United States Patent Application Publication	20250257445
Kind Code	A1
Publication Date	August 14, 2025
Inventor(s)	Xu; Wei et al.

Coating Control System and Method of Controlling a Coating

Abstract

A computer-implemented method for automatically controlling a component of a coating applicator includes: identifying a first coated substrate including a substrate including a surface over which at least one coating layer is positioned, the at least one coating layer positioned over the surface using at least one applicator; in response to identifying the first coated substrate, determining a target coating profile corresponding to the first coated substrate; determining an actual coating profile for the first coated substrate; generating a deviation coating profile for the first coated substrate by comparing the target coating profile to the actual coating profile; inputting the deviation coating profile into a model based on experimental coating control data; and generating, with the model, at least one control instruction for adjusting at least one component of the at least one applicator based on the deviation coating profile prior to coating a second substrate according to the target coating profile.

Inventors: **Xu; Wei (Cheswick, PA), Curliss; Neil (Salem, OR), Dunlap; Zachary (Woodburn, OR), Duong; Amanda (Salem, OR), Gerasimenko; Aleksandr (Wichita Falls, TX), Gibbs; Benjamin (Allison Park, PA), Mahapatra; Priyadarshi (Pittsburgh, PA), Schrier; Russell W. (Oakmont, PA), Wagner; Andrew V. (Pittsburgh, PA)**

Applicant: **Vitro Flat Glass LLC.** (Cheswick, PA)

Family ID: **96661820**

Appl. No.: **19/046969**

Filed: **February 06, 2025**

Related U.S. Application Data

us-provisional-application US 63551692 20240209
us-provisional-application US 63691721 20240906

Publication Classification

Int. Cl.: **C23C14/54** (20060101); **C03C17/00** (20060101); **C23C14/35** (20060101)

U.S. Cl.:

CPC **C23C14/545** (20130101); **C03C17/002** (20130101); **C23C14/35** (20130101); C03C2218/156 (20130101)

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application claims priority to U.S. Provisional Patent Application Nos. 63/551,692 filed Feb. 9, 2024, and 63/691,721 filed Sep. 6, 2024, the disclosures of which are hereby incorporated by reference in their entireties.

BACKGROUND
Field
[0002] The present disclosure is directed to a method for automatically controlling a component of a coating applicator. The present disclosure is also directed to a system for automatically controlling a component of a coating applicator.
Technical Considerations
[0003] Existing systems for forming coated substrates manually control the thickness uniformity of the coatings being applied to the substrate. However, these systems can be unreliable, at least because they depend upon the experience of the operator manually controlling the coating applicator and taking suitable corrective action.
SUMMARY OF THE DISCLOSURE
[0004] According to some non-limiting aspects of the disclosure, a computer-implemented method for automatically controlling a component of a coating applicator includes: identifying, with at least one processor, a first coated substrate including a substrate including a surface over which at least one coating layer is positioned, the at least one coating layer positioned over the surface using at least one applicator; in response to identifying the first coated substrate, determining, with at least one processor, a target coating profile corresponding to the first coated substrate; determining, with at least one processor, an actual coating profile for the first coated substrate; generating, with at least one processor, a deviation coating profile for the first coated substrate by comparing the target coating profile to the actual coating profile; inputting, with at least one processor, the deviation coating profile into a model based on experimental coating control data; and generating, with the model, at least one control instruction for adjusting at least one component of the at least one applicator based on the deviation coating profile prior to coating a second substrate according to the target coating profile.
[0005] In some non-limiting aspects, the computer-implemented method may further include: automatically adjusting, with at least one processor, the at least one component of the at least one applicator based on the at least one control instruction.
[0006] In some non-limiting aspects, the computer-implemented method may further include: displaying, with at least one processor, the at least one control instruction on a user interface of a computing device of a user.
[0007] In some non-limiting aspects, the substrate may include glass.
[0008] In some non-limiting aspects, the first coated substrate may include the surface over which a coating stack including a plurality of coating layers is positioned.
[0009] In some non-limiting aspects, the deviation coating profile may be determined after a first

layer of the coating stack is positioned on the surface but before a second layer of the coating stack is positioned over the first layer.

[0010] In some non-limiting aspects, the deviation coating profile may be determined after the plurality of coating layers of the coating stack are positioned over the surface.

[0011] In some non-limiting aspects, determining the actual coating profile includes: taking, with at least one processor, at least one color measurement of the first coated substrate; inputting, with at least one processor, the at least one color measurement to a second model based on experimental color to thickness data; and generating, with the second model, the actual coating profile based on the at least one color measurement.

[0012] In some non-limiting aspects, the target coating profile and/or the actual coating profile may provide a target and/or actual coating thickness for at least one layer of the at least one coating layer relative to a position on the surface.

[0013] In some non-limiting aspects, the at least one applicator may include a vacuum coating applicator.

[0014] In some non-limiting aspects, the vacuum coating applicator may include at least one gas inlet through which at least one reactive or non-reactive gas is flowed to deposit the at least one coating layer on the surface, where the at least one control instruction may include a control instruction for adjusting a flow rate of the gas through the at least one gas inlet for depositing a coating layer on the second substrate according to the target coating profile.

[0015] In some non-limiting aspects, the vacuum coating applicator may include a magnet bar arranged at a height above the surface to deposit the at least one coating layer on the surface, where the at least one control instruction may include a control instruction for adjusting the height of the magnet bar above the surface for depositing a coating layer on the second substrate according to the target coating profile.

