World Gold Council

Introduction to Jewellery Fabrication Technologies

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Introduction to Jewellery Fabrication Technologies

General Points:

- **Ranges form the traditional hand craft skills to automated production by advanced machines**
- **Market: worldwide competition – cost and quality needed to win!**
- **Quality in jewellery production achieved through understanding of technology – materials and production processes**

Introduction to Jewellery Fabrication Technologies

- **Use of advanced machines not sufficient; need technically educated management and workforce, with total quality approach**
- **Health, safety and enviroemnt regulations having increased impact on production and product**

Gold Jewellery Fabrication

- **Requires:**
    - **DESIGN**
    - **PRODUCTION**
    - **ASSAYING AND QUALITY ASSURANCE**

Alloying and caratage

Alloying influences:

- **Caratage**
- **Colour**
- **Mechanical properties (strength, hardness, etc.)**
- **Fabricability (ductility, malleability, solderability, brittleness, defects, etc.)**
- **Performance in service (scratch/wear resistance, cracking)**

Alloying - Colour

Coloured alloys (yellow/red/green)

- **Based on Gold – Copper – Silver alloys with additions**
  - **Copper/silver ratio control redness- greenness shades**
  - **Zinc additions aid fluidity in casting and lower melting range (useful for solders); cause whitening of alloy**

Alloying - Colour

- **Silicon (small amounts) aids fluidity in casting (deoxidant)**
- **Iridium, cobalt, etc, used in trace amounts as grain refiners**

Alloying - Colour

- **Gold does not influence colour directly**
- **Increasing copper and silver (lower gold content) gives grater colour range**
  - **24 carat: only yellow**
  - **22 carat: pink to light yellow only**
  - **18 carat: deep pink to pale yellow**
  - **9 carat: red to green shade**

Alloying - Colour

White golds:

- **Nickel and palladium have strongest whitening effect on gold**
  - **Nickel white golds alloyed with copper and zinc to get better properties and fabricability.**
    Not perfect white colour!
  - **Palladium white golds alloyed with copper, zinc, etc: have high melting ranges**

Alloying - Colour

- **Nickel whites stronger than palladium whites which are softer and more malleable (and denser)**

Alloying – Properties

- **Cold work (deformation) causes increase in strength and hardness, loss of ductility**
- **Annealing restores ductility and softens alloy (recrystalises alloy)**
    - **necessary during fabrication, if fracture to be avoided**
- **Copper-rich, 9-18 carat alloys must be rapidly cooled (quanched) after annealing to retain softness**

Alloying – Properties

- **Heat treatment of 9-18 carat copper-rich alloys gives hardening of alloy (‘age hardening’)**
- **Nickel white golds difficult to fabricate (fire cracking etc)**
- **Low temperature (‘stress relief) anneal necessary for low carat coloured golds to avoid fracture in service (stress corrosion cracking)**

Alloying – Properties

- **Low carat golds prone to tarnish during service**
- **Nickel white golds can cause allergenic skin reactions to sensitized people on contact**
- **Small amounts of impurities can give rise to embrittlement of alloy, eg lead, silicon**

Alloying – Melting Practice

- **Preferably use pre-alloyed grain: new metal and clean scrap**
  - **zinc added as brass for preference**
  - **zinc loss due to volatilisation**
- **Use of scrap necessary for economic production, but it must be cleaned**
- **Composition of all materials used must be known accurately**

Alloying – Melting Practice

- **Prevention of oxidation during melting and casting essential for quality alloy**

- **Good mixing of melt necessary for uniform composition**
  - **saves over-compensating gold content to ensure all meets Hallmark standard**
  - **induction melting preferred, gives electromagnetic stirring of melt**

Alloying – Melting Practice

- **Melt in graphite of ceramic crucibles**
- **Temperature measurement essential for control of quality**

Alloying – Post casting

- **Cast alloy in iron/graphite mould to ingot**
  - **work down by rolling, forging, drawing to ‘semi-finished’ products such as strip, sheet, rod, wire for fabrication into jewellery**

- **Or continuous cast to strip/rod for subsequent processing**

- **Or cast directly into plaster moulds to yield jewellery components/pieces (investment/casting)**

Alloying – Jewellery Fabrication

- **Jewellery producer may:**

  1. Wrought jewellery

  - **Make own alloy and work down to semi-finished form (from raw metals or pre-alloyed grain – purchased from supplier)**
  - **buy-in semi finished wrought stock (sheet, wire, etc) from specialist supplier**

Alloying – Jewellery Fabrication

2 Cast Jewellery

- **Make own alloy and cast (raw metals or pre-alloyed grain)**
- **Buy-in base metal pre-alloyed grain and mix with gold**
- **Buy-in pre-alloyed gold alloy grain**

