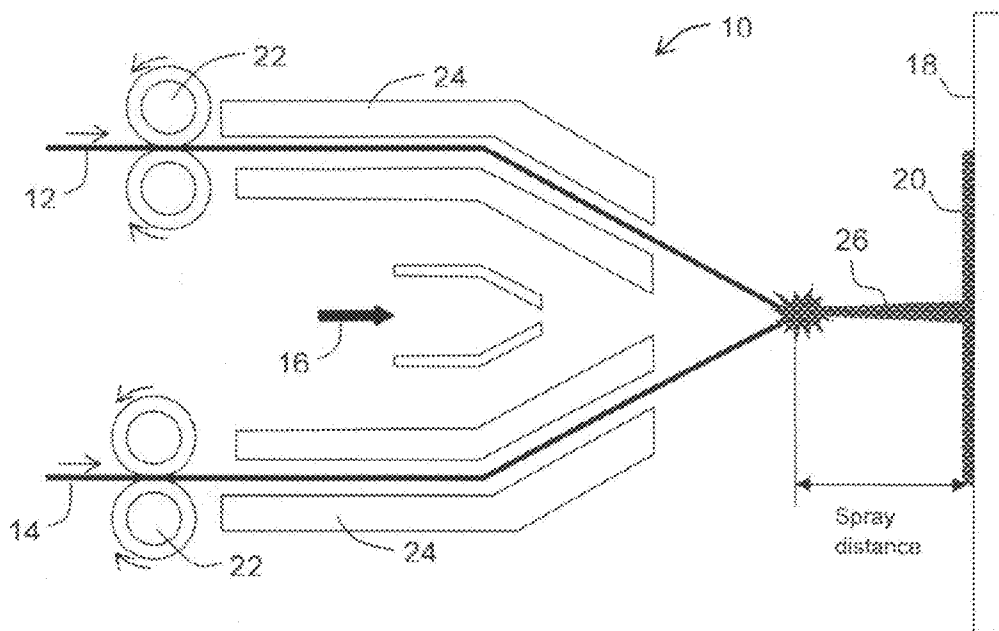




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(19) **United States**(12) **Patent Application Publication**
Pershin et al.(10) **Pub. No.: US 2011/0171396 A1**(43) **Pub. Date: Jul. 14, 2011**(54) **THERMALLY SPRAYED METAL COATINGS
ON WOOD OR WOOD COMPOSITE
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Mississauga (CA)(21) Appl. No.: **12/654,946**(22) Filed: **Jan. 8, 2010****Publication Classification**(51) **Int. Cl.**
C23C 4/06 (2006.01)(52) **U.S. Cl.** **427/456; 427/455**(57) **ABSTRACT**

The present invention provides a method of depositing one or more layers of metal coatings onto an organic substrate. The method includes providing a source of a jet of molten metal particles having an average temperature within a predetermined range, an average velocity within a predetermined range. The jet of molten droplets is then directed at a surface of an organic substrate thereby depositing a metal coating on said organic substrate surface. The source of droplets is spaced from the organic substrate a pre-determined distance, and the average velocity and the average temperature are selected for a given metal such that the temperature of the molten metal particles is very close to the melting point of the metal as the molten droplets coat the surface of the organic substrate to minimize damage to the organic substrate.