[0016] In some non-limiting aspects, the magnet bar may include a plurality of nodes configured to adjust a height of a section of the magnet bar above the surface, where the at least one control instruction may include a control instruction for only a subset of the plurality of nodes to adjust the height of a corresponding section of the magnet bar above the surface for depositing a coating layer on the second substrate according to the target coating profile.

[0017] In some non-limiting aspects, identifying the first coated substrate may include scanning an identifier associated with the first coated substrate.

[0018] In some non-limiting aspects, the first coated substrate may include the surface over which a coating stack including a plurality of coating layers is positioned, where a plurality of applicators may be provided, each applicator of the plurality of applicators configured to apply a different layer of the plurality of layers of the coating stack, where generating the at least one control instruction may include: determining, with the model, at least one applicator of the plurality of applicators requiring adjustment to obtain the target coating profile based on the deviation coating profile; and generating, with the model, the at least one control instruction for at least one component of the at least one applicator of the plurality of applicators requiring adjustment to obtain the target coating profile.

[0019] In some non-limiting aspects, not including a step of directly measuring a thickness of the at least one coating layer.

[0020] In some non-limiting aspects, the at least one control instruction may be generated in response to the model determining that at least a portion of the deviation coating profile satisfies a threshold.

[0021] In some non-limiting aspects, the computer-implemented method may further include: applying, with the adjusted at least one component of the at least one applicator, at least one second coating layer to a surface of the second substrate according to the target coating profile.

[0022] In some non-limiting aspects, the computer-implemented method may further include: automatically identifying, with at least one processor, at least one parameter of the at least one applicator and/or a parameter of a coating process for coating the substrate; and inputting the at least one parameter to the model, where the at least one control instructions may be generated by the model based on the at least one parameter.

[0023] In some non-limiting aspects, inputting the deviation coating profile into the model may include inputting coating profile data associated with a first layer of the plurality of layers and a second layer of the plurality of layers, where the at least one control instruction for adjusting the at least one component of the at least one applicator may be generated to cause the at least one applicator to apply a first layer of a plurality of layers on the second substrate based on the coating profile data associated with the first layer of the plurality of layers and the second layer of the plurality of layers.

[0024] In some non-limiting aspects, determining the actual coating profile for the first coated substrate may include determining a thickness of a first layer of the at least one coating layer, the determined thickness of the first layer of the at least one coating layer different from a thickness for the first layer of the at least one coating layer from the target coating profile, where the at least one control instruction for adjusting the at least one component of the at least one applicator may be generated to cause the at least one applicator to apply a first layer of at least one coating layer on the second substrate at a different thickness compared to the determined thickness of the first layer of the at least one coating layer from the first coated substrate.

[0025] In some non-limiting aspects, the first coated substrate may include a post-tempered substrate having the actual coating profile formed by heating a pre-tempered first substrate having a pre-tempered coating profile, where generating the at least one control instruction may include the model: receiving the input including the deviation coating profile; analyzing experimental coating control data including a plurality of historical pre-tempered coating profiles; determining a first historical pre-tempered coating profile from the plurality of historical pre-tempered coating profiles; and generating the at least one control instruction for adjusting the at least one component of the at least one applicator to cause the at least one applicator to apply the first historical pre-tempered coating profile to a pre-tempered second substrate.

[0026] In some non-limiting aspects, the computer-implemented method may further include: determining, with the model, that the at least one component of the at least one applicator is malfunctioning or satisfies a limit based on the deviation coating profile; and maintenancing the at least one component of the at least one applicator.

[0027] In some non-limiting aspects, the computer-implemented method may further include: in response to determining that the at least one component of the at least one applicator is malfunctioning or satisfies a limit based on the deviation coating profile, automatically updating the model based on the malfunctioning or satisfaction of the limit by generating a control instruction that distributes an adjustment to a remainder of components of the at least one applicator.

[0028] In some non-limiting aspects, the first coated substrate may include a post-tempered substrate having the actual coating profile formed by heating a pre-tempered first substrate having a pre-tempered coating profile, where generating the at least one control instruction may include the model: receiving the input including the deviation coating profile and the pre-tempered coating profile, the deviation coating profile comparing the target coating profile of the post-tempered substrate to the actual coating profile; comparing the pre-tempered coating profile to the actual coating profile; and generating the at least one control instruction for adjusting the at least one component of the at least one applicator based on the comparison of the pre-tempered coating profile to the actual coating profile.

[0029] According to some non-limiting aspects of the disclosure, a system for automatically controlling a component of a coating applicator includes: at least one applicator configured to prepare a first coated substrate including a substrate including a surface over which at least one coating layer is positioned; and a control system including at least one processor programmed or configured to: identify the first coated substrate; in response to identifying the first coated substrate, determine a target coating profile corresponding to the first coated substrate; determine an actual coating profile for the first coated substrate; generate a deviation coating profile for the first coated substrate by comparing the target coating profile to the actual coating profile; input the deviation coating profile into a model based on experimental coating control data; and generate, with the model, at least one control instruction for adjusting at least one component of the at least one applicator based on the deviation coating profile prior to coating a second substrate according to the target coating profile.

[0030] In some non-limiting aspects, the at least one component of the at least one applicator may include an adjustor, where the at least one processor may be programmed or configured to cause the adjustor to adjust the at least one component based on the at least one control instruction.

[0031] In some non-limiting aspects, the system may further include a computing device of a user, the computing device including a user interface configured to display the at least one control instruction.

[0032] In some non-limiting aspects, the system may further include: a measurement device configured to take at least one color measurement of the first coated substrate; and a second model based on experimental color to thickness data and to which the at least one color measurement is input, where the second model may be programmed or configured to generate the actual coating profile based on the at least one color measurement.

