Antimicrobial Copper Alloys

Guidance on Selection

CDA Publication 214

2013

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May 2013

Copper Development Association is a non-trading organisation that promotes and supports the use of copper based on its superior technical performance and its contribution to a higher quality of life. Its services, which include the provision of technical advice and information, are available to those interested in the utilisation of copper and copper alloys in all their aspects. The Association also provides a link between research and the user industries and is part of an international network of trade associations, the Copper Alliance™.

Cu Copper Development Association
Copper Alliance

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Tables and Figures

1. Introduction

This publication aims to provide an introduction to the key families of copper and copper alloys and give guidance to designers, manufacturers and specifiers to help them identify the most appropriate alloy for a product where the intrinsic antimicrobial characteristics of copper may be beneficial. Whilst primarily focussed on touch surfaces for the healthcare sector, the information here is just as relevant to other antimicrobial applications and environments.

Antimicrobial Copper

Copper is a powerful antimicrobial with proven rapid, broad-spectrum efficacy against pathogens threatening public health in both hospitals and the wider community. Recent clinical trials around the world have confirmed the benefit of deploying touch surfaces made from antimicrobial copper to reduce microbial contamination and lower the risk of acquiring infections, improving patient outcomes and saving costs.

Copper and more than 450 copper alloys that benefit from copper's inherent antimicrobial efficacy have been granted a registration by the US Environmental Protection Agency (EPA), permitting them to be marketed in the US with public health claims. Antimicrobial Copper is shorthand for these approved alloys and their close equivalents. It is also the brand associated with an industry stewardship scheme which helps suppliers market, and specifiers identify, efficacious alloys and products.

While more than 450 are approved as antimicrobial copper alloys, a table of the more commonly available alloys, conveniently ordered by colour, is provided in this publication. It gives compositions, mechanical properties, product forms available and suitability for different manufacturing processes. Further sources of information on properties and applications are given in Section 13, along with details of how to get in touch with your local Copper Alliance Copper Centre.

Touch surfaces

Heating, ventilation and air-conditioning

Food processing and preparation

2. Antimicrobial Copper Applications

Antimicrobial Copper can be harnessed to continuously reduce microbial contamination and help prevent the spread of infection in a wide range of applications where hygiene is important, such as touch surfaces, food preparation areas and heating, ventilation and air-conditioning (HVAC) systems.

Touch Surfaces

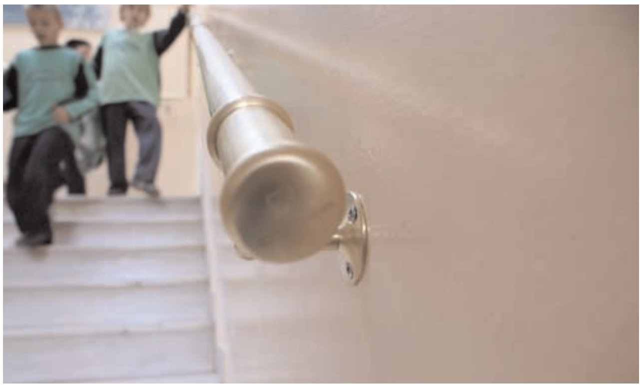
In recent years, government and commercial advertising campaigns have raised awareness of the risk to public health posed by bacteria and viruses on hard surfaces, particularly at the height of threats from influenza and norovirus. It is reported that 80% of all infections are spread by touch, and a contaminated hand can contaminate the next seven surfaces it touches. Hospitals, in particular, faced with the problem of healthcare-associated infections (HCAIs), are looking more closely at the role of the environment in the spread of these infections as hand washing campaigns alone have failed to control the problem.

Antimicrobial Copper offers a new approach in that it can be built into key areas and act as a continuous antimicrobial surface, all day, every day. It is a new way of thinking: employing an engineering material with intrinsic antimicrobial properties to help protect public health.

When used to supplement standard hygiene practices, such as hand washing, cleaning and disinfection, copper reduces contamination and the risk of infection. In hospitals, clinicians have identified medical equipment (e.g. bed rails, drip poles and stethoscopes), furniture (e.g. chairs, overbed tables, bedside cabinets) and fixtures and fittings (e.g. taps, door handles and light switches) as high risk touch surfaces. In other environments, like schools, daycare centres, airports and train stations, touch points like door handles, sink areas and hand rails are considered key surfaces.

Healthcare touch surfaces

Mass transit touch surfaces



Education touch surfaces

Heating, Ventilation and Air-conditioning

Heating, ventilation and air-conditioning (HVAC) systems are believed to be factors in over 60% of all sick building situations and can also benefit from Antimicrobial Copper components such as filters, cooling fins, drip pans and tubes which eliminate bacterial and fungal growths that typically thrive on damp internal surfaces. This can improve the system's thermal and electrical efficiency as well as, potentially, the resultant air quality. Apart from commercial and public buildings, controlled air spaces such as operating theatres and food preparation areas may especially benefit.