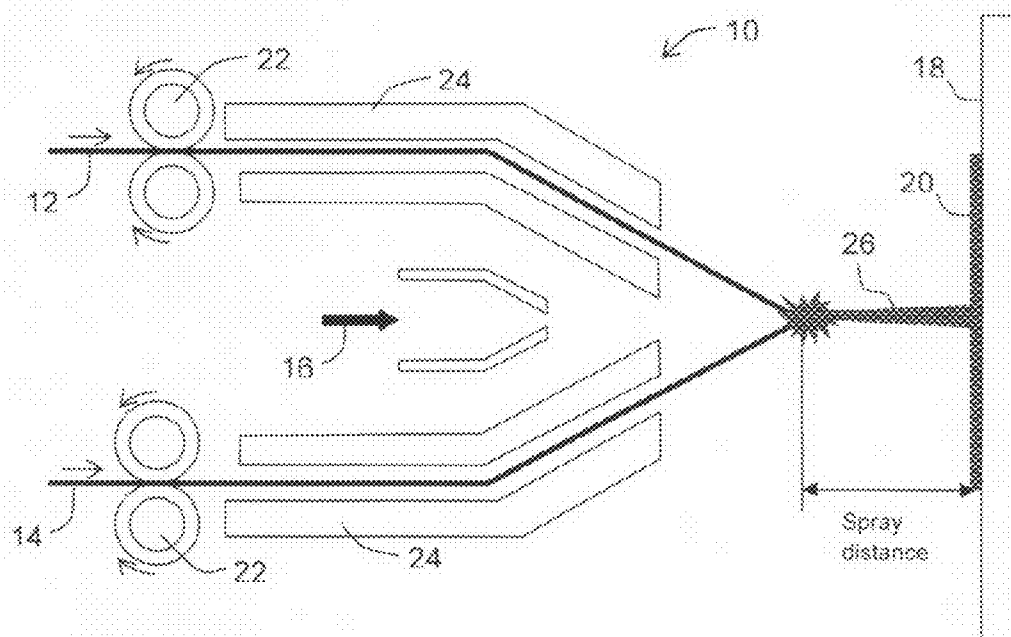


FIGURE 1

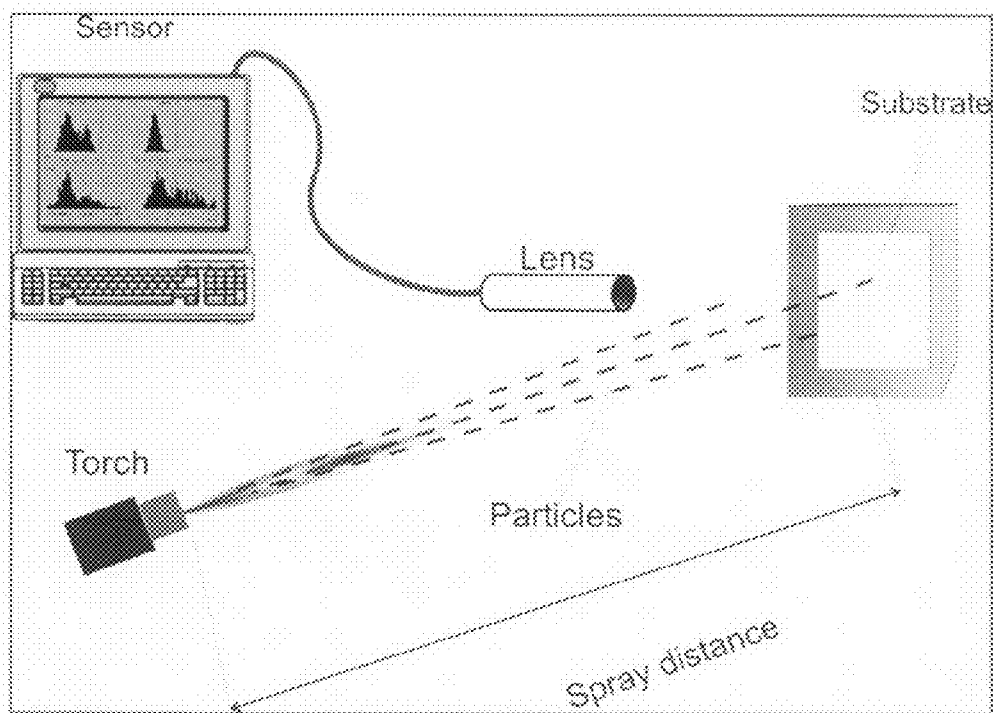