[0033] In some non-limiting aspects, the at least one applicator may include a vacuum coating applicator.

[0034] In some non-limiting aspects, the vacuum coating applicator may include at least one gas inlet through which at least one reactive or non-reactive gas is flowed to deposit the at least one coating layer on the surface, where the at least one control instruction may include a control instruction for adjusting a flow rate of the gas through the at least one gas inlet for depositing a coating layer on the second substrate according to the target coating profile.

[0035] In some non-limiting aspects, the vacuum coating applicator may include a magnet bar arranged at a height above the surface to deposit the at least one coating layer on the surface, where the at least one control instruction may include a control instruction for adjusting the height of the magnet bar above the surface for depositing a coating layer on the second substrate according to the target coating profile.

[0036] In some non-limiting aspects, the magnet bar may include a plurality of nodes configured to adjust a height of a section of the magnet bar above the surface, where the at least one control instruction may include a control instruction for only a subset of the plurality of nodes to adjust the height of a corresponding section of the magnet bar above the surface for depositing a coating layer on the second substrate according to the target coating profile.

[0037] In some non-limiting aspects, the system may further include a scanner configured to identify the first coated substrate by scanning an identifier associated with the first coated substrate.

[0038] In some non-limiting aspects, the first coated substrate may include the surface over which a coating stack comprising a plurality of coating layers is positioned, where the at least one applicator may include a plurality of applicators, each applicator of the plurality of applicators configured to apply a different layer of the plurality of layers of the coating stack, where generating the at least one control instruction may include: determining, with the model, at least one applicator of the plurality of applicators requiring adjustment to obtain the target coating profile based on the deviation coating profile; and generating, with the model, the at least one control instruction for at least one component of the at least one applicator of the plurality of applicators requiring adjustment to obtain the target coating profile.

[0039] In some non-limiting aspects, the system does not include a device for directly measuring a thickness of the at least one coating layer.

[0040] In some non-limiting aspects, the model may be programmed or configured to generate the at least one control instruction in response to determining that at least a portion of the deviation coating profile satisfies a threshold.

[0041] In some non-limiting aspects, the adjusted at least one component may be configured to apply at least one second coating layer to a surface of the second substrate according to the target coating profile.

[0042] In some non-limiting aspects, the at least one applicator may include a magnetron sputtering vapor deposition (MSVD) applicator.

[0043] In some non-limiting aspects, the first coated substrate may include the surface over which a coating stack including a plurality of coating layers is positioned, where inputting the deviation coating profile into the model may include inputting coating profile data associated with a first layer of the plurality of layers and a second layer of the plurality of layers, where the at least one control instruction for adjusting the at least one component of the at least one applicator may be generated to cause the at least one applicator to apply a first layer of a plurality of layers on the second substrate based on the coating profile data associated with the first layer of the plurality of layers and the second layer of the plurality of layers.

[0044] In some non-limiting aspects, determining the actual coating profile for the first coated substrate may include the at least one processor determining a thickness of a first layer of the at least one coating layer, the determined thickness of the first layer of the at least one coating layer different from a thickness for the first layer of the at least one coating layer from the target coating profile, where the at least one control instruction for adjusting the at least one component of the at least one applicator may be generated to cause the at least one applicator to apply a first layer of at least one coating layer on the second substrate at a different thickness compared to the determined thickness of the first layer of the at least one coating layer from the first coated substrate.

[0045] In some non-limiting aspects, the first coated substrate may include a post-tempered substrate having the actual coating profile formed by heating a pre-tempered first substrate having a pre-tempered coating profile, where generating the at least one control instruction may include the model: receiving the input including the deviation coating profile; analyzing experimental coating control data including a plurality of historical pre-tempered coating profiles; determining a first historical pre-tempered coating profile from the plurality of historical pre-tempered coating profiles; and generating the at least one control instruction for adjusting the at least one component of the at least one applicator to cause the at least one applicator to apply the first historical pre-tempered coating profile to a pre-tempered second substrate.

[0046] In some non-limiting aspects, the at least one processor may be further programmed or configured to determine, with the model, that the at least one component of the at least one applicator is malfunctioning or satisfies a limit based on the deviation coating profile, where the at least one component of the at least one applicator may be maintenanced based on the determination that the at least one component of the at least one applicator is malfunctioning or satisfies a limit.

[0047] In some non-limiting aspects, the at least one processor may be further programmed or configured to: in response to determining that the at least one component of the at least one applicator is malfunctioning or satisfies a limit based on the deviation coating profile, automatically update the model based on the malfunctioning or satisfaction of the limit by generating a control instruction that distributes an adjustment to a remainder of components of the at least one applicator.

[0048] In some non-limiting aspects, the first coated substrate may include a post-tempered substrate having the actual coating profile formed by heating a pre-tempered first substrate having a pre-tempered coating profile, where generating the at least one control instruction may include the model: receiving the input including the deviation coating profile and the pre-tempered coating profile, the deviation coating profile comparing the target coating profile of the post-tempered substrate to the actual coating profile; comparing the pre-tempered coating profile to the actual coating profile; and generating the at least one control instruction for adjusting the at least one component of the at least one applicator based on the comparison of the pre-tempered coating profile to the actual coating profile.