Food Processing and Preparation

The incidence of foodborne infections and high spoilage rates suggests that current measures are not always effective in minimising contamination of the world's food supplies. Hygienic surfaces, made with copper and copper alloys, can be used in food-processing facilities to help reduce the risk of cross-contamination of moulds and even dangerous foodborne pathogens. Copper has an intrinsic ability to destroy these dangerous microbes quickly at both refrigeration temperature (4°C) and room temperature (20°C). Suggested applications include dry food contact surfaces (e.g. mixers, transfer chutes, conveyors and work tables) and touch surfaces (e.g. door furniture and taps).

3. Copper and Copper Alloys

The following section provides an overview of copper and copper alloys and their properties. Table 1 lists examples of the more commonly available alloys and gives designations, compositions, mechanical properties and an indication of suitability for different manufacturing processes. Further details are given in the technical publications available from Copper Alliance Copper Centres.

Designers and manufacturers who wish to use copper alloys for the production of antimicrobial components will find that they are easy to fabricate by machining, hot or cold working or casting. There should be no problem with existing tooling and fabrication equipment used for other materials. There is a wealth of experience and 'know how' gained over many years during the production and use of components in brass, bronze and other copper alloys. One of the key requirements of an approved Antimicrobial Copper alloy is that there must be a minimum copper content of 60%. Copper contents for the different alloy families are given in Table 1 and the family descriptions below.

What is an Alloy?

Copper is well known for excellent thermal and electrical properties, as well as high ductility. However, copper also forms alloys with a wide range of elements to produce the following cast and wrought alloy families:

Copper with:

- tin makes tin bronze
- tin and phosphorus makes phosphor bronze
- aluminium makes aluminium bronze
- zinc makes brass
- tin and zinc makes gunmetal
- nickel makes copper-nickel
- nickel and zinc makes nickel silver.

Alloying provides improvements to strength, hardness, ductility, machining and joining properties, and castability and corrosion resistance, but results in lower electrical and thermal conductivities.

Engineering Grade Copper

The usual grade of copper used for engineering (non-electrical) applications is CuDHP - CW024A or Phosphorus-deoxidised Copper. It has a minimum copper content of 99.90% with a small addition of phosphorus, which allows this grade of copper to be welded and brazed. The properties which make copper the standard material for engineering, architectural and plumbing applications are:

- Thermal conductivity – copper has a thermal conductivity of 394W/mK, about twice that of aluminium and thirty times that of stainless steel. Copper is used for components where rapid heat transfer is essential, but examples like saucepan bottoms and heat exchangers (such as air conditioning tubes, car and vehicle radiators) demonstrate the versatility and formability of copper.
- Corrosion resistance - copper is non-reactive and does not rust like mild steel.
- Resistance to UV light - copper does not become brittle in sunlight. Together with copper alloys, it does not have a 'shelf life'.
- Ease of joining – copper can be readily joined by brazing, soldering or adhesives.
- High ductility – tubes and sheet are easily bent, even when hard.
- Malleability- copper may be rolled into very thin sheets and foil.
- Toughness – copper does not become brittle at sub-zero temperatures.
- Heat resistance - copper withstands fire well, melting point is 1083ºC.
- Recyclability - copper is 100% recyclable without loss of properties.

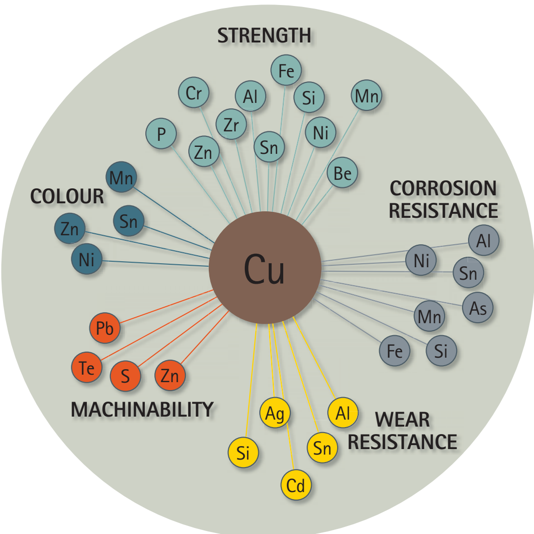


Figure 1 - Properties enhanced by the addition of different alloying elements.

Electrical Grade Copper

For many electrical applications the appropriate grade will be Electrolytic Tough Pitch copper (Cu-ETP – CW004A), which also has greater than 99.90% copper and is readily available in many forms. This and other electrical grades have the same antimicrobial efficacy as copper used for engineering, but the purity and conductivity are not essential properties for antimicrobial applications.

Brasses

Brass is the generic term for a range of copper-zinc alloys with a copper content ranging from 60 to 95%. Apart from the major alloying element, zinc, small amounts (1 to 3%) of alloying elements such as lead, manganese, aluminium, silicon, nickel, iron and tin may be added. Alloys referred to as special brasses contain higher levels of key alloying elements. All these elements alter or enhance a wide range of mechanical and physical properties, including strength, machinability, ductility, wear resistance, hardness, colour and corrosion resistance.