FIGURE 2

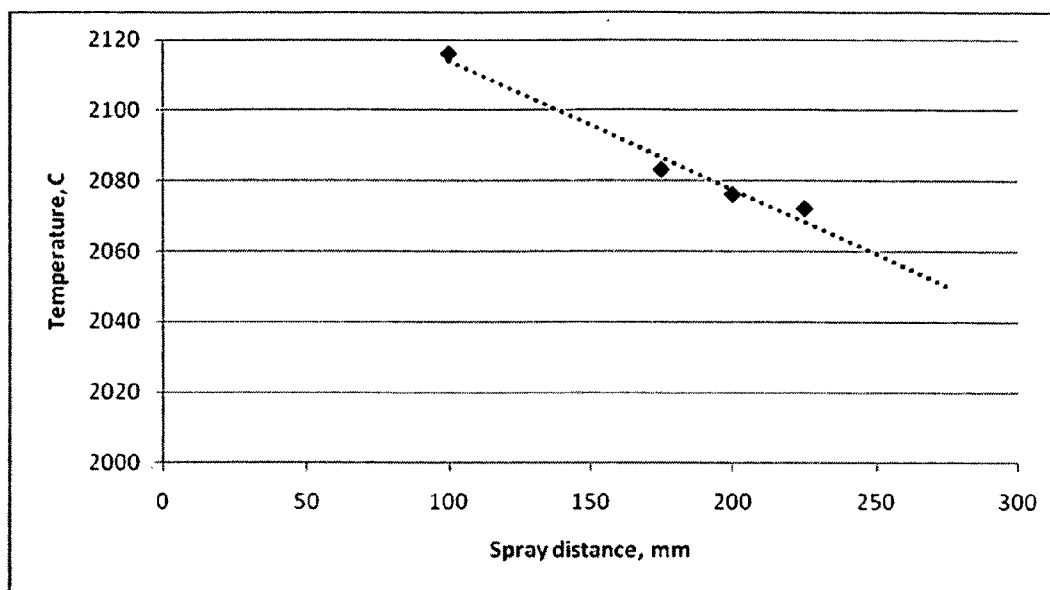
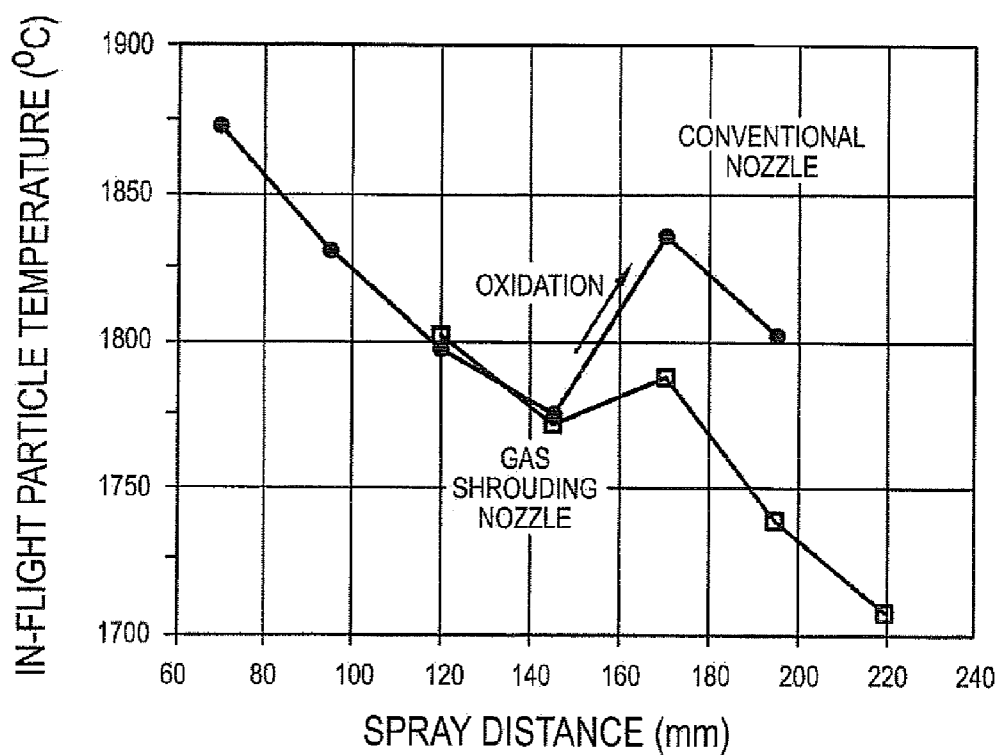