[0049] The following numbered clauses are illustrative of various aspects of the disclosure:

[0050] Clause 1: A computer-implemented method for automatically controlling a component of a coating applicator, comprising: identifying, with at least one processor, a first coated substrate comprising a substrate comprising a surface over which at least one coating layer is positioned, the at least one coating layer positioned over the surface using at least one applicator; in response to identifying the first coated substrate, determining, with at least one processor, a target coating profile corresponding to the first coated substrate; determining, with at least one processor, an actual coating profile for the first coated substrate; generating, with at least one processor, a deviation coating profile for the first coated substrate by comparing the target coating profile to the actual coating profile; inputting, with at least one processor, the deviation coating profile into a model based on experimental coating control data; and generating, with the model, at least one control instruction for adjusting at least one component of the at least one applicator based on the deviation coating profile prior to coating a second substrate according to the target coating profile.

[0051] Clause 2: The computer-implemented method of clause 1, further comprising: automatically adjusting, with at least one processor, the at least one component of the at least one applicator based on the at least one control instruction.

[0052] Clause 3: The computer-implemented method of clause 1 or 2, further comprising: displaying, with at least one processor, the at least one control instruction on a user interface of a computing device of a user.

[0053] Clause 4: The computer-implemented method of any of clauses 1-3, wherein the substrate comprises glass.

[0054] Clause 5: The computer-implemented method of any of clauses 1-4, wherein the first coated substrate comprises the surface over which a coating stack comprising a plurality of coating layers is positioned.

[0055] Clause 6: The computer-implemented method of clause 5, wherein the deviation coating profile is determined after a first layer of the coating stack is positioned on the surface but before a second layer of the coating stack is positioned over the first layer.

[0056] Clause 7: The computer-implemented method of clause 5, wherein the deviation coating profile is determined after the plurality of coating layers of the coating stack are positioned over the surface.

[0057] Clause 8: The computer-implemented method of any of clauses 1-7, wherein determining the actual coating profile comprises: taking, with at least one processor, at least one color measurement of the first coated substrate; inputting, with at least one processor, the at least one color measurement to a second model based on experimental color to thickness data; and generating, with the second model, the actual coating profile based on the at least one color measurement.

[0058] Clause 9: The computer-implemented method of any of clauses 1-8, wherein the target coating profile and/or the actual coating profile provide a target and/or actual coating thickness for at least one layer of the at least one coating layer relative to a position on the surface.

[0059] Clause 10: The computer-implemented method of any of clauses 1-9, wherein the at least one applicator comprises a vacuum coating applicator.

[0060] Clause 11: The computer-implemented method of clause 10, wherein the vacuum coating applicator comprises at least one gas inlet through which at least one reactive or non-reactive gas is flowed to deposit the at least one coating layer on the surface, wherein the at least one control instruction comprises a control instruction for adjusting a flow rate of the gas through the at least one gas inlet for depositing a coating layer on the second substrate according to the target coating profile.

[0061] Clause 12: The computer-implemented method of clause 10 or 11, wherein the vacuum coating applicator comprises a magnet bar arranged at a height above the surface to deposit the at least one coating layer on the surface, wherein the at least one control instruction comprises a control instruction for adjusting the height of the magnet bar above the surface for depositing a coating layer on the second substrate according to the target coating profile.

[0062] Clause 13: The computer-implemented method of clause 12, wherein the magnet bar comprises a plurality of nodes configured to adjust a height of a section of the magnet bar above the surface, wherein the at least one control instruction comprises a control instruction for only a subset of the plurality of nodes to adjust the height of a corresponding section of the magnet bar above the surface for depositing a coating layer on the second substrate according to the target coating profile.

[0063] Clause 14: The computer-implemented method of any of clauses 1-13, wherein identifying the first coated substrate comprises scanning an identifier associated with the first coated substrate.

[0064] Clause 15: The computer-implemented method of any of clauses 1-14, wherein the first coated substrate comprises the surface over which a coating stack comprising a plurality of coating layers is positioned, wherein a plurality of applicators are provided, each applicator of the plurality of applicators configured to apply a different layer of the plurality of layers of the coating stack, wherein generating the at least one control instruction comprises: determining, with the model, at least one applicator of the plurality of applicators requiring adjustment to obtain the target coating profile based on the deviation coating profile; and generating, with the model, the at least one control instruction for at least one component of the at least one applicator of the plurality of applicators requiring adjustment to obtain the target coating profile.

[0065] Clause 16: The computer-implemented method of any of clauses 1-15, not including a step of directly measuring a thickness of the at least one coating layer.

[0066] Clause 17: The computer-implemented method of any of clauses 1-16, wherein the at least one control instruction is generated in response to the model determining that at least a portion of the deviation coating profile satisfies a threshold.

[0067] Clause 18: The computer-implemented method of any of clauses 2-17, further comprising: applying, with the adjusted at least one component of the at least one applicator, at least one second coating layer to a surface of the second substrate according to the target coating profile.

[0068] Clause 19: The computer-implemented method of any of clauses 1-18, further comprising: automatically identifying, with at least one processor, at least one parameter of the at least one applicator and/or a parameter of a coating process for coating the substrate; and inputting the at least one parameter to the model, wherein the at least one control instructions is generated by the model based on the at least one parameter.

[0069] Clause 20: The computer-implemented method of any of clauses 5-19, wherein inputting the deviation coating profile into the model comprises inputting coating profile data associated with a first layer of the plurality of layers and a second layer of the plurality of layers, wherein the at least one control instruction for adjusting the at least one component of the at least one applicator is generated to cause the at least one applicator to apply a first layer of a plurality of layers on the second substrate based on the coating profile data associated with the first layer of the plurality of layers and the second layer of the plurality of layers.