Brasses set the standard by which the machinability of other materials is judged and are extensively used for complex parts. Free-machining brass may contain lead for inherent lubrication or silicon to help chip formation. Brasses are available in a very wide variety of product forms and sizes to allow minimum machining to finished dimensions. Brass has excellent formability and good thermal conductivity and corrosion resistance, making it a preferred choice for heat exchangers (radiators).

Nickel silvers may be considered to be special brasses (with no silver content); they were developed in the early 19th century to resemble silver in appearance. They have high zinc and nickel content, which gives them an enhanced corrosion resistance and strength. They are extensively used for small machined and stamped parts, as well as fine detail designs in the tableware and jewellery sectors.

All brass alloys are available in a variety of wrought and equivalent cast forms. When considering the use of brasses it should be noted that they have comparable yield strengths to low alloy steels, some stainless steels and some aluminium alloys. Brasses have a variety of attractive colours, ranging from red to yellow to gold to silver. With the addition of 1% manganese, brass will patinate to a chocolate brown colour. Nickel silvers will polish to a brilliant silver colour.

Tin Bronzes and Phosphor Bronzes

Wrought alloy bronzes have a tin content of 4 to 8% and a copper content of 91 to 96% and are generally harder, stronger and stiffer than the wrought brasses. In strip and wire form, these alloys have a combination of high yield strength and good corrosion resistance, which makes them ideal for use as springs. The extra addition of small amounts of phosphorus (0.01 to 0.45%) in the phosphor bronzes further increases the hardness, fatigue resistance and wear resistance, making these alloys suitable for applications such as fasteners, masonry fixings, drive shafts, valve spindles, gears and bearings.

Casting versions of these alloys contain additional elements to assist in obtaining an intricate component.

The colour of these alloys is reddish brown, darker than the yellow-gold brasses.

Aluminium Bronzes

These are alloys with a copper content of 78 to 95% with 5 to 12% aluminium, some having additions of iron, nickel, manganese and silicon. Alloys are available in cast and wrought form. They are stronger than the brasses or tin bronzes with better corrosion resistance due to a hard, adherent, protective oxide. Due to their corrosion resistance and strength, the major use for aluminium bronzes has been in seawater applications, such as pumps and valve components. They have an attractive golden colour which will darken slightly over time.

Copper-nickels

These alloys have a copper content from about 70 to 95% with nickel ranging from 5 to 30%. The addition of nickel improves strength and corrosion resistance while retaining good ductility. The two main alloys are 90-10 (90% copper, 10% nickel) and 70-30 (70% copper, 30% nickel). The 70-30 is stronger, but the 90-10 will provide good service for most applications and, being lower cost, tends to be more widely used. Both alloys contain small but important additions of iron and manganese which have been chosen to provide the best combination of strength and overall corrosion resistance.

Copper-nickel alloys are widely used for cryogenic and marine applications due to their excellent resistance to corrosion, good mechanical characteristics and fabricability. Typical applications include pipework, heat exchangers and condensers, aquaculture cages and desalination units.

The colour of the 90-10 is a slightly pink silver, whilst the 70-30 is completely silver in colour, resembling the appearance of stainless steel; they do not darken significantly when used indoors.

Colour Stability

The previous content describes the colours of the different alloy families and some examples are shown on this page. For specific alloys, suppliers will generally provide samples on request.

Copper and copper alloy surfaces need to be active to exert antimicrobial efficacy – so they must never be coated or plated. This means that the component colour will change, or develop a patina, over the course of the first few weeks/months after installation. Depending upon the exact cleaning regime, the patina will develop and stabilise to a slightly darker version of the original. Copper alloys are not damaged by detergents and disinfectants when used according to the manufacturer's instructions.

Because copper is more active than the alloys, it will darken most readily whilst bronzes and brasses will change less noticeably, developing a matte oxide finish. Nickel silvers and copper-nickels are very stable and will not patinate noticeably. Long term clinical trials have shown that the patina does not reduce the efficacy of the material.

If green oxides are observed, it usually means that strong disinfectants have been used and not washed off, or the surface has been contaminated and has not been cleaned for many weeks. In this way copper can been seen as 'self indicating', showing when cleaning has not been properly undertaken.

Copper (CW024A)

90-10 Brass (CW501L)

70-30 Brass (CW505L)

90-10 Copper-nickel (CW352H)

Nickel silver (CW409J)

Alloy colours in brushed finish, as delivered. Some darkening may occur following use and cleaning. For accurate visualisation of colours, samples may be requested from suppliers or Copper Centres.

