blank which was then skillfully polished to get the reflective mirror (Fig. 3). Its reflective properties can be compared very favourably with those of the glass mirrors that are manufactured in modern day factories with mercury coating or earlier, silvered mirrors.

However, alloying of tin in such high proportions to bronze greatly embrittles it and it seems for that reason that Chinese and Roman mirrors of the early Common Era resorted to alloying some lead to cast bronze mirrors with no more than 25% tin.

However, lead is an opaque material and would have diminished the reflectance. In that sense, the Aranmula mirror-making tradition both successfully achieved the optimal delta bronze composition for the mirror and also found a way to minimise brittleness by casting a very thin mirror blank with minimum flaws. A blank of barely a couple of millimeters thick, which could cool rapidly with finer grain structure and thereby less brittle, was cast in a specially devised jug-shaped closed-crucible-cum mould. The closed crucible would avoid open casting and thereby reduce surface impurities due to oxidation reactions of the molten metal. The bottom contained a two-piece disc mould held apart a bare 2 millimetres by spacers of the same alloy into which the metal would be cast, with a fine slip applied on the moulds to get the best-cast surface for the blank. The top of the crucible-cum-mould consisted of a channel leading from the mould to a hollow cup in the top of a jug into which the metal to be cast was placed. Then, the jug was heated in a hearth with the neck down (Fig. 4) and then tipped over so that molten metal could flow into the mould and then solidly into the blank which was retrieved after cooling and breaking open the mould.

Fig. 4 Hearth for heating alloy in inverted crucible-cum-mould

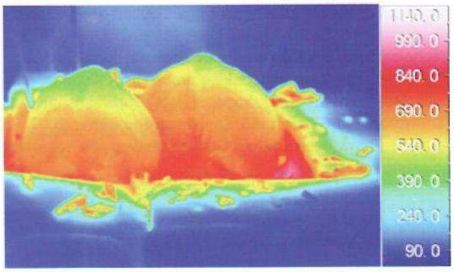


Fig. 5 Thermal camera measurements of hearth

Thermal camera investigations (Fig. 5) proved useful in understanding the cooling process and showed a significant differential in temperature in the crucible-cum-mould with the molten alloy at about 900 degrees centigrade and the mould for the blank at about 500 degrees centigrade. This factor combined with the slimness of the blank would have resulted in more rapid cooling to give a homogenous blank with reduced brittleness. The polishing process was also important in getting a flawless mirror process whereby the oval blank was lapped for several days on a wooden board, after setting it into a wooden mount in resin (Fig. 6, 7). As told to the author by late Janardhan Achary, a secret ingredient in getting a good polish was to use the ground brittle alloy in the polishing powders. This also makes scientific sense as it would lead to filling in of the minor defects with the same alloy to get the best possible reflective surface.

Fig. 6 Cast thin blank of silvery delta bronze mounted on Wooden board for polishing

Fig. 7 Polishing and lapping of mirror blank

**Artisanal metal technologies: Historical trajectory and survival**

Respectability for traditional technologies and practioners are an important part of the overall development paradigm as argued by late developmental scientist C.V. Seshadri. He pointed out that the historical nexus between industry and science had led to practitioners of non-western technologies losing out whereby the thermodynamic definition of efficiency became the criterion for development and processes such as artisanal handicrafts became discounted as being inefficient. Scientific validation is thus an important means of adding value to handicrafts.

The mirror-making tradition is not an isolated example of skilled metallurgy in India and southern India. The earliest known evidence in the world for the smelting of metallic zinc comes from 12th century retorts from Zawar in Rajasthan. The southern Indian region was famed for the legendary wootz steel, a European corruption of the word '*ukku*' in southern Indian languages, which was traded to West Asia to make patterned Damascus swords. *Ukku* was a high-carbon steel of 1.5% carbon made by crucible processes as seen at from sites in southern India such as *Kodumanal*, *Mel-siruvalur*, and *Konasamudram* (Srinivasan 2007). Metal icon making and bronze and bell metal making flourished in the Thanjavur heartland going back to Chola times. There has been a vibrant tradition of making highly skilled wrought and quenched vessels of high-tin beta bronze (23% tin) especially by the Kammalar community in places like Kerala which goes back to Iron Age finds such as from *Adichanallur* (as shown by the author's studies in Srinivasan and Glover 1998, Srinivasan 2017).

While the earliest bronze mirrors are known from Egyptian times, some bronze objects are also identified as mirrors from Harappan sites such as Quetta in Baluchistan and Dholavira in Gujarat, c 2000-1900 BCE, although these all these early mirrors would have been of low-tin bronze. At the same time, one could get a speculative idea of how the flatter, thin, and oval blanks of Harappan mirror forms could have been cast using a similar mould assemblage as in the Aranmula mirror process. Intriguingly, a bronze mirror uncovered from the cairns of the Nilgiri Hills, in Tamil Nadu and analysed by Breeks (1873) was found to have 30% tin, not totally dissimilar to the Aranmula metal mirror composition. The author has also previously pointed out that the style of the depiction of the mirror in certain sculptures such as the 12th century *Hoysalamadanika* from Belur, remarkably resembles the wooden polishing mount with a back handle, as another form of the mirror (Fig. 8). Thus, from the above archaeometallurgical explanations and from scientific investigations and validation, it can be conjectured that the Aranmula metal mirror represents a distinctive and skilled innovation in terms of traditional knowledge from the Indian subcontinent.

Fig. 8 12th century Hoysala Madanika stone sculpture from Belur shown holding a mirror.

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