npj Heritage Science

https://doi.org/10.1038/s40494-026-02757-4

Article in Press

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Received: 5 February 2026

Accepted: 16 June 2026

Published online: 30 June 2026

Cite this article as: Tian, Z., Ren, K., Jiang, Z. Restoration of Ming dynasty Jin zhe si: a lost Chinese goldsmithing technique. *npj Herit. Sci.* (2026). https://doi.org/10.1038/s40494-026-02757-4

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Restoration of Ming Dynasty Jin zhe si: A Lost Chinese Goldsmithing Technique

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Abstract:

Hubei Province was a significant center for Ming Dynasty vassal princes, whose tombs have yielded exceptional gold jewelry. A distinctive but lost technique, "Jin zhe si," characterized by ultra-thin folded and corrugated gold sheets (foils) with a unique satin texture, remains poorly understood. This study investigates gold gourd earrings from the tomb of Prince Zhu Zairong (d. 1545) through micro-analysis and experimental archaeology. By combining historical records with reverse engineering, we analyzed the manufacturing process and the crucial role of material properties. Comparative experiments using gold, silver, and aluminum foils demonstrated that the superior ductility of high-purity gold is essential for achieving the complex hyperbolic folding without fracture. The successful replication of these artifacts bridges the gap between ancient textual descriptions and material evidence. This interdisciplinary approach provides new insights into Ming Dynasty metalwork and contributes to the preservation of traditional goldsmithing craftsmanship.

Introduction

Hubei Province, as a significant political hub for vassal princes, has provided a wealth of archaeological evidence regarding the luxurious material culture of the nobility**Error! Reference source not found.**,[1] . The history of the Ming dynasty outlines the archaeological evidence for cities, tombs and crafts related to the achievements of the period[2]. Tianshui bingshan lu

(Figure. 1) (Iceberg Records) is a 16th- century catalogue of Ming officials' jewellery collections, recording 3,938 pieces of jewellery, including 66 items beginning with "woven with gold thread."(It is important to note that while the literal translation of the Chinese records implies the use of “thread” or “wire”, our study proves that these specific artefacts were actually made from corrugating sheets of metal foil, creating a visual illusion of wirework). These items include earrings, pendants, and jewellery sets, such as "Chrysanthemum Earrings Woven with Gold Thread," "Lantern Earrings Woven with Gold Thread," and "Pavilion Earrings Woven with Gold Thread[3,4]. One of the earrings is a "gourd earring woven with gold thread," which is confirmed by the surviving artefacts. To date, all known examples of this corrugated metal jewellery from Ming tombs are in the form of gourd earrings, the vast majority of which are in the form of gourd earrings, with one in the form of a lantern. Fourteen such pairs or single pieces have been recorded, from various locations: for example, one from the Jing Prince tomb at Yaowan, Hubei; one pair from the Qichun Duchang Prince (Zhu ZaiRong) tomb in Hubei (now in the Qichun Museum); a pair from the 1465–1487 tomb of General Dai in Nanchang, Jiangxi; a pair from Lady Wang's tomb (ca. 1465–1505) in the Wang family cemetery; others from Wuxi (Jiangsu), Enshi (Hubei), Jingmen (Hubei), Nantong (Jiangsu), Chongren (Jiangxi), and Lanzhou (Gansu). Furthermore, contemporary Ming portraits (e.g. in the National Museum of Denmark and the Wei County Museum in Hebei) depict noblewomen wearing such gold gourd earrings. These records indicate that jewellery made of gold sheets corrugated into ribbed hollow spheres was a popular fashion for high-status women in the mid-to-late Ming Dynasty.

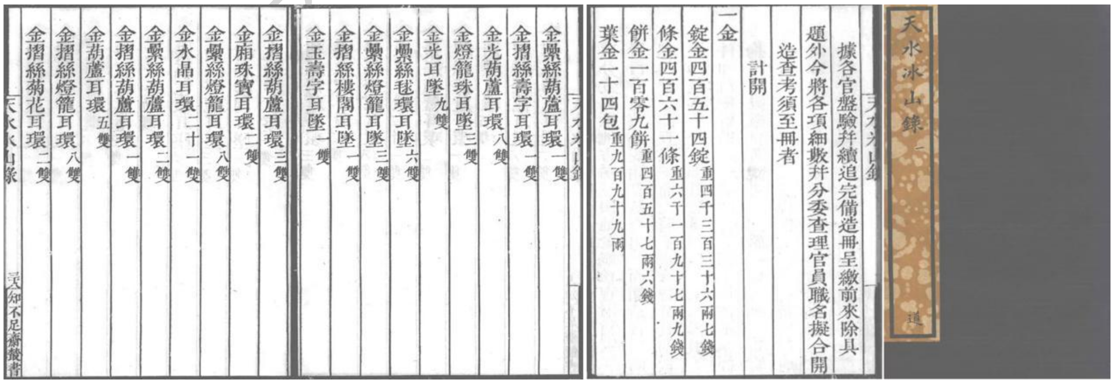

Fig. 1 | The historical source Tianshui Bingshan Lu recording Ming-dynasty jewellery.
Tianshui Bingshan Lu is a Qing-dynasty transcript of the property inventory of Yan Song, a powerful official of the Ming dynasty. The text records large numbers of jewellery objects, including items described as being “woven with gold thread,” which provide important documentary evidence for the historical terminology associated with Jin zhe si. In this study, these textual records are compared with surviving archaeological ornaments to clarify that the term refers to a corrugated gold-foil technique rather than true wirework.