Table 1 - Commonly Available Approved Antimicrobial Copper Alloys: Designations, Compositions, Mechanical Properties and Availability

	Designation				Nominal Composition (%)									Typical Mechanical Properties (See Section 4)		
Colour	Name/Description	EN Number	ISO Symbol	UNS (Closest)	Cu	Zn	Ni	Si	Sn	Fe	Al	Mn	Other	Specified Hardness (HV)	0.2% Proof Strength (N/mm^2)	Elongation (%)
Brown	Phosphor bronze/ tin bronze	CW452K	CuSn6	C51900	94				6				P: 0.2	80-240	140-950	60-1
	De-oxidised high-phosphorus copper	CW024A	CuDHP	C12200	99.9								P: 0.02	40-120	50-340	50-5
Red/pink	Low alloyed copper	CW107C	CuFe2P	C19400	97.5					2.5				110-160	270-490	32-3
	Gilding metal	CW501L	CuZn10	C22000	90	10								60-165	120-560	45-2
	Copper-nickel tin	CW351H	CuNi9Sn2	C72500	89		9		2.2					75-210	250-580	45-2
	Gilding metal	CW502L	CuZn15	C23000	85	15								65-170	120-590	50-2
	Free machining brass	CW724R	CuZn21Si3P	C69300	76	21		3					P: 0.05	152-222	300-450	35-10
Yellow/gold	Aluminium brass	CW703R	CuZn23Al3Co	C68800	74	22					3.5		Co: 0.4	200-250	600-800	36-2
	Cartridge or deep-drawing brass	CW505L	CuZn30	C26000	70	30								65-200	130-810	55-1
	Brass	CW507L	CuZn36	C27000	64	36								80-190	170-600	50-1
	Copper-nickel	CW352H	CuNi10Fe1Mn	C70600	88		10			1.5		1		80-160	100-350	40-12
	Nickel silver	CW403J	CuNi12Zn24	C75700	64	24	12							80-210	180-800	50-2
Silver	Nickel silver	CW409J	CuNi18Zn20	C75200	60	20	18							85-230	380-900	40-2
	Copper-nickel	CW354H	CuNi30Mn1Fe	C71500	68		30			1		1		90-190	130-450	35-12
	Copper-manganese alloys - under development		CuMnXX													

The wrought grades and alloys listed in this table are representative of a family within a particular colour bracket: brown, red/pink, yellow/gold and silver. Many other alloys, including casting variants, are available which match these familial colours, but these fifteen have been chosen as readily available and to illustrate the main characteristics.
A full list of approved Antimicrobial Copper alloys can be found on www.antimicrobialcopper.org.

Availability								Joining					Ease of Manufacture				Remarks
Strip	Sheet	Rod	Forging	Wire	Profiles	Hollow Rod	Tube	Welding (gas shielded)	Brazing	Soldering	Adhesive	Mechanical	Cold Forming	Hot Stamping	Machinability#	Bending	
✓	✓	✓	✓*	✓	✓*	✓*	✓*	2	2	1	1	4	1	4	3	1	Bronzes are stronger and harder than copper or brass with excellent corrosion, fatigue and sliding wear characteristics. They are widely available as strip and bar stock.
✓	✓	✓	✓	✓	✓	✓	✓	2	2	1	1	2	1	3	4	2	All grades of copper have maximum efficacy and similar mechanical and physical characteristics to each other.
✓	✓	✓		✓	✓	✓	✓	2	2	1	1	2	2	2	3	2	Low alloyed copper grades have improved strength over copper. Many have been developed for electrical applications, but can be used for antimicrobial applications.
✓	✓	✓	✓*	✓	✓*	✓*	✓	2	1	1	1	1	1	4	4	2	This is a low zinc brass which retains a red colour and has good cold working characteristics.
✓	✓	✓		✓*	✓	✓	✓	1	1	1	1	3	1	2	4	2	This copper-nickel alloy also retains a red colour, but is stronger and springier than most red alloys.
✓	✓	✓	✓	✓	✓		✓	2	1	1	1	1	1	4	4	1	Like CuZn10, this is a brass but has a yellow colour and is widely used for intricate cold formed components.
		✓	✓	✓*	✓	✓	✓	3	2	2	1	2	2	1	1	3	Yellow machining brasses are extensively used for complex components and are widely stocked.
✓	✓*	✓	✓*	✓	✓	✓	✓	2	2	2	1	1	1	2	2	2	Special brasses have additional alloying elements to provide increased strength and corrosion resistance, but may not be so readily available.
✓	✓	✓		✓	✓	✓	✓	2	1	1	1	1	1	4	3	1	The most ductile brass with good strength. It is widely available and with good corrosion properties; this is the alloy of choice for cold drawing and thin wall tube.
✓	✓	✓		✓	✓	✓	✓	3	1	1	1	3	1	2	3	2	Brasses with more than 35% zinc have excellent hot working properties and can be stamped or forged. They are generally less expensive than CuZn30.
✓	✓	✓	✓	✓	✓	✓	✓	1	1	1	1	2	1	2	3	2	This alloy is a pink-silver colour which is retained over time. It has excellent cold ductility and formability.
✓	✓	✓		✓	✓	✓	✓	1	1	1	1	1	1	3	3	1	The nickel silvers have no silver content, but can look similar with a slight yellow tint or almost white with higher nickel content. They are strong and easily cold worked.
✓	✓	✓		✓	✓	✓	✓	1	1	1	1	1	1	3	2	1	As above.
	✓	✓	✓	✓*	✓*	✓	✓	1	1	1	1	2	1	4	3	2	This alloy is visually undistinguishable from stainless steel and may be considered where this is desired. It is very corrosion resistant, strong and formable.
✓	✓	✓				✓											Copper manganese alloys are under development in order to provide zero nickel silver-coloured materials. Talk to your supplier for details.