- **Note: specialist alloy supplier can incorporate special alloy additions, eg grain refiners, casting additivies to give optimised alloys**

Alloying – Solders

- **Cadmium very good – confers fluidity for good joint filling and flow**
    - **but toxicity (of oxide) now makes it undesirable**
- **Non cadmium solders available commercially, many proprietary compositions, 8-22 carat**

Alloying – Solders

- **Colour match of solder is important; need to adjust composition to match jewellery colour (copper/silver-zinc)**
- **Need to control gold content to ensure conformance to Hallmark regulations**
- **Need range of solders – hard, medium, soft – with decreasing melting ranges, especially for repair**

Alloying – Solders

- **Solderpaste approach more ‘high tech’ (solder powder + flux + binder)**

  - **more expensive (to buy)**
  - **apply by hand syringe or automated dispenser**
  - **productivity higher, less excess, less wastage = more economic!**

Alloying – Solders

- **Alternative to soldering is welding by torch or laser (chain-making)**
- **Many solders for chain are silver/base metal compositions; gold content of chain wire higher (eg by ½ carat) to compensate for Hallmark conformance**

Alloying – Solders

- **Soldering done at temperatures lower than melting range of alloy**
  - **Solders need lower melting ranges**
  - **Achieved by alloy additions to base gold-copper-silver alloys**
  - **Eg zinc, cadmium, indium, tin … (low MPs)**

Caratage

- **Pure gold = 24 carats = 1000 parts fineness = 100% Fine gold**

Carat	Fineness	% fine gold	Comment
23.76	**990**	**99.0**	**‘990’ Au-Ti**
22	**917**	**91,7**	**India**
21	**875**	**87,5**	**Arabic**
18	**750**	**75,0**	**Western**
14	**585**	**58,5**	**Ditto**
10	**417**	**41,7**	**USA**
9	**375**	**37,5**	**UK**
8	**333**	**33,3**	**Germany**

Note: other caratages exist, e.g. Portugal – 19.25 ct = 80,0%; 23 carat in Turkey

Caratage Control

- **Need to conform to national regulations (Hallmarks, etc)**
  - **Restricted carat levels allowed, e.g. in UK only 9,14,18,22 ct**
- **Some countries have ‘zero tolerance’, others allow ‘negative tolerance’, e.g. 18 carat**
  - **In UK, minimum gold content is 75,0% (zero tolerance)**
  - **Others allow 74,7% (3 parts per thousand negative tolerance)**

Caratage Control – Assaying

- **Assaying is about gold content only**
- **‘Fire Assay’ is still the standard gold analysis/assay method**
  - **The most accurate and reliable**
- **ICP Spectroscopy only other accepted method for accuracy**
- **ICP and other methods give analysis of all metals in alloy**
- **Other methods can be useful for quality control purposes BUT NOT for Assaying**

Electroforming

- **Production of hollow jewellery – lightweight jewellery**
- **Based on electroplating on a (removable) shaped former/mandrel to form a hollow shell copy of the mandrel**
- **Relatively slow process; several items done simultaneously in bath**

Electroforming

- **Traditional technology uses a metal mandrel (very low melting point alloy), coated with copper or nickel ‘flash’ or zinc alloy)**
  - **Alloy mandrel removed after electroforming by heating or acid dissolution**
  - **Electroforming done in electrolyte/bath at high temperature (55-75°C)**
  - **Hard deposit is brittle and requires post heat treatment to restore ductility**

Electroforming

- **New technology uses wax mandrels and low (40-45°C) temperature baths**
  - **Less processing steps, less complex**

Electroforming

- **Carat golds – 8 to 18 ct possibile plus 24 ct gold**
- **Traditional technology produces yellow gold-copper-cadmium alloy (about 7% Cd)**
- **New technology produces pale yellow gold-silver alloy**

Electroforming

- **Au-Cu-Cd has better properties and colour than Au-Ag alloy**
- **Red/pink or white gold NOT possible**
- **Pure gold ‘flash’ often put on to restore good colour**

Electroforming

- **Caratage control is vital**
  - **Through wall thickness**
  - **From piece to piece**

- **Computer control of process essential to good electroforming and caratage control**
    - **Automatic weighting to control deposit thickness**
    - **Caratage precision controlled by applied current density/process efficiency**
    - **Equipment runs automatically 24 hours**

Electroforming

- **High capital cost of equipment**
- **Production costs higher than other methods (casting, stamping)**
- **Plating speed 0.25-1.0 mm/min**

Electroforming

- **Typical results:**
    - **Weight distribution: 89% of electroformed pieces in bath are +/-5% (all within +/-10%)**
    - **Caratage: all within +/- 0.5 carat**
- **Aim at +0.5 carat higher than target to ensure all pieces conform**