Although popular in the 15th and 16th centuries, this corrugated metal (foil) technique was not passed on to later generations of craftsmen and eventually disappeared from jewellery making[5]. There are no known records of folded metal in Qing or modern craft records.To clarify the terminology used in this study: in the Chinese jewelry tradition, the term “Jin zhe si” literally translates to "gold folded wire." However, this terminology is somewhat of a historical misnomer. Unlike traditional “filigree,” which involves applying actual plain or twisted wire to a gold or silver substrate, the technique explored in this research does not involve true wire at all. Instead, it relies entirely on corrugating a flat, ultra-thin sheet of metal (foil). This unique method of forming hyperbolic hollow spheres by folding and corrugating thin metal foils creates a texture similar to silk, providing the visual illusion of filigree wirework. Therefore, we use the term “Jin zhe si” to specifically refer to this historical technique of “corrugating sheet of metal,” distinguishing it from genuine burin or granulation , among other gold and silver craft techniques[6].Reconstructing this lost art is essential to enriching our understanding of historical gold and silver craftsmanship.It also has cultural significance: the revival of the corrugated metal technique(Jin zhe si Technique) contributes to the wider preservation of traditional craftsmanship and demonstrates the ingenuity of Ming craftsmen,it also provides room for innovation in modern design.

In this paper, we systematically study the method of recovering Jin zhe si Technique by taking the example of Ming Dynasty gold gourd earrings[7,8]. We combine archaeological scientific methods (e.g., detailed examination of artefacts under a microscope, material analysis) with practical craft experiments (trial production using traditional techniques) to deduce the production method of the original objects[9,10]. The craft experiments were followed by a discussion of the appropriate nomenclature of the technique in the classification of the art of goldsmithing and its placement in a historical context. By successfully restoring a Jin zhe si gourd earring that matches the original in form, texture, and weight, we demonstrate an effective way to revive this lost art. The results also shed light on the use of the term Jin zhe si Technique and its relationship to other Chinese fine goldsmithing techniques[11,12](Introduction combined with Figure. 2).

Fig. 2 | Unearthed Ming Dynasty golden gourd earrings crafted by the Jin zhe si technique

(a) Ming-dynasty golden gourd earring excavated from the tomb of Mrs. Wang Wenyuan, Sichuan Province, preserved in Sichuan Provincial Institute of Cultural Relics and Archaeology; gourd body height 5.1 cm, width 1.8 cm.

(b) Ming-dynasty golden gourd earring unearthed from Changmen, Wuxi, Jiangsu Province; gourd body height 4.8 cm, width 1.7 cm.

(c) Ming-dynasty golden gourd earring excavated from the tomb of Yao Wanjingfan, Yingshan County, Hubei Province; deformed sample, gourd body height 4.5 cm, width 3.0 cm.

(d) Ming-dynasty golden gourd earring excavated from the tomb of Wang Xuanming, Yingshan County, Hubei Province; gourd body height 4.6 cm, width 2.7 cm.

(e) Ming-dynasty golden gourd earring excavated from the tomb of Zhao Yong and Dai Xian, Nanchang, Jiangxi Province; deformed sample, gourd body height 4.0 cm, width 1.6 cm.

These archaeological findings prove that gold foil corrugated gourd earrings were widely popular among noble tombs in the Ming Dynasty.

Methods

Artifact Studied and Initial Analysis

The main reference artefacts for this study are a pair of gold 'Jin zhe si gourd' earrings from the tomb of Zhu Zairong (Prince Duchang, d. 1545) in Zhenhu village, Herbchun county, Hubei province. The tomb is one of a number of magnificent Ming dynasty royal tombs excavated in Hubei, and its contents have been reported in local museum catalogues. Each earring consists of a hollow double gourd-shaped pendant crafted in thin gold and topped with four gold leaves and vines suspended from a gold hook. The gourd pendants measure approximately 6.2 centimetres in length and 4.7 centimetres in width, and the pair weighs a total of 33.4 grams.

In order to accurately document the design and construction of the object, we first produced technical drawings of the earrings' overall form. Historical Ming dynasty portraits provide additional insight into the appearance of these earrings when worn, depicting their general shape and the way the corrugated foil texture is represented in the paintings (Figure. 3). However, these paintings stylise the objects in two dimensions and fail to convey structural details such as the thickness of the sheets or the method of fixation. Therefore, direct examination of the artefacts is essential to understanding the details of construction.

Fig. 3 | Ming-dynasty portraits showing noblewomen wearing gold gourd earrings.
(a) Portrait of Wang Ru Ren from the Ming dynasty, collection of the National Museum of Denmark.
(b) Portrait of Mrs. Yang, mother of Hao Jie, from the Ming dynasty, collection of the Wei County Museum, Hebei Province. The portraits provide visual evidence for the use of gourd-shaped earrings by high-status women in the Ming dynasty. Although the painted images are stylized, they support the archaeological evidence that this type of ornament was part of elite female dress during the period.