FIGURE 3



VARIATION IN THE IN-FLIGHT PARTICLE
TEMPERATURES ALONG THE SPRAY DISTANCE

FIGURE 4

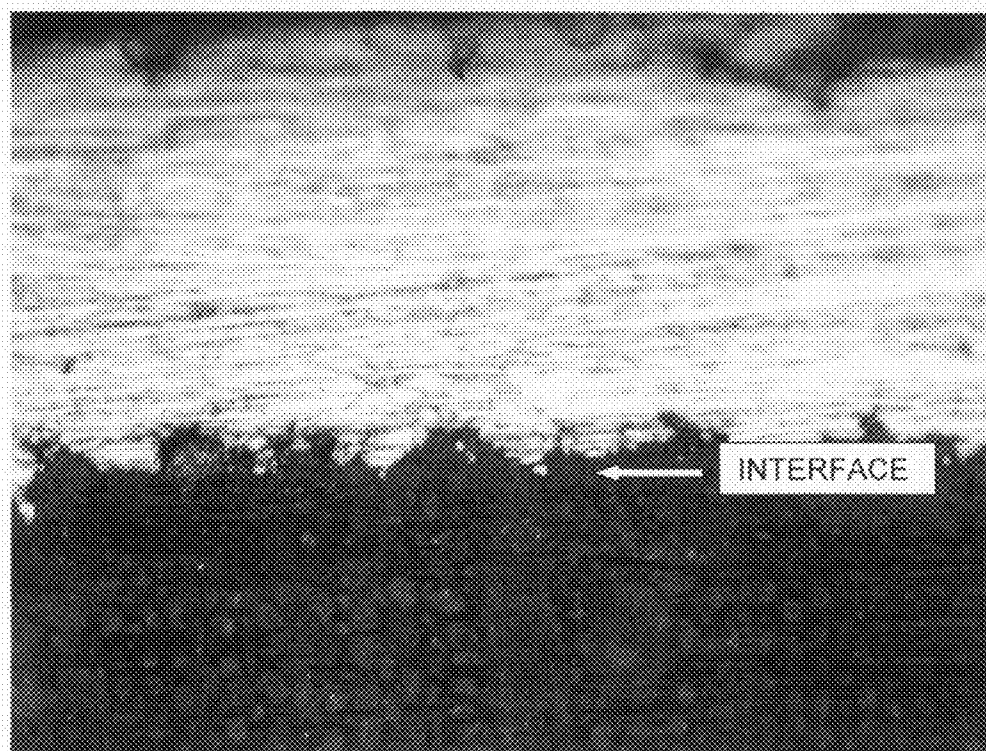


FIGURE 5

THERMALLY SPRAYED METAL COATINGS ON WOOD OR WOOD COMPOSITE SURFACES

FIELD OF THE INVENTION

[0001] The present invention relates to a method for deposition of thermally sprayed coatings on wood or wood composite surfaces for protective and decorative purposes.

BACKGROUND OF THE INVENTION

[0002] Traditionally, exterior wood fixtures such as doors and windows have been protected by polymer based coatings (paints or varnishes) which are prone to deteriorate quickly in the open environment due to UV radiation, seasonal humidity and temperature variations. Vinyl cladding of wood structures offers longer protection of the underlying wood but is not always esthetically appealing. Thick gage metal cladding offers the greatest protection but it is labor intensive to install, there are limitations where the surface being protected has a non planar shape and fine detailing, thereby resulting in a high cost. Wood fixtures that have a thinner layer of sprayed metal coating are expected to be less expensive without limitations to the substrate size and shape and more esthetically pleasing than the existing technologies.

[0003] Moreover, for interior uses copper and its alloys offer antimicrobial properties which will be very advantageous for hospital/institutional uses. The U.S. Environmental Protection Agency has acknowledged [1] the antimicrobial efficacy of copper-based products against the disease-causing bacteria. On Feb. 29, 2008, the EPA registered five copper-containing alloy products. The registration allows the Copper Development Association (CDA) to market these products with a claim that copper, when used in accordance with the label, "kills 99.9% of bacteria within two hours." These products will be marketed in sheets that can be fabricated into various articles such as door knobs, counter tops, hand rails, I.V. (intravenous) poles, and other objects found in commercial, residential, and healthcare settings.