✓ widely available

✓* available, sometimes as special order

1 = very good

4 = poor

machinability grading is a comparison between copper alloys, not stainless steels which, at best, have a machinability rating of just 50% that of free machining brasses.

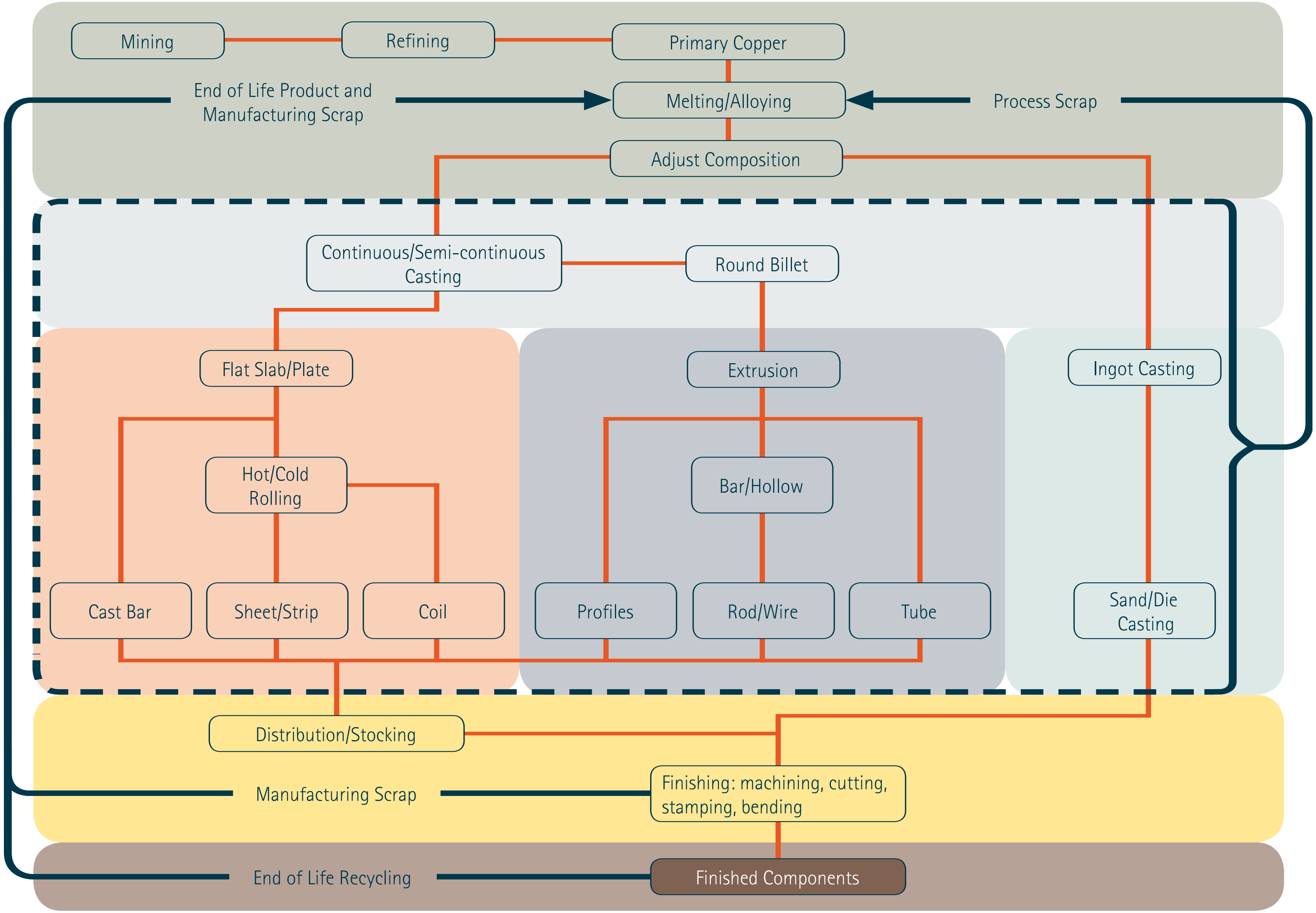


Figure 2 - Simplified copper and copper alloy component production flowchart.
The sustainability credentials of copper are illustrated by constant attention to recycling at every stage/process shown in the diagram.

4. Product Form, Availability and Colour

With over 450 approved alloys to choose from, offering a wide range of properties and attributes, it is easy to select an appropriate alloy for the application and fabrication route required. In fact, there will usually be several that meet particular design requirements.

Product Form and Availability

Copper and copper alloys may be manufactured by extrusion, drawing, rolling, forging (stamping) and casting, which enables fabricators to make products such as wire, rod, tube, sections, sheet, plate and strip. An alloy manufacturer (mill) will produce large quantities (tonnes) of these products which will be sold in smaller amounts to stockists or distributors who, in turn, are the usual suppliers to product and component manufacturers.

As with other material types, small differences in chemical composition are required for optimum properties to be attained for a given manufacturing route. For example, a wrought brass will have a different composition to a cast version and so will have a different designation. When colour matching, these differences should not be of great concern as they generally make no difference to long term mechanical performance or colour.