Using a Leica M205A stereomicroscope, we carefully examined the surface and edges of the gourd pendant for manufacturing clues. The microscope revealed that the surface of the gourd has a fine and regular concave-convex texture, giving it a rope-like or pleated texture, which is very different from any chiselled or wirework work (such as soldered metal wires or engraved lines)[13]. It is interesting to note that in the damaged area, where the upper and lower halves of the gourd are slightly separated, we observe a cross-section of the material: very thin sheets of gold form a folded layer, with compressed "wrinkles" visible at the ends of the folds. The interior of the gourd is hollow, with no evidence of a core or filler, confirming that the piece was not made by pushing, pulling, or casting on a mould.These observations strongly suggest that the gourd was made by folding and corrugating flat metal sheets (foils) layer by layer into a hollow shape. In other words, this artefact exemplifies the lost “corrugated metal” technique described in historical documents[14,Error! Reference source not found.](Technical Analysis Figure. 4).

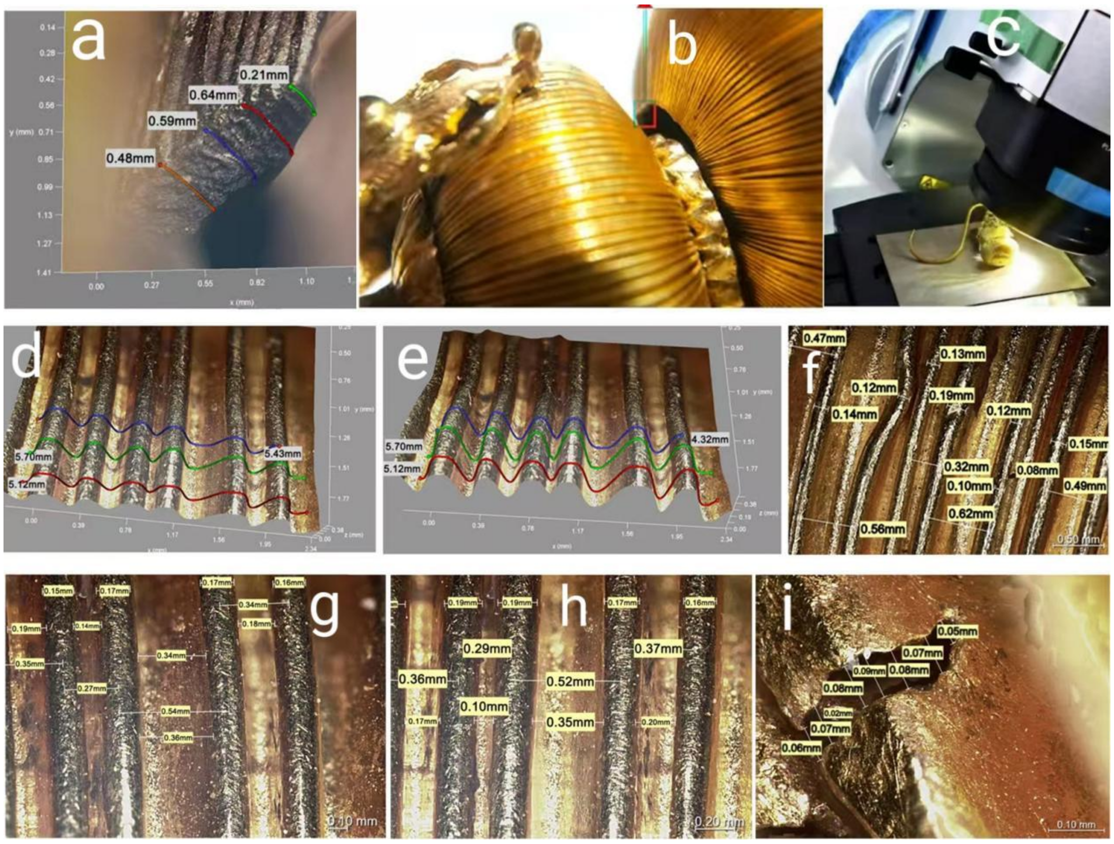

Fig. 4 | Microscopic observations of folds and fractures on a Ming-dynasty Jin zhe si gold gourd earring.
(a – c) Localized stereomicroscope observations of the folded structure in the cracks where the upper and lower spherical sections of the gourd meet.
(d – f) Stereomicroscope observations of localized fold angles, including folds of approximately 16° and 20°.
(g, h) Top views of the folded ribs, showing the regular concave-convex surface texture produced by corrugation.
(i) Localized fracture section of the folds, showing the thin gold sheet and compressed wrinkle-like layers at the fold edges. All images were obtained using a Leica M205A stereomicroscope. These microscopic features indicate that the ornament was made from folded and corrugated gold foil rather than from soldered wire, engraved lines, casting, or repoussé over a solid core.

Experimental Reproduction Process

Given that this work was made by folding and corrugating thin gold sheets, the challenge was to reverse engineer the process in order to create a faithful replica[15,16].The criteria for a successful reconstruction are defined as follows (based on our "Reproduction Criteria"): (1) the surface texture (fine raised ridges) and overall shape of the replica should match that of the original;(2) the dimensions and shape should be consistent with that of the original; (3) Sheet metal and block metal forming have their limitations in the manufacture of these geometrically demanding components, which are characterised by specific variations in sheet metal thicknesses.the weight should be essentially the same as that of the original (within ~1 gram, noting that we did not artificially adjust the gold content to meet the weight target) (4) the production time should be within the reasonable range of craftsmanship (in fact, after many trials, an experienced craftsman can complete a gourd earring in about one day).