[0070] Clause 21: The computer-implemented method of any of clauses 1-20, wherein determining the actual coating profile for the first coated substrate comprises determining a thickness of a first layer of the at least one coating layer, the determined thickness of the first layer of the at least one coating layer different from a thickness for the first layer of the at least one coating layer from the target coating profile, wherein the at least one control instruction for adjusting the at least one component of the at least one applicator is generated to cause the at least one applicator to apply a first layer of at least one coating layer on the second substrate at a different thickness compared to the determined thickness of the first layer of the at least one coating layer from the first coated substrate.

[0071] Clause 22: The computer-implemented method of any of clauses 1-21, wherein the first coated substrate comprises a post-tempered substrate having the actual coating profile formed by heating a pre-tempered first substrate having a pre-tempered coating profile, wherein generating the at least one control instruction comprises the model: receiving the input comprising the deviation coating profile; analyzing experimental coating control data comprising a plurality of historical pre-tempered coating profiles; determining a first historical pre-tempered coating profile from the plurality of historical pre-tempered coating profiles; and generating the at least one control instruction for adjusting the at least one component of the at least one applicator to cause the at least one applicator to apply the first historical pre-tempered coating profile to a pre-tempered second substrate.

[0072] Clause 23: The computer-implemented method of any of clauses 1-22, further comprising: determining, with the model, that the at least one component of the at least one applicator is malfunctioning or satisfies a limit based on the deviation coating profile; and maintenancing the at least one component of the at least one applicator.

[0073] Clause 24: The computer-implemented method of clause 23, further comprising: in response to determining that the at least one component of the at least one applicator is malfunctioning or satisfies a limit based on the deviation coating profile, automatically updating the model based on the malfunctioning or satisfaction of the limit by generating a control instruction that distributes an adjustment to a remainder of components of the at least one applicator.

[0074] Clause 25: The computer-implemented method of any of clauses 1-24, wherein the first coated substrate comprises a post-tempered substrate having the actual coating profile formed by heating a pre-tempered first substrate having a pre-tempered coating profile, wherein generating the at least one control instruction comprises the model: receiving the input comprising the deviation coating profile and the pre-tempered coating profile, the deviation coating profile comparing the target coating profile of the post-tempered substrate to the actual coating profile; comparing the pre-tempered coating profile to the actual coating profile; and generating the at least one control instruction for adjusting the at least one component of the at least one applicator based on the comparison of the pre-tempered coating profile to the actual coating profile.

[0075] Clause 26: A system for automatically controlling a component of a coating applicator, comprising: at least one applicator configured to prepare a first coated substrate comprising a substrate comprising a surface over which at least one coating layer is positioned; and a control system comprising at least one processor programmed or configured to: identify the first coated substrate; in response to identifying the first coated substrate, determine a target coating profile corresponding to the first coated substrate; determine an actual coating profile for the first coated substrate; generate a deviation coating profile for the first coated substrate by comparing the target coating profile to the actual coating profile; input the deviation coating profile into a model based on experimental coating control data; and generate, with the model, at least one control instruction for adjusting at least one component of the at least one applicator based on the deviation coating profile prior to coating a second substrate according to the target coating profile.

[0076] Clause 27: The system of clause 26, wherein the at least one component of the at least one applicator comprises an adjustor, wherein the at least one processor is programmed or configured to cause the adjustor to adjust the at least one component based on the at least one control instruction.

[0077] Clause 28: The system of clause 26 or 27, further comprising: a computing device of a user, the computing device comprising a user interface configured to display the at least one control instruction.

[0078] Clause 29: The system of any of clauses 26-28, further comprising: a measurement device configured to take at least one color measurement of the first coated substrate; and a second model based on experimental color to thickness data and to which the at least one color measurement is input, wherein the second model is programmed or configured to generate the actual coating profile based on the at least one color measurement.

[0079] Clause 30: The system of any of clauses 26-29, wherein the at least one applicator comprises a vacuum coating applicator.
[0080] Clause 31: The system of clause 30, wherein the vacuum coating applicator comprises at least one gas inlet through which at least one reactive or non-reactive gas is flowed to deposit the at least one coating layer on the surface, wherein the at least one control instruction comprises a control instruction for adjusting a flow rate of the gas through the at least one gas inlet for depositing a coating layer on the second substrate according to the target coating profile.
[0081] Clause 32: The system of clause 30 or 31, wherein the vacuum coating applicator comprises a magnet bar arranged at a height above the surface to deposit the at least one coating layer on the surface, wherein the at least one control instruction comprises a control instruction for adjusting the height of the magnet bar above the surface for depositing a coating layer on the second substrate according to the target coating profile.
[0082] Clause 33: The system clause 37, wherein the magnet bar comprises a plurality of nodes configured to adjust a height of a section of the magnet bar above the surface, wherein the at least one control instruction comprises a control instruction for only a subset of the plurality of nodes to adjust the height of a corresponding section of the magnet bar above the surface for depositing a coating layer on the second substrate according to the target coating profile.
[0083] Clause 34: The system of any of clauses 26-33, further comprising: a scanner configured to identify the first coated substrate by scanning an identifier associated with the first coated substrate.
[0084] Clause 35: The system of any of clauses 26-34, wherein the first coated substrate comprises the surface over which a coating stack comprising a plurality of coating layers is positioned, wherein the at least one applicator comprises a plurality of applicators, each applicator of the plurality of applicators configured to apply a different layer of the plurality of layers of the coating stack, wherein generating the at least one control instruction comprises: determining, with the model, at least one applicator of the plurality of applicators requiring adjustment to obtain the target coating profile based on the deviation coating profile; and generating, with the model, the at least one control instruction for at least one component of the at least one applicator of the plurality of applicators requiring adjustment to obtain the target coating profile.
[0085] Clause 36: The system of any of clauses 26-35, wherein the system does not comprise a device for directly measuring a thickness of the at least one coating layer.
[0086] Clause 37: The system of any of clauses 26-36, wherein the model is programmed or configured to generate the at least one control instruction in response to determining that at least a portion of the deviation coating profile satisfies a threshold.
[0087] Clause 38: The system of any of clauses 27-37, wherein the adjusted at least one component is configured to apply at least one second coating layer to a surface of the second substrate according to the target coating profile.
[0088] Clause 39: The system of any of clauses 26-38, wherein the at least one applicator comprises a magnetron sputtering vapor deposition (MSVD) applicator.
[0089] Clause 40: The system of any of clauses 26-39, wherein the first coated substrate comprises the surface over which a coating stack comprising a plurality of coating layers is positioned, wherein inputting the deviation coating profile into the model comprises inputting coating profile data associated with a first layer of the plurality of layers and a second layer of the plurality of layers, wherein the at least one control instruction for adjusting the at least one component of the at least one applicator is generated to cause the at least one applicator to apply a first layer of a plurality of layers on the second substrate based on the coating profile data associated with the first layer of the plurality of layers and the second layer of the plurality of layers.
[0090] Clause 41: The system of any of clauses 26-40, wherein determining the actual coating profile for the first coated substrate comprises the at least one processor determining a thickness of a first layer of the at least one coating layer, the determined thickness of the first layer of the at least one coating layer different from a thickness for the first layer of the at least one coating layer