Standards

Copper and copper alloy products are produced to conform to a wide variety of national and international standards. The 'Copper Key' software enables users to find the nearest equivalent designations for EN, US (ASTM), German (DIN), Japanese (JIS) and Chinese (GB) copper and copper alloys. The software allows users to compare compositions of equivalent designations and see which national standards apply and is available online (www.copperkey.org). When ordering alloys or otherwise considering international standards – especially those outside of Europe – reference should always be made to the full standard.

European Standards

Most European countries comply with the EN (EuroNorm) standards, which are co-ordinated by the European Committee for Standardisation (CEN). Some relevant standards are listed below:

- EN12449 Seamless round tubes for general purposes
- EN12163 Rod for general purposes
- EN12166 Wire for general purposes
- EN1652 Plate, sheet, strip and circles for general purposes
- EN12167 Profiles and rectangular bar for general purposes

Copper Development Association Pub 120 'Copper and Copper Alloys - Compositions, Applications and Properties' contains a significant level of technical information. National standards bodies have websites with details of how to acquire specific documents, for example The British Standards Institution (bsigroup.com) and Deutsches Institut für Normung (din.de). It is essential to use the standards to properly define the type, form and condition of an alloy. They form part of the complex technical language used in communication between producers of alloys, manufacturers, designers and stockists and any technical person concerned with materials usage.

American Standards

Americans are not usually familiar with European Standards. They use the Unified Numbering System (UNS), which is the accepted alloy designation system in North America for wrought and cast copper alloy products, managed by ASTM International and SAE International. When comparing the European and American Standards for a particular alloy, care should be taken as the requirements of the standards may not be exactly the same. Minor differences in alloy composition make some close equivalent European alloys unsuitable for the US market.

Grades or Designations in EN Standards

All grades of copper and alloys in the EN standards are given a symbol according to ISO 1190-1 and a number according to EN 1412. For example, the ubiquitous grade of copper used for plumbing tube and other engineering applications is coded with:

- the semi-descriptive symbol e.g. Cu-DHP (Copper - Deoxidised, High Phosphorus)
- a six-character, alpha numeric series which begins with C (copper). The second character indicates the product form (e.g. W for wrought, C for cast). The third, fourth and fifth characters are the digits that allow precise identification of the alloy. The sixth character indicates the alloy group or family: e.g. CW024A.

C	W	024	A
Copper	Wrought	Alloy Code	Group

Representation of Properties in EN Standards

Copper alloys have the advantage that a grade or alloy in the standards may be ordered and specified either by tensile properties (R) or hardness (H), (though not by both). This is referred to as the 'condition' of the alloy. The R is followed by a number signifying the minimum tensile strength in N/mm^2 (MPa), so is easy to remember.

It is not unusual to specify a copper alloy by hardness alone (e.g. H050) and some standards will also provide a guide to proof strength, a key design factor, under these circumstances. Specifying an alloy by tensile properties (e.g. R450, which calls for a minimum tensile strength of 450 N/mm^2) may also require a particular minimum or maximum proof stress to be attained.

Depending upon the method of manufacture, the hardness or mechanical requirements, i.e. condition, will vary slightly. A CuNi18Zn20 rod may be available in different specified conditions depending upon whether it is extruded or drawn to size.

Some examples of alloys specified by either hardness or tensile properties are given in Table 2. If in doubt about how to specify the condition, your supplier should be able to advise.

Table 2 - Mechanical Properties Specified by either Condition R or H

Description	EN	Designation		Condition	Tensile Strength (N/mm^2)		0.2% Proof Strength (N/mm^2)		Elongation (%)	Hardness	
		Symbol	Number		Min.	Max.	Min.	Max.	Min.	Min.	Max.
Copper strip	1652	Cu-DHP	CW024A	R240	240	300	180	-	8	-	-
Copper strip	1652	Cu-DHP	CW024A	H065	-	-	-	-	-	65 HV	95 HV
Tin bronze strip	1652	CuSn6	CW452K	R350	350	420	-	(300)*	45	-	-
Tin bronze strip	1652	CuSn6	CW452K	H080	-	-	-	-	-	80 HV	110 HV
Tin bronze rod	12163	CuSn6	CW452K	R420	420	-	220	-	-	-	-
Brass rod	12163	CuZn30	CW505L	R280	280	-	-	250	45	-	-
Brass strip	1652	CuZn30	CW505L	R270	270	350	-	(160)*	50	-	-
Nickel silver strip	1652	CuNi18Zn20	CW409J	H055	-	-	-	-	-	55 HV	90 HV
Nickel silver rod	12163	CuNi18Zn20	CW409J	R400	400	-	-	290	35	-	-
Nickel silver rod	12163	CuNi18Zn20	CW409J	H095	-	-	-	-	-	95 HB	135 HB
Copper-nickel strip	1652	CuNi10Fe1Mn	CW352H	R300	300	-	(100)*	-	30	-	-
Copper-nickel strip	1652	CuNi10Fe1Mn	CW352H	H070	-	-	-	-	-	70 HV	120 HV
Copper-nickel rod	12163	CuNi10Fe1Mn	CW352H	R280	280	-	90	-	30	-	-
Copper-nickel rod	12163	CuNi10Fe1Mn	CW352H	H100	-	-	-	-	-	100 HB	

* The figures in brackets are provided in the standard for information only.