Electroforming

- **Thickness of deposit typically 100-200 μm, depends on size and shape of item**
  - **Need to have adequate strenght to resist denting**
  - **Depends on design and quality required (compromise between cost and stability of piece)**

Electroforming – Requirements

- **1 Jewellery**
  - **Structural strenght/stability**
  - **Ductility**
  - **Colour**
  - **Range of caratages**
  - **Solderability (without softening of item)**
  - **Brightness and polishability**

Electroforming – Requirements

- **2 Process**
  - **Ability to produce complex shapes, small to large size**
  - **Suited to multiple production of pieces**
  - **Carat gold plating and control of caratage**
  - **Gold plating speed**
  - **Good deposit uniformity**

Electroforming – Requirements

- **2 Process**
  - **Good deposit properties at high thicknesses**
  - **Good consistency of deposit weight from piece to piece**
  - **Stable electroforming bath (chemical/physical)**
  - **Automatic operation and control**
  - **Safe operation**

Stamping of Jewellery

- **Traditional way of mass manufacture**
- **Strip, sheet, etc placed in steel dies/tools and pressure applied to cut and shape pieces (in mechanical or hydraulic presses)**
  - **Blanking shapes (cutting)**
  - **Forming shapes into 3-D components (pressing, deep drawing)**
  - **Coining to produce surface relief and detail**

Stamping of Jewellery

- **Stamped pieces assembled by eg soldering and further decorated into jewellery and'finished' to give polish or texture**
- **Versatile process – can produce jewellery in all caratages and colours, including tricolours, striated effects, etc**

Stamping of Jewellery

- **Quality of surface depends on quality of die surface**
- **Tooling critical to quality and productivity**
  - **Quality of tool steel and its treatment to yield optimum properties**
  - **Tooling is expensive and requires specialist skills and equipment**
  - **Hence, stamping suited to mass production**

Stamping of Jewellery

- **Typically, thin metal used**
  - **Die design is important to control metal deformation pattern**
  - **Fine grain size required to prevent ‘orange peel’ surface**

- **Forming may require more than one stamping operation**
  - **Sequence of stamping dies to archive final shape**

Stamping of Jewellery

- **Danger of overworking metal: split/fracture piece**
  - **Interstage annealing may be necessary**

Stamping of Jewellery

- **Mechanical presses**
  - **Hammer, fly, screw: operate by hand,steam or electric motor/flywheel**
  - **Fast impact (deformation rate)**
  - **Suited to blanking and’shallow’ shaping, coining of medals and pendants**

Stamping of Jewellery

- **Hydraulic Presses**
  - **Slow pressing (deformation rate)**
  - **Suited to deep drawing / shaping**
  - **Double action presses for complex shaping (two rams, complex tooling)**

Chain Manufacture

- **The only continuous mass production process**
- **A ‘commodity’ product**
- **Uses wire as feedstock**
    - **Wire bent and twisted to produce inter-linked ‘links’**
    - **Use round, oval or flat wires**

Chain Manufacture

- **Chain machines are precision engineered**
  - **Operate at high speeds (50 – 500 links per min)**
  - **Tooling specific for each chain design and size**
  - **Need different machines for different chain types**

Chain Manufacture

- **Chain links need to be joined for chain integrity:**
  - **Welded on line or soldered afterwards**

- **Further processing required for some designs:**
  - **Hammering to flatten links**
  - **Diamond cut to give reflective facets (ice lathe, diamond facetting machines)**
  - **Polishing**

- **End fittings need to be added (soldered)**

Chain Manufacture

- **Machine puts wire under tension**
  - **‘Snatching’ can fracture wire**
  - **machine tool settings critical**
  - **accuracy and uniformity of wire diameter important**
  - **‘temper’ and ductility of wire important (hard, half-hard, soft)**

Chain Manufacture – Joining of Links

- **On line (modern method):**
  - **Welding by laser or plasma/gas microtorch**
  - **Welding cycle must be rapid and syncronised with machine**
  - **Suited to medium – light chains**

Chain Manufacture

- **Post manufacture (traditional method):**
  - **Soldering by ‘powder’ technique or use of solder-cored wire**
  - **Want solder only in link gap, not on surface**
  - **Soldering by passing chain through tunnel furnace**

Chain Manufacture

- **Solder may not be gold-based, so compensate by higher gold content of wire**

- **Powder method:**
  - **Clean (degrease chain)**
  - **Immerse/agitate chain in solder powder/flux/binder mixture**
  - **Remove unwanted solder from surface by agitating in talc**
  - **Pass chain through tunnel furnace to effect soldering**