A number of experiments, both theoretical and practical, were carried out to develop a feasible method. In order to achieve the corrugated foil effect (folded line texture), different metal materials were tested: 96% pure gold sheet with a thickness of 0.15 mm, 94% pure silver sheet with a thickness of 0.15 mm, and 99% aluminium sheet with a thickness of 0.2 mm[17,18,19]. The 96% purity of the gold leaf was intentionally selected for the reproduction sample because it accurately coincides with the purity levels of ancient Ming Dynasty gold jewelry. Due to the technological limitations of historical gold smelting and refining, archaeological evidence shows that Ming noble gold objects generally hovered around this purity rather than modern 99.9% standards. Using 96% gold ensures our physical testing matches the actual material constraints faced by medieval craftsmen. In each case, the metal sheets were cut to a size sufficient to form the gourd and annealed as necessary during the moulding process. An attempt was made to fold and compress the sheets progressively to simulate the possible formation of the original material[20,21].

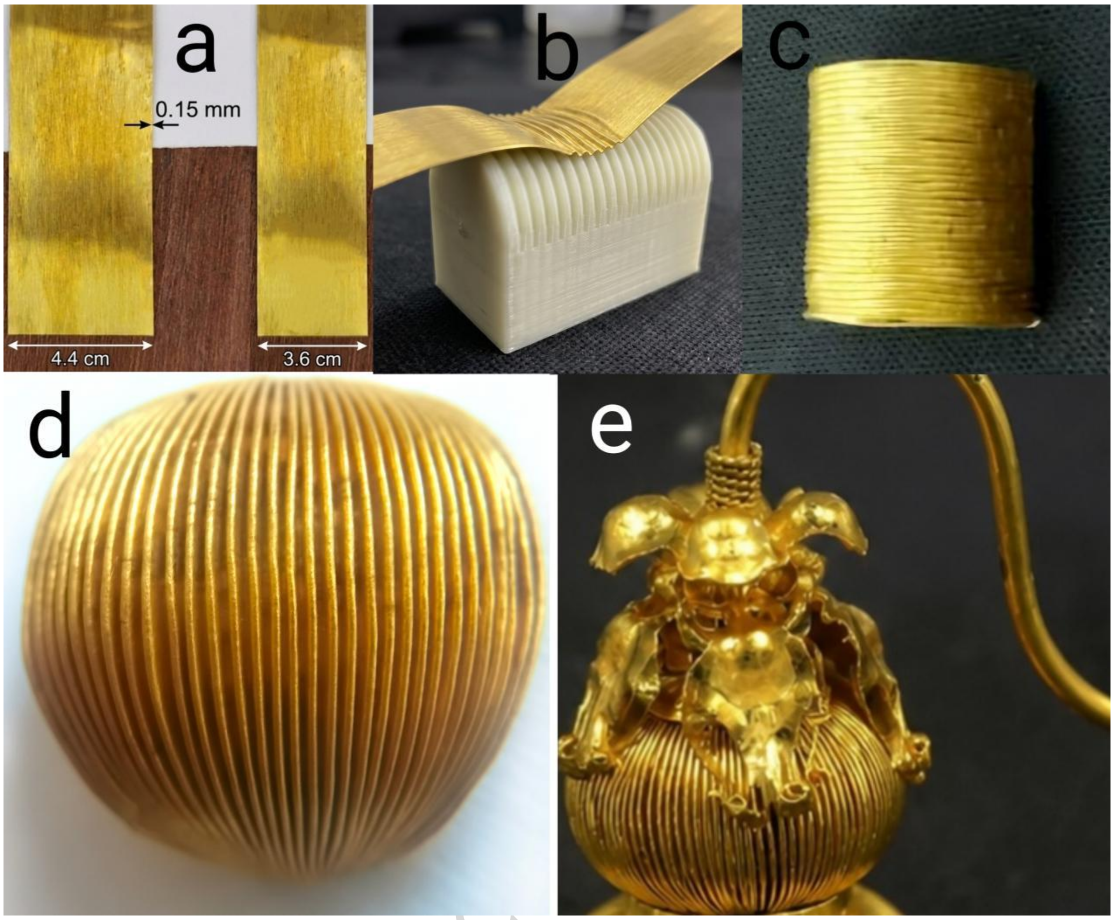

Fig. 5 | Experimental reconstruction process for producing a Jin zhe si gold gourd earring.

(a) Preparation of high-purity gold foil (approx. 96% Au, 0.15 mm thick), cut into blanks for the upper and lower gourd halves and fully annealed.

(b) Die imprinting of the gold foil into serrated grooves with a press bar, with intermittent annealing to maintain ductility during deformation.

(c) Manual folding of the foil into regular parallel accordion-like pleats using a smooth, hard tool.

(d) Forming of the pleated foil into a hemispherical gourd half over a domed support, creating the characteristic smooth ribbed surface.

(e) Fabrication and soldering of the four-leaf tendril ornament, followed by assembly of the domed calyx and ear hook.

This sequence illustrates the experimentally reconstructed manufacturing workflow, from flat gold foil to a hollow, corrugated gourd-shaped ornament.

The reproduction process we ultimately developed includes the following key steps(Figure. 5):

1. Preparation of plates (Fig. 5a): High purity gold foil (~96% Au) was cut into blanks roughly corresponding to one half of the gourd (upper or lower). The thickness (~0.15 mm) was selected based on the subtle folds observed in the original artefact: a thicker sheet would be difficult to fold, whereas a thinner sheet would lack sufficient strength. The sheets were fully annealed to a soft state.

2. Die imprinting (Fig. 5b): The sheet metal was placed on the die and pressed uniformly into the serrated grooves using a specially designed press bar to ensure close fitting. Repeated annealing was carried out during this process to maintain ductility.