[0004] In many industries for protecting metal substrates from wear, heat or corrosion thermal spray processes are extensively used for coating applications. A thermal spray process utilizes energy of an electric arc or combustion to melt and propel sprayed material towards a substrate. Molten particles upon impact rapidly spread and solidify forming a coating. The coating materials vary from high temperature ceramics to metals with low melting point such as tin or zinc. A feedstock material could be in powder or wire form. Typically, prior to spraying metal surfaces are grid blasted to create surface roughness which is necessary for coating adhesion.

[0005] Prior art attempts to spray molten metal on wood have been unsuccessful as wood is easily burned or tarnished from the high temperature of thermal sprays. Being able to deposit molten metal onto organic surfaces such as hard wood or wood fibers composites would be of great commercial benefit.

SUMMARY OF THE INVENTION

[0006] In order to provide thermally sprayed coatings on organic surfaces, particle impact conditions, i.e. temperature and velocity, are significant parameters in coating formation.

[0007] In an aspect of the present invention, there is provided a method for deposition of metal coatings by means of

thermal spraying on hard wood or wood composite substrates. Prior to spraying, particles temperature in-flight is measured at various spray distances in order to establish the distance where particle temperature is equal or slightly above its melting point for the sprayed metal.

[0008] In a further aspect of the present invention, there is provided a method of depositing one or more layers of metal coatings onto an organic substrate, the method comprising: providing a jet of molten metal particles having an average temperature within a predetermined range; and directing said jet at an organic substrate, thereby depositing a metal coating on said organic substrate. The jet may originate at a point within a predetermined range from the organic substrate. The organic substrate may be hardwood (such as ash, mahogany, maple, birch, etc.), or wood fibers-polymer composites.

[0009] An embodiment of the invention includes a method of depositing one or more layers of metal coatings onto an organic substrate, the method comprising:

[0010] providing a source of a jet of molten metal particles having an average temperature within a predetermined range, an average velocity within a predetermined range; and

[0011] directing said jet of molten metal particles at a surface of an organic substrate thereby depositing a metal coating on said organic substrate surface, said source being spaced from said organic substrate a pre-determined distance, and said average velocity and said average temperature being selected for a given metal such that the temperature of the molten metal particles is very close to the melting point of the metal as the molten droplets coat the surface of the organic substrate to minimize damage to the organic substrate.

[0012] In a further aspect of the present invention, the a first layer is deposited onto the organic substrate, followed by a second layer deposited onto the first layer, the second layer having a higher melting point than the first layer.

[0013] A further understanding of the functional and advantageous aspects of the present invention can be realized by reference to the following detailed description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Preferred embodiments of the invention will now be described, by way of example only, with reference to the drawings, in which:

[0015] FIG. 1 is a schematic cross-section of a wire arc thermal spray gun;

[0016] FIG. 2 shows the setup for particle in-flight temperature measurements;

[0017] FIG. 3 shows particle in-flight temperature evolution of stainless steel sprayed by wire-arc;

[0018] FIG. 4 shows in-flight temperature variation as a function of spray distance from Ref [6]; and

[0019] FIG. 5 shows an optical microscope photograph of a cross section of a hardwood maple substrate coated with brass by wire-arc spraying without damaging the wood surface.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Without limitation, the majority of the systems described herein are directed to a thermal spray system. As required, embodiments of the present invention are disclosed herein. However, the disclosed embodiments are merely exemplary, and it should be understood that the invention may be embodied in many various and alternative forms.

[0021] The figures are not to scale and some features may be exaggerated or minimized to show details of particular elements while related elements may have been eliminated to prevent obscuring novel aspects. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention. For purposes of teaching and not limitation, the illustrated embodiments are directed to a thermal spray system.

[0022] As used herein, the term “about”, when used in conjunction with ranges of dimensions, velocities, temperatures or other physical properties or characteristics is meant to cover slight variations that may exist in the upper and lower limits of the ranges of dimensions as to not exclude embodiments where on average most of the dimensions are satisfied but where statistically dimensions may exist outside this region. For example, in embodiments of the present invention dimensions of components of a thermal spray system are given but it will be understood that these are non-limiting.