from the target coating profile, wherein the at least one control instruction for adjusting the at least one component of the at least one applicator is generated to cause the at least one applicator to apply a first layer of at least one coating layer on the second substrate at a different thickness compared to the determined thickness of the first layer of the at least one coating layer from the first coated substrate.

[0091] Clause 42: The system of any of clauses 26-41, wherein the first coated substrate comprises a post-tempered substrate having the actual coating profile formed by heating a pre-tempered first substrate having a pre-tempered coating profile, wherein generating the at least one control instruction comprises the model: receiving the input comprising the deviation coating profile; analyzing experimental coating control data comprising a plurality of historical pre-tempered coating profiles; determining a first historical pre-tempered coating profile from the plurality of historical pre-tempered coating profiles; and generating the at least one control instruction for adjusting the at least one component of the at least one applicator to cause the at least one applicator to apply the first historical pre-tempered coating profile to a pre-tempered second substrate.

[0092] Clause 43: The system of any of clauses 26-42, the at least one processor further programmed or configured to determine, with the model, that the at least one component of the at least one applicator is malfunctioning or satisfies a limit based on the deviation coating profile, wherein the at least one component of the at least one applicator is maintenanced based on the determination that the at least one component of the at least one applicator is malfunctioning or satisfies a limit.

[0093] Clause 44: The system of clause 43, the at least one processor further programmed or configured to: in response to determining that the at least one component of the at least one applicator is malfunctioning or satisfies a limit based on the deviation coating profile, automatically update the model based on the malfunctioning or satisfaction of the limit by generating a control instruction that distributes an adjustment to a remainder of components of the at least one applicator.

[0094] Clause 45: The system of any of clauses 26-44, wherein the first coated substrate comprises a post-tempered substrate having the actual coating profile formed by heating a pre-tempered first substrate having a pre-tempered coating profile, wherein generating the at least one control instruction comprises the model: receiving the input comprising the deviation coating profile and the pre-tempered coating profile, the deviation coating profile comparing the target coating profile of the post-tempered substrate to the actual coating profile; comparing the pre-tempered coating profile to the actual coating profile; and generating the at least one control instruction for adjusting the at least one component of the at least one applicator based on the comparison of the pre-tempered coating profile to the actual coating profile.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0095] The disclosure will be described with reference to the following drawing figures wherein like reference numbers identify like parts throughout.

[0096] FIG. **1** shows a schematic diagram of a coated substrate, according to some aspects of the disclosure;

[0097] FIG. **2** shows a schematic diagram of a system for automatically controlling a component of a coating applicator, according to some aspects of the disclosure;

[0098] FIG. **3** shows a schematic diagram of a control system, according to some aspects of the disclosure;

[0099] FIGS. **4**A-**4**B show schematic diagrams of an adjustable magnet bar coating applicator,

according to some aspects of the disclosure;
[0100] FIG. **5** shows a schematic diagram of a trim gas coating applicator, according to some aspects of the disclosure;
[0101] FIG. **6** shows a step diagram of a process for automatically controlling a component of a coating applicator, according to some aspects of the disclosure; and
[0102] FIG. **7** shows a schematic diagram of example components of a device used in connection with some aspects of the disclosure.