- **Solder-cored wire only needs soldering in tunnel furnace after cleaning**

Mass Finishing Basic Rules

- **The surface roughness attained depends on the type of medium**
- **Do not place in the same batch objects too different in characteristics**

Mass Finishing Basic Rules

- **Rate of metal removal depends on the medium type:**
  - **Coarser media cut faster**
  - **Finer media cut slower**

Mass Finishing Basic Rules

- **Coarser surfaces take longer to be finished**
- **Improve the production quality by starting as good as possible**

Types of Media

- **Abrasive**
  - **ceramic**
  - **plastic**

Types of Media

- **Non Abrasive**
  - **Porcelain**
  - **Stainess steel**
  - **Wood**

Suggested ratios by volume media versus objects

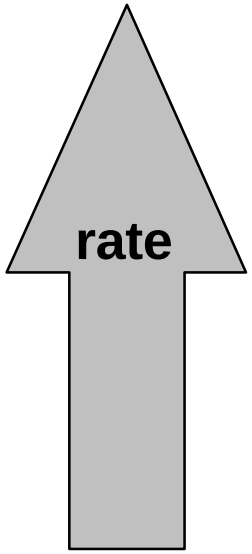
- **Abrasive:**
  - **Ceramic 4:1**
  - **Plastic 7:1**

Suggested ratios by volume media versus objects

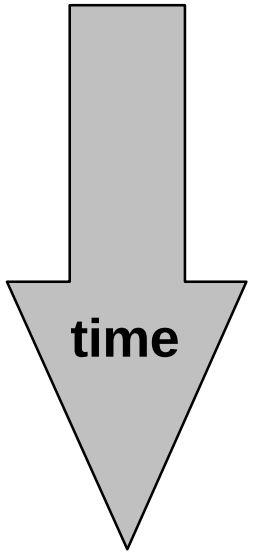
- **Non-Abrasive:**
  - **Ceramic** **10:1**
  - **Stainless steel:** **8:1**

- **The volume of the objects to be finished SHOUL NEVER BE MORE than 25-30% of the total volume.e**

Different equipment



- **Rotary barrels**
- **Vibratory barrels**
- **Centrifugal disc barrels**
- **Centrifugal planetary barrels**



Statistics on Jewellery defects

Fabrication methods %

Casting	**79***
Mechanical	**17**
Others	**4**

Type of defects %

Porosity, cavities	**47***
Cracks and fractures	**33**
Corrosion, tarnish	**20**
Annealing	**10**

Investment casting steps

1. Design
2. Making the master model
3. Moulding
4. Making the wax pattern
5. Assembling the wax tree
6. Filling the flask
7. Dewaxing
8. Burnout
9. Melting
10. Casting
11. Removing investment
12. Cutting
13. Finishing *

Making the master model

- **Use metals with high hardness**
- **Ensure a high quality finish**
- **Employ designers with workshop experience**
- **Use gates proportional to the size of the model**

Moulding

- **Use silicon rubber**
- **Keep moulds perfectly clean**

Making the wax pattern

- **Use compact, good quality wax**
- **Choose wax with a narrow melting range**
- **Choose vacuum injectors with automatic mould filling**
- **Eliminate defective wax patterns**

Assembling the wax tree

- **Assemble the tree according to the model to be cast**
- **Respect distance between patterns**
- **Ensure welding spots are rounded off and of sufficient size**
- **Wash the tree after assembling**
- **Weigh the tree, to determine the weight of the metal needed for casting**

Filling the flask

- **Weigh out the ingredients**
- **Use the exact amount of water required**
- **Mix, degasify and pour the investment, respecting the time intervals indicated by the manufacturer**

Dewaxing and burnout

- **Use steam dewaxing for less porosity**
- **Adhere strictly to the burnout cycle**
- **Do not exceed the critical temperature**
- **Soak the flask at the final casting temperature for an adequate lenght of time**

Melting and casting

- **Do not use oxidised metals**
- **Avoid overheating**
- **Flux the surface of the metal**
- **Pour in the shortest possible time**

Conclusions: What is economy?

1. Prefer good quality waxes
2. Prefer silicone rubber moulds
3. Do not maker tree too complex: leave sufficient gap between contiguous objects: provide a correct gating system
4. Do not use the cheapest investment
5. Follow carefully manufacturers' recommendations to prepare the investment:relative amounts of powder and water, tempreature, etc.

Conclusions: What is economy?

6. Prefer steam dewaxing
7. Prefer a carousel oven for burnout
8. Preparing hte cast, do not use oxidized metals and alloys for the charge
9. Control the molten metal temperature and avoid overheating (max 100°C)
10. Do not pour into flask at too high temperature (max 650° C)