3. Squeezing and folding (Fig. 5c): The gold foil was gently folded back and forth to form a series of parallel folds, similar to an accordion. This was performed manually with the aid of a smooth, hard tool to flatten the metal and keep the folds even in width.

4. Forming a hemisphere (Fig. 5d): Using a domed support, the pleated sheet was gradually bent into a hemispherical gourd half. During this process, the folds naturally spread slightly, producing smooth and regular ridges comparable to those observed on the original artefact.

5. Added decoration (Fig. 5e): The four-leaf tendril ornament at the top was produced from a thin gold sheet by piercing and cutting a symmetrical pattern, which was then curved downward to form four leaves around the top of the gourd, with the central strips twisted into tendrils. These elements were soldered to the gourd, which was then finished with a small domed calyx for attachment of the ear hook.

In our replica, we have experimented with both laser and traditional welding, welding the four hemispheres two by two to form the gourd shape. Given the technology of the Ming dynasty, the use of gold soldering was probably more common, although it is quite tricky to work on such a thin edge.

The use of high purity gold proved to be critical during the testing process. 96% gold sheets were far superior to silver and aluminium sheets in terms of ductility and malleability. We found that only gold could be folded repeatedly without breaking, and was able to maintain a pleated structure during the moulding process[22,23]. Silver (even at 94% purity) and aluminium were prone to tearing or springing back and did not retain their fine textures. The gold samples achieved almost 100% success in forming a complete gourd shape and achieving the desired texture(Figure. 6). In contrast to the silver and aluminium attempts, the silver had a lower success rate in terms of yield and folding effects that matched the original shape. Aluminum has the advantage of being able to change colours and is lighter.But the yield is even lower than silver. It is almost impossible to make a hemisphere that will be complete. Therefore, high purity gold is the ideal material for the Jin zhe si Technique, which further explains why historical records always refer to these ornaments as "gold" Jin zhe si, emphasising the uniqueness of gold in this technique.

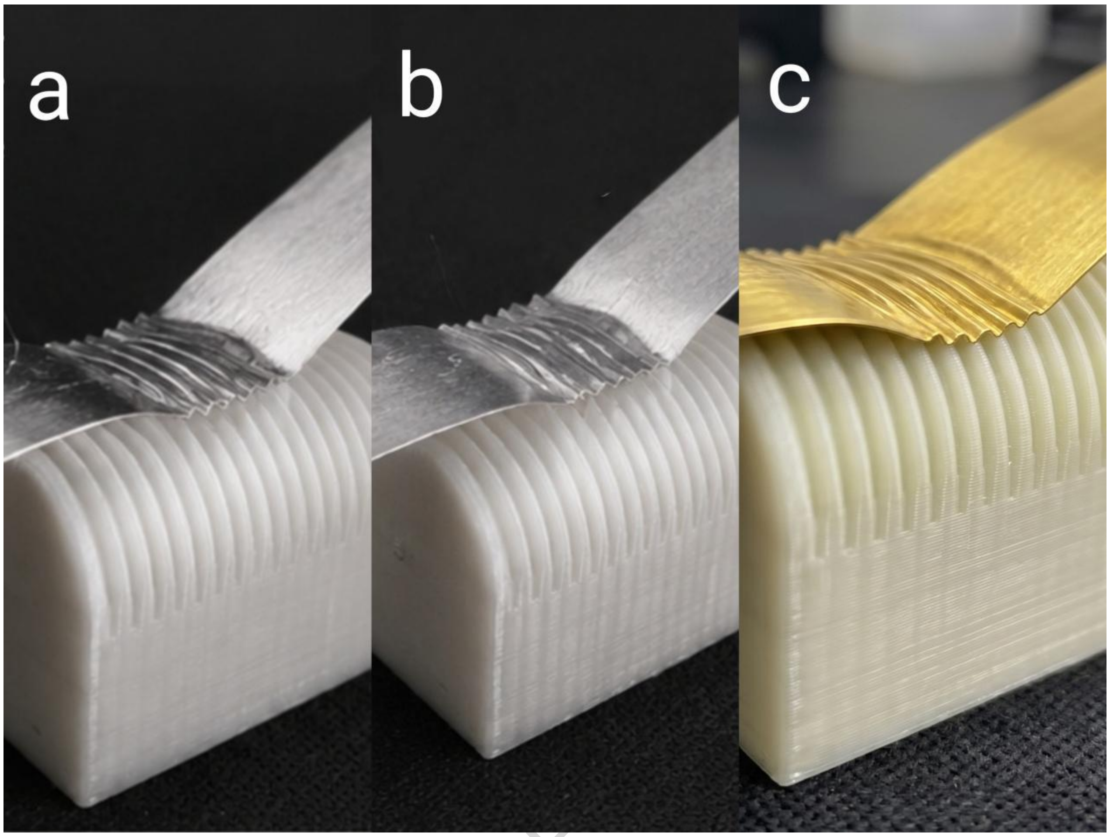

Fig. 6 | Comparative folding experiments of silver, aluminium and gold sheets.

(a) Folding experiment of silver sheet

(b) Folding experiment of aluminium sheet

(c) Folding experiment of gold sheet

These experiments compare the forming characteristics of different metals in repeated folding and corrugation processes. Silver and aluminium are easy to crack, rebound or fail to form complete hemispheres. In contrast, high-purity gold has excellent ductility and malleability. It can maintain delicate folded textures and be processed into intact gourd-shaped parts, which proves that high-purity gold is essential for making works with the Jin zhe si technique.