[0023] In a preferred embodiment of the present invention, metal is deposited onto a substrate via an electric arc wire spray process. A functional schematic of the process is shown in FIG. 1 which illustrates a wire arc spray gun generally at 10. During the coating process, a large voltage is applied between two metallic wires 12 and 14 such that high currents flow between the wires.

[0024] Compressed air 16 atomizes the molten material and accelerates the metal into a jet 26 which contacts substrate 18 to form a coating 20. The wires are fed using rollers 22 and guided by wire guides 24. The wires may be of any metal; non-limiting examples include bronze, copper, aluminum, or stainless steel.

[0025] It will be appreciated by those skilled in the art that many other methods of deposition may be used and it is understood that the present invention is not restricted to the use of the wire arc spray process to deposit the metal layers, although it is the most cost effective and robust process and thus is a preferred embodiment. Other types of thermal spray such as flame spray, plasma spray, high-velocity oxygen-fuel spray, kinetic or cold spray, may be used in place of the wire arc spray gun 10 of FIG. 1.

[0026] One of the important features of the present process is that the thermal spraying passes a relatively low heat load to the substrate. This feature is important as it allows one to spray metal coatings on heat sensitive materials such as solid organic substrates, e.g. wood or wood composites. To protect wood substrates from decomposition, it is preferable that the incoming metal plume spray is at the lowest temperature possible. At the point of impact between the jet 26 and substrate 18, the metal particles should be molten but still have a temperature close to the melting point of the metal.

[0027] Accordingly, the particle temperature may be measured optically by two-color pyrometry to determine an optimal spray distance depending on melting point of the sprayed metal, as shown in FIG. 2. Among systems for in-flight particle temperature measurements available on the market, DPV-2000 and Accuraspray are well-established systems manufactured by TECNAR Automation Ltd., St-Bruno, Qc, Canada [2].

[0028] Prior applying the coating onto a surface of a substrate, in-flight particle conditions such as temperature, velocity, size and number of particles are measured for the particular metal being deposited along the centerline of the

particulate plume by a sensor at various spray distances. Since particles in-flight are cooled by ambient air, substantially all particles will solidify after travelling a certain distance. Based on these measurements one can determine at what distance from the surface of the substrate 18 being coated the particles temperature is close to its melting point but are not yet solidified and are still in a molten phase. As a result, a set of spray parameters such as spray distance and torch input power for specific metallic materials is established. This set of parameters will allow the deposition of metal coatings with minimal damage to wood substrate. The data shown in FIG. 3 obtained by the inventors in combination with data from Ref [6] show examples of particle temperature evolution during flight, in which temperature is plotted as a function of spray distance for stainless steel particles during wire-arc spray. The plot illustrates the inverse relationship between spray distance and mean particle temperature.

[0029] Based on the authors tests and data available in literature the optimal spray distance for stainless steel was established in a range from about 350 to about 400 mm. For copper and its alloys the distance was from about 270 to 300 mm. The spray distance is defined as a distance from nozzle or tip of the spray gun to the substrate.

[0030] In order to reduce substrate damage the coating is preferably rapidly cooled down immediately after it is deposited. The temperature should be reduced from the melting point of the metal to a temperature safe for the substrate, typically below about 150° C. This cooling will be provided by air jets directed to the spray area. The air flow rate will depend on several parameters including the distance of the air nozzle from the substrate surface, nozzle diameter, deposition rate and metal thermal properties. For instance the applicants calculations show that for an air jet with a 25 mm diameter placed at a distance of 50 mm from the surface when the spraying rate is approximately 54 g/min, the air flow should be somewhere between 50 to 250 l/min. The higher the flow rate, the more effective the cooling of the substrate will be.