5. Cu^+ Certification Mark

As the global industry representative, the International Copper Association, Ltd. (ICA), working with New York-based Copper Development Association Inc, has established the Antimicrobial Copper brand and Cu^+ mark. The brand and mark ensure that ICA, and its global network of Copper Centres, collectively known as the Copper Alliance, address stewardship with regard to the deployment of copper and copper alloys in the field.

The use of the Antimicrobial Copper brand and mark by an organisation indicates it has permission to do so based upon adherence to particular rules that guide that organisation's understanding of the underlying technology and the way they promote, advise on and deploy it in line with existing research, regulatory and legislative requirements. The Conditions of Use agreement describes the eligibility criteria for use of the brand and mark, and lists approved alloys. This, and the accompanying application forms, is available on antimicrobialcopper.org. To discuss an application to use the brand, contact your local Copper Centre.

The mark signifies scientific validation backed by peer-reviewed published laboratory and clinical research and independent verification of comprehensive laboratory test data through US EPA registration. Certain alloys not regulated by the EPA are also recognised as antimicrobial outside of the US and have been included within the Cu^+ eligibility criteria. The brand and Cu^+ mark assist specifiers, designers and end users in procurement of both Antimicrobial Copper products and services.

Due to the regulatory position in the US, it is essential for all suppliers into that market to register with the federal EPA and state authorities and to use only those Cu^+ alloys on the EPA approved list in the Conditions of Use.

6. Antimicrobial Testing

Other than the EPA protocol, there is currently no other published protocol or national standard test representing typical in-use conditions for hard surfaces to compare how effectively materials perform when exposed to microbes, making it difficult to make valid comparisons. However, the test developed at Southampton University, which is similar to the EPA protocol, has formed the basis of much of the published work on antimicrobial copper.

The widely used Japanese Industrial Standard, JIS Z 2801 (developed into ISO 22916) does not represent standard indoor touch surface conditions. It has been investigated by the Organisation for Economic Co-operation and Development (OECD) and deemed inappropriate for many applications.

BSI in the UK, working with the OECD, and ASTM in the US, are currently undertaking the development of new test standards recognising the shortcomings of existing standards and inappropriate marketing claims based upon them.

Test houses offering antimicrobial efficacy testing under typical indoor conditions can be located through the Antimicrobial Copper website Services directory at antimicrobialcopper.org.

7. Alloy Selection Criteria

Product design must encompass many factors including aesthetics, economics, ergonomics and engineering. Together, these inform the choice of material and manufacturing route to achieve the most suitable design solution. Copper alloys continue to be widely specified because they are the most suitable material for those applications where they excel. However, the use of copper alloys for key touch surfaces is a relatively new field of design and requires consideration.

While all Cu^+ approved copper alloys perform to a minimum standard, based on the EPA registration testing, as a general rule, efficacy increases with copper content. Alloy selection will often be a balance between aesthetics and antimicrobial efficacy – the higher the copper, the better the efficacy. In long term clinical trials, where copper and alloys have been used in a busy hospital environment, no significant difference in performance has been detected between alloys. This is probably because other factors such as recontamination and cleaning frequency influence the efficacy more than the differences between alloys. This is important as it allows choice to be made on the basis of other factors such as strength, form and colour: copper alloys are stronger and generally easier to fabricate or machine than pure copper.

In cool or refrigerated spaces, copper has been shown to be the most active surface and should be considered first. In such environments, often in pathology departments or food preparation factories, regular cleaning is the norm, so undue tarnishing should not become an issue. Many copper alloys will perform in the same way as, or better than, steel when fabricated into complex shapes by deep drawing or stamping. Brass is specified for complex near to net shape cast components because it holds sharp detail. Many common components use copper alloys specifically because they are easier to work than other materials and offer both technical and economic advantages. Examples where copper alloys are the ubiquitous choice are brass door locks, nickel silver ball pen refills and water taps.

For antimicrobial touch surfaces, often colour will be a primary factor in alloy choice, confining the designer to a small family of alloys – this is why Table 1 is organised by colour. For components where colour may not be important, normal design criteria can be accommodated by one or more of the alloy families. The table highlights representatives of common alloy families and gives the designer the opportunity to work up a prototype in a readily available alloy knowing that it can be subsequently optimised using a different manufacturing technique. For example, a toilet cubicle bolt system may be easily machined from readily available brass plate stock for market testing but later optimised by using finished shape extrusions. Similarly, a stocked size of solid bar may be fabricated by bending into a grab rail and later designed with tube of a standard size.

These raw material choices can be made with the help of an alloy manufacturer, local metal stockists or Copper Centre. In fact, strong partnerships with suppliers often benefit forward-thinking designers as they can be introduced to new processes or subcontractors, allowing innovative products to be manufactured.