Tool Reconstruction and Analysis

In order to understand an extinct craft, one must first identify the tools that were used at the time. In our reconstruction, we have considered the tools used by Ming craftsmen to make folded wire gourds[24,Error! Unknown switch argument.]. To make these tools, the following conditions were required:

An abrasive tool for embossing or guiding initial creases.

Tools for simultaneous embossing and polishing of metal foil.

Through repeated experiments, we found that it is likely to use a combination of hard calendering moulds and moulding tools. We tried to make moulds with various materials: brass, 3D printed resin moulds, and jade to test the feasibility.

Considering the level of technology in the 16th century, metal moulds after casting lacked the equipment needed for fine machining and polishing; instead, jade, commonly used in ancient times, became a reasonable material for moulds. According to the author's experience and the conditions of the process of forming, the use of jade as a mould has the following reasons:

1. The traditional tool for grinding jade was the "steelyard" (powered by a pedal-driven wheel), which used a wheel to cut and grind very precise and fine "V"-shaped grooves into the surface of the jade. The moulds were shaped as rows of parallel "V"-shaped grooves, which could have been achieved with the technology and tools available to craftsmen at the time.
2. The hardness and density of jade has been an important tool for gold polishing until today. A smooth metal rod is used to press and slide over and over again the gold pieces embedded in a smooth jade mould, simultaneously forming creases and calendering the gold pieces to give them a shiny surface. This is important because the Jin zhe si Technique produces a thin, hollow form that cannot be polished after assembly, and all processing must be done during the moulding process.
3. Jade decorative objects, both quantitatively and allegorically, were of great importance in ancient China, and the choice of a different material for the grinding tools can be seen as a subconscious choice based on the experience of the craftsmen.

When the polished jade moulds are pressed against each other, they leave a clear, evenly distributed triangular bump on the gold piece. From this, we speculate that Ming craftsmen may have had a set of specialised tools:

A jade mould (small enough to form a half-gourd) is used as the base.

A moulded rod (possibly hardened metal bronze or iron, or another piece of jade) that matches the shape of the "V" to apply force and form the "V".

An anvil in the shape of a ball to help bend the folded sheet of metal foil into a hemisphere.

Various small tweezers, scissors, scrapers.

The reverence for the tools of traditional craftsmanship is reflected in the adage: "To do a good job, you must first sharpen your tools."Indeed, our restoration experience underscores the importance of having the right tooling to achieve a uniform (silky undulating prisms) appearance. As a craftsman with nearly 20 years of experience in traditional metalwork, the authors believe it is likely that the original makers of Jin zhe si Technique would have treasured their customised jade moulds as the secret of their craft-a true "heirloom" tool passed down from generation to generation.A true "family heirloom" tool, passed down from generation to generation. Over the years, the wear and polish of these jade moulds only enhanced their effectiveness (Process reduction process combination Figure. 7).

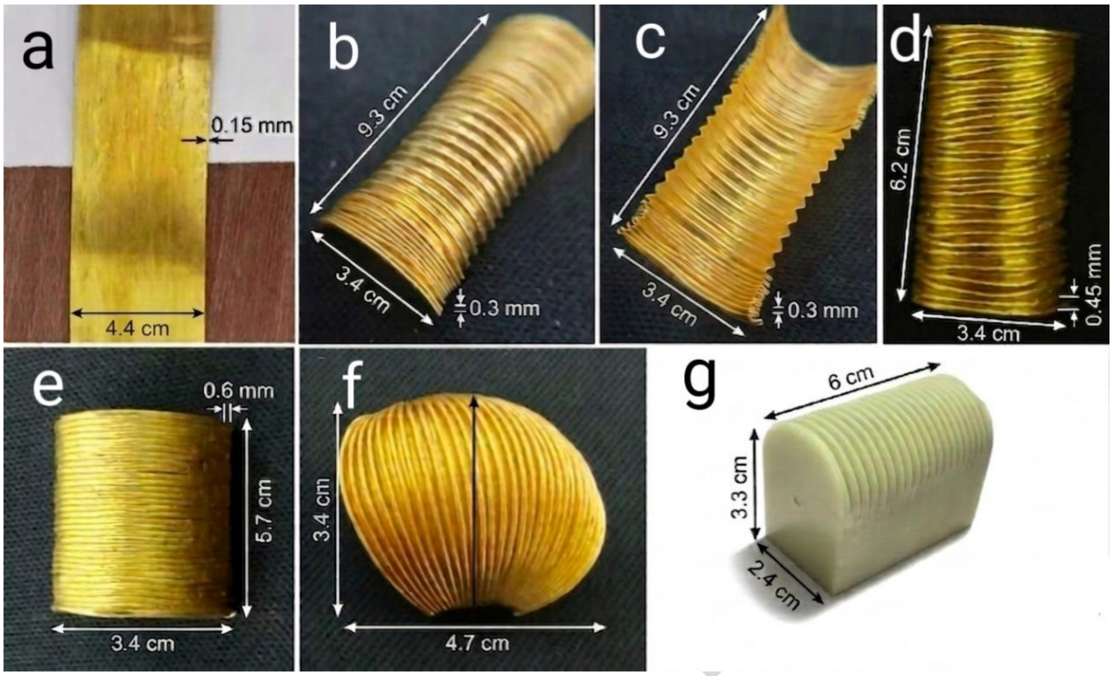

Fig. 7 | Tool-assisted forming of gold foil and the jade mould used in the reconstruction of the Jin zhe si technique.
(a) 0.15mm gold piece.
(b, c) the Gold Piece Attached to the Mould on the First Folding, Positive, Back.
(d) After two folding annealing start gold piece.
(e) After the gold piece.
(f) After the Gold Piece Attached to the Spherical Mould, Will Be Pressed to Open the Prongs, the Formation of Hemispheres.
(g) Jade Mould.