[0031] Metal bonds to organic substrates in different ways depending on the nature of the substrate. The choice of substrate has an effect on the coating procedure. In a preferred embodiment of the present invention, the substrate is a hardwood. Microscopic observations show that hardwoods have specialized structures called vessels for conducting sap vertically, which on the end grain appear as pores. Therefore, hardwoods are referred to as porous woods in contrast to nonporous softwoods in which the sap is transferred vertically only through cells called tracheids. The pores of hardwoods vary considerably in size, being visible without a magnifying glass in some species but not in others [3].

[0032] The surface morphology of hardwoods allows deposition of metal coating without any surface conditioning like grit blasting or cutting grooves as it was required in prior art [4,5]. Using a hardwood maple substrate and proper spray distance it was possible to deposit well adhered brass coating by wire-arc spraying without damaging the wood surface. The sample was cut polished and the coating-substrate interface was photographed under optical microscope (FIG. 5). The interface shows that the coating penetrates into substrate grains/roughness providing good adhesion.

[0033] The type of organic substrates that can be coated using the method disclosed herein include hardwoods with a fine porous wood interface such as Mahogany, Oak, Ash, Hard Maple, Birch or Beech. The choice of wood may depend on the amount interface desired. Mahogany, Oak, and Ash

have a very porous surface which would give the greatest mechanical bond. Hard Maple, Beech and other smaller grain hardwoods the least interface. The wood selection would depend on the end use, weather for interior or exterior applications.

[0034] Moisture content of hard wood substrates should be controlled by Kiln drying according to industry standards to ensure a good mechanical bond. Any woods with high resin content such as soft woods (pine, fur etc) should be avoided, because the nature of these woods will compromise the adhesion of the metal layer to the wood surface.

[0035] In addition to the temperature of the droplets as they hit the substrate surface, studies by the inventors have shown that particle velocity is also an important parameter. The inventors studies of the wire-arc process show that the metal particles acceleration continues to distances 170-200 mm depending on the process parameters, primarily on atomizing gas flow rate and the metal density. At longer spray distances for organic substrates particle velocities may be adjusted by increasing of atomizing gas flow rate or using spray guns which provide higher particle velocities.

[0036] The process disclosed herein is not restricted to depositing one layer of metal. Different types of metals may be applied, in successive layers. In a preferred embodiment, the layer closest to the surface of the substrate **18** has a low melting point, and successive layers have higher melting points. This ensures that the substrate surface is not damaged by high temperatures, and that the outer layers are more resilient. Non-limiting examples of metals that may be used include aluminum and its alloys, copper and its alloys, silver and its alloys, zinc, tin, and combinations thereof.

[0037] The coatings may have thickness between about 100 and about 400 micrometers depending on the purpose of the coating (protective or decorative), the environment in which the coated article will be located (interior, exterior, cold, warm etc.) but it will be appreciated the thickness of the final coating(s) is not restricted to this range.

[0038] Subsequent to coating with metal, the wood may require post-treatment such as polishing and coating with a sealant. Use of a sealant to seal inherited porosity of thermally sprayed coatings will provide longer protection for the organic substrate. A sealant could be a low viscosity polymer solution from but not limited to polymers such as phenolic, epoxy, urethane, silicone or acrylic.

[0039] More particularly, acrylic coatings are available in air drying or thermosetting compositions, acrylics are relatively high cost materials. The air drying modifications are popular for exterior applications, while the thermosetting types are useful for interior applications requiring high resistance to heat and abrasion. Since the thermosetting coatings are not conveniently stripped, they are unsuitable for major architectural applications.

[0040] Epoxy coatings have excellent resistance to wear and chemicals. They are relatively expensive and are only available in thermosetting or two part (catalyst activated) compositions with relatively short pot lives. They are good for severe indoor applications, but they degrade rapidly and darken in a few months of exterior service.

[0041] Silicone coatings provide the best potential for coatings which must operate at elevated temperatures. Thin films of these high-cost coatings are used and protection by a second coat of a more durable abrasion resistant lacquer may be necessary. Ultraviolet absorbing compounds are added to prevent darkening of the silicone during exterior exposures.

[0042] Alkyd coatings are slow drying and baking is required when applying the alkyd coatings. Modified with melamine resins, these coatings are low cost and durable enough for exterior applications. Resistance to chemicals is usually good.