DETAILED DESCRIPTION

[0103] As used herein, spatial or directional terms, such as “left”, “right”, “inner”, “outer”, “above”, “below”, and the like, relate to the disclosure as it is shown in the drawing figures. However, it is to be understood that the disclosure can assume various alternative orientations and, accordingly, such terms are not to be considered as limiting. Further, as used herein, all numbers expressing dimensions, physical characteristics, processing parameters, quantities of ingredients, reaction conditions, and the like, used in the specification and claims are to be understood as being modified in all instances by the term “about”. Accordingly, unless indicated to the contrary, the numerical values set forth in the following specification and claims may vary depending upon the desired properties sought to be obtained by the present disclosure. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical value should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Moreover, all ranges disclosed herein are to be understood to encompass the beginning and ending range values and any and all subranges subsumed therein. For example, a stated range of “1 to 10” should be considered to include any and all subranges between (and inclusive of) the minimum value of 1 and the maximum value of 10; that is, all subranges beginning with a minimum value of 1 or more and ending with a maximum value of 10 or less, e.g., 1 to 3.3, 4.7 to 7.5, 5.5 to 10, and the like. “A” or “an” refers to one or more.
[0104] Further, as used herein, the terms “formed over”, “deposited over”, “arranged over”, or “provided over” mean formed, deposited, arranged, or provided on but not necessarily in contact with the surface. For example, a coating layer “arranged over” a substrate does not preclude the presence of one or more other coating layers or films of the same or different composition located between the formed coating layer and the substrate.
[0105] As used herein, the terms “communication” and “communicate” may refer to the reception, receipt, transmission, transfer, provision, and/or the like of information (e.g., data, signals, messages, instructions, commands, and/or the like). For one unit (e.g., a device, a system, a component of a device or system, combinations thereof, and/or the like) to be in communication with another unit means that the one unit is able to directly or indirectly receive information from and/or send (e.g., transmit) information to the other unit. This may refer to a direct or indirect connection that is wired and/or wireless in nature. Additionally, two units may be in communication with each other even though the information transmitted may be modified, processed, relayed, and/or routed between the first and second unit. For example, a first unit may be in communication with a second unit even though the first unit passively receives information and does not actively transmit information to the second unit. As another example, a first unit may be in communication with a second unit if at least one intermediary unit (e.g., a third unit located between the first unit and the second unit) processes information received from the first unit and transmits the processed information to the second unit. In some non-limiting embodiments or aspects, a message may refer to a network packet (e.g., a data packet and/or the like) that includes data.
[0106] Additionally, all documents, such as, but not limited to, issued patents and patent applications, referred to herein are to be considered to be “incorporated by reference” in their entirety.

[0107] The disclosure relates to a computer-implemented method for automatically controlling a component of a coating applicator, comprising: identifying, with at least one processor, a first coated substrate comprising a substrate comprising a surface over which at least one coating layer is positioned, the at least one coating layer positioned over the surface using at least one applicator; in response to identifying the first coated substrate, determining, with at least one processor, a target coating profile corresponding to the first coated substrate; determining, with at least one processor, an actual coating profile for the first coated substrate; generating, with at least one processor, a deviation coating profile for the first coated substrate by comparing the target coating profile to the actual coating profile; inputting, with at least one processor, the deviation coating profile into a model based on experimental coating control data; and generating, with the model, at least one control instruction for adjusting at least one component of the at least one applicator based on the deviation coating profile prior to coating a second substrate according to the target coating profile.
[0108] The disclosure also relates to a system for automatically controlling a component of a coating applicator, comprising: at least one applicator configured to prepare a first coated substrate comprising a substrate comprising a surface over which at least one coating layer is positioned; and a control system comprising at least one processor programmed or configured to: identify the first coated substrate; in response to identifying the first coated substrate, determine a target coating profile corresponding to the first coated substrate; determine an actual coating profile for the first coated substrate; generate a deviation coating profile for the first coated substrate by comparing the target coating profile to the actual coating profile; input the deviation coating profile into a model based on experimental coating control data; and generate, with the model, at least one control instruction for adjusting at least one component of the at least one applicator based on the deviation coating profile prior to coating a second substrate according to the target coating profile.
[0109] Referring to FIG. **1**, the method and system for automatically controlling a component of a coating applicator may be used for preparing a coated substrate **100**. The coated substrate **100** may comprise a substrate **102** having a surface coated with at least one coating layer **104***a*-**104***n*. The coated substrate **100** may comprise the substrate **102** having a single coating layer **104***a* thereover. The coated substrate **100** may comprise the substrate **102** having a coating stack thereover comprising a plurality of coating layers **104***a*-**104***n* (e.g., a multi-layer coating).
[0110] The material of the substrate **102** is not particularly limited and may include, for example, glass, plastic, metal, ceramic, and/or any combination thereof. The substrate **102** may comprise glass.
[0111] Non-limiting examples of suitable plastic materials include acrylic polymers, such as as polyacrylates; polyalkylmethacrylates, such polymethylmethacrylates, polyethylmethacrylates, polypropylmethacrylates, and the like; polyurethanes; polycarbonates; polyalkylterephthalates, such as polyethyleneterephthalate (PET), polypropyleneterephthalates, polybutyleneterephthalates, and the like; polysiloxane-containing polymers; or copolymers of any monomers for preparing these, or any mixtures thereof.
[0112] Non-limiting examples of suitable glass materials include conventional soda-lime-silicate glass, borosilicate glass, or leaded glass. The glass can be clear glass. By “clear glass” is meant non-tinted or non-colored glass. Alternatively, the glass can be tinted or otherwise colored glass. The glass can be annealed or heat-treated glass. As used herein, the term “heat treated” means tempered or at least partially tempered. The glass can be of any type, such as conventional float glass, and can be of any composition having any optical properties, e.g., any value of visible transmission, ultraviolet transmission, infrared transmission, and/or total solar energy transmission. By “float glass” is meant glass formed by a conventional float process in which molten glass is deposited onto a molten metal bath and controllably cooled to form a float glass ribbon. Examples of float glass processes are disclosed in U.S. Pat. Nos. 4,466,562 and 4,671,155. The glass materials may comprise a low iron glass, such as a glass having a total iron Fe.sub.2O.sub.3 in the

range of greater than 0.00 to 0.10 wt. % or less than 0.02 wt. %. The low iron glass may be less green and have a high visible light transmittance.