Results

Verification of Repeatability

Using the method described above, we have succeeded in producing a replica of the Jin zhe si gourd earrings that meets the required standards. The replica matches the original in size and shape, and exhibits the characteristic tightly folded ribbing on its surface, making it virtually indistinguishable from the 500-year-old piece. The weight of the replica differs from the historical example by no more than one gram, confirming that no significant excess material or omissions have been introduced into our process. This result demonstrates that,with sufficient skill and understanding of the material, it is indeed possible to reproduce the folded wire technique using high purity gold and simple hand tools. It took the author several iterations of attempts and refinements (including two complete reconstructions) to finally perfect the technique, but once mastered, the final replica was completed in about one working day. This time suggests that an experienced goldsmith could have efficiently produced these earrings during the Ming dynasty, explaining their popularity with the aristocracy.

Experiments with different metals validate the material specificity of the Jin zhe si Technique.Only gold, with its unique ductility and malleability, can withstand the demands of repeated folding and compression, while still being able to be welded and formed into a stable final product. Silver and aluminium work-harden faster and tear more easily, making it unsuitable for such delicate folds. This explains an interesting phenomenon in the historical record: every such item in the TSW Iceberg Road is clearly marked with the word "gold", which not only highlights its value, but also emphasises the necessity of gold in this process. As we have established, the Jin zhe si Technique can only be successfully executed in gold. This insight helps scholars to avoid misidentifying similar artefacts - if an object appears to have been made using this technique but is not made of gold, it is likely that other methods were employed.

The similarity was further verified by microscopic examination of the replica under the same conditions as the original.The folds on the replica are smooth, bright and evenly distributed, and are identical to the original, with no scratches or irregularities. This suggests that our assumption of the use of a polished jade mould and careful handcrafting is reasonable. The hollow and thin-walled structure of the interior of the replica is consistent with that of the original, further confirming that there was no need for and no possibility of internal support or post- polishing treatment[Error! Reference source not found.,27,28](Figure. 8).

Fig. 8 | Restored Jin zhe si gourd earrings produced through experimental reconstruction.
The restored earrings were made using high-purity gold foil and the reconstructed manufacturing process developed in this study. The final objects reproduce the characteristic double-gourd form, hollow structure, fine corrugated surface texture, and overall visual appearance observed in archaeological examples. The successful restoration supports the interpretation that Ming-dynasty Jin zhe si ornaments were produced by folding and shaping ultra-thin gold foil rather than by true wirework.

Names and Relationships to Other Metallurgical Techniques

Having reconstructed this artefact, we are in a better position to explore the question: what is the correct name and classification of the "Jin zhe si Technique"? In Chinese silversmith terminology, there is some ambiguity in naming techniques, often complicated by historical context.The term "filigree and inlay" is often used by modern artisans to refer to fine gold wire work in general, but scholars Tang and Li (2004) have argued that this is not entirely accurate. The more accurate technical term is XiJin Technique, "fine gold work", which covers a variety of openwork and granulation techniques using precious metals. Traditional terms can describe the form or method. For example, "filigree inlay" refers to both the use of twisted silk threads (filigree) and decorative motifs (usually floral, with gemstone settings); and "millet grain technique" refers to the use of small gold particles resembling grains of rice that are attached to the surface of an object.

For the Jin zhe si Technique, the term actually focuses on the method itself. It emphasises that the metal is folded to form line-like elements.Our reconstruction confirms that this is an apt description - thin sheets of gold are folded to create a large number of tiny, thread-like ridges on the surface, similar to folding fabric into many tiny pleats (akin to the "pleating" textile technique).The term "Jin zhe si Technique" is therefore appropriate, especially in reference to this particular method and its final effect[29,30].

However, while many items in historical records such as Tianshui Bingshan Lu are listed as "gold sheet folding objects" (gourds, chrysanthemums, lanterns, pavilions, etc.), not all of these forms have been found.This raises the question of whether the 'folding line' in these names refers uniformly to this method of folding, or whether it became a label for a broader artistic style.Some objects with roof-like ridges (e.g., earrings in the shape of pavilions) may superficially resemble folded-line motifs, but may actually have been made by carving lines to mimic folding. Until other so-called folded-line objects can be identified and analysed, we should be cautious about promoting this terminology.So far, gourd and lantern earrings are the clearest examples that correspond to the literal meaning of "folded wire". It may be premature to assume that all items in the literature labelled "folded gold" were made using the same technique;some may be named for visual similarity rather than actual construction.Our successful reproduction of the gold gourd earrings not only establishes the craftsmanship of the form, but further suggests that similarly complex objects such as the chrysanthemum or pavilion earrings, if they existed at all, may indeed have used a genuine folding technique.Objects with simpler names (e.g., "folded wire pavilion") may not involve the actual folding of the entire piece.This nuance in nomenclature reflects the fact that historical nomenclature sometimes captures a distinctive feature, perhaps form or craftsmanship(Figure. 9).