8. Cost-effectiveness

Copper alloys continue to be major industrial metals because they are both technically and economically most suited to their chosen application. There are many factors, sometimes overlooked, that contribute to the low costs of copper alloy components:

- Close tolerance manufacturing techniques can be employed so that finishing costs are minimal
- Tooling costs may be significantly lower than for other materials or processes
- Ease of machining means that production costs can be minimised
- In addition to these benefits, the high value of any process scrap can be used to reduce production costs significantly
- The long service life normally expected of well-designed components means that the costs of service failures are minimal
- Copper alloys are easy to work with and can reduce overall manufacturing costs.

9. Hygienic Product Design

When designing functional products with hygiene in mind, selecting an antimicrobial copper alloy is the first step, but consideration also needs to be given to optimising design for the following:

- Avoidance of crevices, rough surfaces, joins and hard-to-reach contours, which could trap dirt
- Surface finish – generally the smoother the finish, the easier it will be to keep clean, although a satin or brushed finish will retain its appearance for longer
- Ease of cleaning and decontamination
- Encouraging touch in specific areas so cleaning staff know where to focus their efforts
- Compatibility with different design schemes
- Importance of colour-matching with other components in a suite of Antimicrobial Copper products (including non-touch surfaces)
- Compliance with local disability laws, which may require colour or shade contrast
- Compliance with relevant product standards, especially in healthcare settings where additional requirements may have to be considered.

10. Environmental Credentials

Copper and copper alloys make sense environmentally through their key attributes of recyclability, positive life cycle analysis and product safety.

Recyclability

Copper is a finite resource, mined from ore deposits formed in the ground millions of years ago. However, little copper is used up since it can be endlessly recycled without loss of properties; it is conserved for future generations. There is a well-established Europe-wide recycling business that has been in place for decades; typically, more than 40% of Europe's copper needs are satisfied from recycled sources.

Recycling also uses only 15% of the energy that would be used to mine and produce the same copper, so recycling copper helps to conserve the world's supply of fossil fuels and reduce CO_2 emissions. Clearly, recycling provides both an economic and environmental benefit.

Life Cycle Data

In the building and construction sector, there is an increasing demand for life cycle data on different materials in order to aid with the selection of environmentally friendly products. The copper industry has developed up-to-date life cycle data for its tube, sheet and wire products. The information has been prepared in co-operation with recognised life cycle practitioners, using international methodologies (ISO standards), leading software (GaBi), and proprietary production data collected across the copper industry. For more information visit www.copper-life-cycle.org.

Safety

The copper industry has undertaken a Voluntary Risk Assessment for copper, the assessment process for which was agreed on behalf of the European Commission and the EU Member States by the Italian Government's Istituto Superiore di Sanità, acting as the review country. One of the conclusions is that 'the use of copper products is in general safe for Europe's environment and the health of its citizens.' This statement has been accepted by the European Commission and EU Member State experts.

11. Conclusion

Copper is a powerful antimicrobial with proven rapid, broad-spectrum efficacy against pathogens threatening public health. Threats exist in many environments including healthcare, food processing and mass transport hubs. Touch surfaces, preparation areas and ventilation systems, in particular, have been identified as major contributors to cross contamination and infection and present opportunities for incorporating copper alloys.

Copper and more than 450 copper alloys that benefit from copper's inherent antimicrobial efficacy (collectively 'Antimicrobial Copper') can be used to upgrade or enhance existing designs of equipment and an introduction to the key alloy families has been made in this publication. The Antimicrobial Copper brand and Cu+ mark provide a trusted acknowledgement of antimicrobial efficacy.

Like other materials, international standards ensure consistency of quality and ease of procurement. Copper alloys are also widely available through long-established and expert primary manufacturers, as well as through stocking organisations. Pre-production samples can be made available to aid alloy selection and suppliers will advise on cost-effective material choices. A network of local Copper Centres is on hand to offer information and technical support.

The alloys are strong and amenable to common fabrication techniques without expensive tool changes and present a new colour palette to designers. In the factory, antimicrobial copper alloys are easy to work and there is a well-developed infrastructure to take advantage of copper's excellent recyclability. In the field, copper alloys are durable, will not lose their intrinsic antimicrobial efficacy over time and are safe to use.

Copper alloys have always held a strong place in the league table of materials due to their exceptional blend of characteristics. With appropriate alloy selection and product design, these materials offer an opportunity to develop cost-effective and innovative hygienic components to enhance any product range.

12. About Copper Alliance

International Copper Association, Ltd. (ICA) and its global Copper Centres, collectively known as the Copper Alliance, are an international network of non-profit trade associations whose common mission is to promote and support the use of copper based on its superior technical performance and its contribution to a higher quality of life.

Cu Copper Alliance

13. Further information

The following websites provide useful additional information and local contact points.

www.antimicrobialcopper.org - information on antimicrobial copper science, case studies, news, events, products and services directories and contacts for national Copper Centres.

www.copperalliance.org.uk - information on properties and applications of copper alloys.

www.copperkey.org - a database of equivalents of copper alloys worldwide, their chemical compositions, material designations and national standards.

www.copper-life-cycle.org - latest life cycle data on copper products.

www.copperalliance.eu - information on the Copper Voluntary Risk Assessment.

www.copperalliance.org - about the Copper Alliance.

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