[0043] Urethane coatings may be used but color degradation on exterior exposure has been a problem with urethane coatings. Resistance to chemicals and abrasion are good even for the air drying coatings.

[0044] Polyvinyl fluoride films (Tediars) may be applied by roll bonding with an adhesive. Tedlar films have been used to protect sheet copper in exterior applications. It has been projected that these clear films can protect a properly prepared substrate for twenty years or more.

[0045] As used herein, the terms "comprises", "comprising", "includes" and "including" are to be construed as being inclusive and open ended, and not exclusive. Specifically, when used in this specification including claims, the terms "comprises", "comprising", "includes" and "including" and variations thereof mean the specified features, steps or components are included. These terms are not to be interpreted to exclude the presence of other features, steps or components.

[0046] The foregoing description of the preferred embodiments of the invention has been presented to illustrate the principles of the invention and not to limit the invention to the particular embodiment illustrated. It is intended that the scope of the invention be defined by all of the embodiments encompassed within the following claims and their equivalents.

REFERENCES

- [0047]** 1. EPA website (<http://www.epa.gov/pesticides/factsheets/copper-alloy-products.htm>)
- [0048]** 2. F. Bissons, M. Lamontagne, C. Moreau, L. Pouliot, J. Blain, and F. Nadeau, Ensemble In-flight Particle Diagnostics under Thermal Spray Conditions, *Thermal Spray 2001: New Surfaces for a New Millennium*, C. C. Berndt, K. A. Khor, and E. F. Lugscheider, Ed., May 28-30, 2001 (Singapore), ASM International, 2001, p 705-714.
- [0049]** 3. "Structure of Wood." Research Note FPL-04, Forest Products Laboratory, US Department of Agriculture, March 1980.
- [0050]** 4. GB461988A
- [0051]** 5. U.S. Pat. No. 2,157,456
- [0052]** 6. J-H. Kim, B.Seong, J-H. Ahn "Nozzle Modification for Property Improvement of Arc Spray-formed Steel Tools" RIST 研究文 第 20 卷 第 4 号 (2006) pp 294-299

Therefore, what is claimed is:

1. method of depositing one or more layers of metal coatings onto an organic substrate, the method comprising:
 - a) providing a source of a jet of molten metal particles having an average temperature within a predetermined range, an average velocity within a predetermined range; and
 - b) directing said jet of molten metal particles at a surface of an organic substrate thereby depositing a metal coating on said organic substrate surface, said source being spaced from said organic substrate a pre-determined distance, and said average velocity and said average temperature being selected for a given metal such that the temperature of the molten metal particles is very close to the melting point of the metal as the molten droplets coat the surface of the organic substrate to minimize damage to the organic substrate.

2. The method of claim 1 wherein the metal coating has a thickness between about 100 and about 500 micrometers.

3. The method of claim 1 wherein the molten metal particles are selected from the group consisting of aluminum and its alloys, copper and its alloys, silver and its alloys, zinc, tin, stainless steel and any combination thereof.

4. The method of claim 1 wherein the organic substrate is hard wood.

5. The method of claim 1 wherein the jet of molten metal particles are provided by a wire arc spray gun.

6. The method of claim 1 wherein, subsequent to step (b), the organic substrate is post-treated with a sealant.

7. The method of claim 6 wherein the sealant is selected from the group consisting of: acrylic coatings, epoxy coatings, silicone coatings, alkyd coatings, urethane coatings and polyvinyl fluoride.

8. The method of claim 1 wherein the organic substrate is selected from the group consisting of: Hard Maple, Oak, Birch, Ash, Mahogany family, Beech, and any other hard woods.

9. The method of claim 1 wherein the organic substrate is a polymer-wood fibers composite.

10. The method of claim 1 wherein the wood is chosen to have a moisture content Kiln dried to that woods industries standards.

11. The method of claim 1 wherein a first coating is deposited onto the organic substrate, followed by a second coating deposited onto the first coating.

12. The method of claim 1 wherein the metal of the second coating has a higher melting point than the metal of the first coating.

13. The method of claim 1 including directing a gas jet at said substrate to cool the deposited metal coating.

14. The method of claim 13 wherein said gas jet is an air jet.

* * * * *