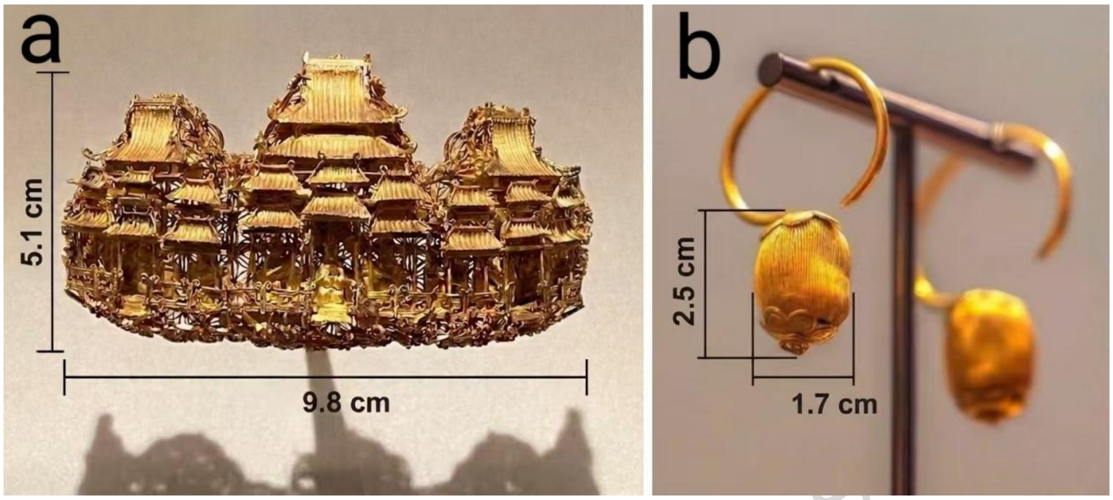

Fig. 9 | Other Ming-dynasty ornaments associated with the Jin zhe si technique.
(a) Gold hairpin in the form of a pavilion, excavated from the tomb of Zhu Houye in Nancheng County, Jiangxi Province, collection of the National Museum of China.
(b) Gold earrings in the form of lanterns, unearthed at the General Machinery Factory site in Nanchang, Jiangxi Province, collection of the Jiangxi Provincial Museum.

Our research has also shown that folded wire is not a variant of filigree (tired wire), since filigree involves the use of pre-drawn metal wires or filaments, whereas folded wire creates elongated elements in situ by folding metal sheets. It is a unique branch of fine metalwork that has been experimentally proven.

Discussion

Through a combination of historical research, scientific tests and practical experiments, this study revived a lost Ming Dynasty goldsmithing technique, the gold filigree technique.By reverse engineering the manufacturing steps and tools, we successfully produced a replica of a gold filigree earring from the 15th to 16th century, thus proving the feasibility of this technique. The main findings include:

Folded metal filigree work involves folding high-purity gold sheets into thin parallel folds to form a hollow object, which in the Ming example takes the shape of a gourd. It is fundamentally different from filigree or cameo work, but it achieves a similarly delicate aesthetic effect.

The high purity of gold was the key to the success of the technique; attempts to use silver or other metals failed, which explains why folded metal objects throughout history have been gold. In historical nomenclature, the word "gold" is not just a description of the value of the material - it is actually part of the definition of the technique.

It is likely that the original Ming craftsmen used specialised jade-polishing tools to press and form the folds of the gold leaf, a hypothesis supported by our need for equally smooth, hard tools to replicate this texture without damaging the metal.This insight connects to the broader practice of using jade/agate polishers in traditional metalwork.

We clarify the terminology (folded wire) and its use: although the gourd earrings are a typical example of the folded wire method, it is not recommended that the terminology be extended to all objects historically labelled as "folded wire" without physical verification. This work provides a reference point for the identification of genuine folded-wire pieces in museum collections or new archaeological finds.

Culturally, the successful restoration bridges the gap between the past and the present: it demonstrates the ingenuity of Ming craftsmen, who skilfully utilised the properties of gold to create exquisite forms with minimal technical means. At the same time, it enriches the attention of modern craftsmen and conservators to traditional jewellery, allowing this heritage to be taught, appreciated, and perhaps even incorporated into contemporary design.

This study emphasises an interdisciplinary approach to gemmological and jewellery studies, in which the tacit knowledge of the artisan and experimental archaeology are as important as academic analysis. By "letting the artefacts speak for themselves" and through hands-on reenactment, we can gain a deeper understanding of historical techniques than the written word. The revival of gold wire folding not only fills a gap in the classification of Chinese gold and silver craftsmanship, but also pays homage to the creative legacy of the past and ensures that the wisdom of ancient artisans continues to inspire and guide the art of jewellery today and in the future.

Data availability

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Acknowledgements

This research was supported by the Project funded by the Research on the Aesthetic Craftsmanship of Filigree (Project Number: CJHIXM-02-202102)

Author contribution

Z.H. Tian, was responsible for the overall writing, editing, and preparation of the manuscript. K. Ren, conceived and directed the research, provided primary literature and visual materials, conducted data collection and image acquisition, and supervised the project. Z.Y Jiang, reviewed the manuscript, identified issues, and provided critical feedback and revisions. All authors reviewed and approved the final manuscript.

Competing interests

The authors declare no competing financial or non-financial interests.

Consent for publication

As the first author of the paper, I hereby solemnly declare that I agree to submit this paper to "npj Heritage Science" and agree to publish it in this journal.

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