[0113] The material of the coating layers **104***a*-**104***n* is not particularly limited and may include, for example dielectric layers, such as zinc oxide, zinc stannate, tin oxide, silicon nitride, titanium oxide, hafnium oxide, zirconium oxide, niobium oxide, bismuth oxide, lead oxide, indium oxide, silicon oxide, gallium oxide, vanadium oxide, and the like; metallic layers, such as silver, gold, copper, aluminum, titanium, and the like; or any combination thereof. The coating layers **104***a*-**104***n* may have the same or different thicknesses and may be arranged in any suitable order, as specified by the specifications of the coated substrate **100**.

[0114] Referring to FIG. **2**, a system **105** is shown for automatically controlling a component of a coating applicator, according to some aspects of the disclosure. The system **105** may comprise at least one applicator **106***a*-**106***c* for applying at least one coating layer. The system **105** of FIG. **2** shows a plurality of coating applicators **106***a*-**106***c* in series, but it will be appreciated that the system **105** may have any number or arrangement of coating applicators **106***a*-**106***c* and, in some non-limiting embodiments or aspects, may have a single coating applicator **106***a*. Each coating applicator **106***a*-**106***c* may comprise an adjustor configured to automatically adjust a component of the coating applicator **106***a*-**106***c*, such as based on a control instruction from control system **110**.

[0115] The coating applicator **106***a*-**106***c* may be any suitable coating applicator for applying a coating layer to a substrate. Non-limiting examples of the coating applicator **106***a*-**106***c* may comprise at least one of a vacuum coating applicator; a sputter coating applicator, such as a magnetron sputtering vapor deposition (MSVD) applicator, an ion beam sputtering (IBS) applicator, and the like.

[0116] In the non-limiting example of the system **105** of FIG. **2**, three coating applicators **106***a*-**106***c* are included in series with each coating applicator **106***a*-**106***c* applying a single coating to the substrate **102**. The system **105** may include a conveyor **108** for moving the substrate **102** and/or coated substrate **100** through the coating applicators **106***a*-**106***c*. The conveyor **108** in FIG. **2** moves the substrate **102** and/or coated substrate **100** from left to right. The conveyor **108** can be any suitable device for moving the substrate **102** and/or coated substrate **100** through the system **105**.

[0117] With continued reference to FIG. **2**, the system **105** may comprise the control system **110** for controlling one or more aspect of the system **105**. The system **105** may comprise a user device **112** configured to enable a user to interact with and/or control components of the system **105**. The user device **112** may be a computing device that may comprise a user interface to display for the user at least one parameter of the system **105**. The user device **112** may comprise at least one input component configured to receive input from the user, which input may be used to control at least one component of the system **105**.

[0118] The system **105** may comprise at least one analyzer **114***a*-**114***c*. The analyzer **114***a*-**114***c* may be arranged at any location in the system **105**, and in some non-limiting embodiments or aspects may be arranged before and/or after one or more coating applicators **106***a*-**106***c*. The system **105** may comprise a plurality of analyzers **114***a*-**114***c* or may comprise a single analyzer **114***a*. The analyzers **114***a*-**114***c* may automatically analyze one or more parameters of the system **105** and/or the substrate **102** and/or coated substrate **100**, such as by automatically taking one or more measurements or making one or more readings.

[0119] The analyzers **114***a*-**114***c* may automatically analyze any suitable parameters of the system.

[0120] For example, the analyzers **114***a*-**114***c* may analyze one or more parameter of the applicators **106***a*-**106***c*, such as a temperature condition in the applicators **106***a*-**106***c*, an amount of coating material remaining in the applicators **106***a*-**106***c*, an application rate of coating material, position of the applicators **106***a*-**106***c* in the system **105**, and/or the like.

[0121] The analyzers **114***a*-**114***c* may analyze one or more parameters associated with the conveyor **108**, such as conveyor speed and/or location of substrates **102** and/or coated substrates **100** on the conveyor **108**, and/or the like.

[0122] The analyzers **114**a-**114**c may analyze one or more parameters associated with the substrate **102**, such as dimensions of the substrate **102**, material of the substrate, whether the substrate **102** has been coated or not, the location of the substrate **102**, the unique identity of the substrate **102**, and/or the like. For example, the unique identity of the substrate **102** may be identified based on the location of the substrate **102** in the system **105** and/or by the analyzers **114**a-**114**c (e.g., a scanner) scanning a unique identifier (e.g., a barcode, QR code, or other type of unique identifier) arranged on the substrate **102** or associated with the substrate **102**.
[0123] The analyzers **114**a-**114**c may analyze one or more parameters associated with the coated substrate **100**. The analyzers **114**a-**114**c may analyze the coated substrate **100** after all coating layers have been applied and/or may analyze the coated substrate **100** between coating layer applications (e.g., after application of a first coating layer but before application of the subsequent second coating layer). The analyzers **114**a-**114**c may analyze, for example, thickness or thickness profile of one or more coating layers using an indirect measurement technique (e.g., ellipsometry, interferometry, Eddy current method, and the like), color or color profile (e.g., spectrometer, spectrophotometer, colorimeter, and the like) of the coating layer and/or coated substrate **100**, material of the coating layer(s) (e.g., as predetermined for the coated substrate **100**, determined using x-ray spectroscopy, and the like), and the like.
[0124] The analyzers **114**a-**114**c may take a plurality of different measurements and/or readings described above and may be a single measurement device configured to take all of the measurements or readings or a plurality of different measurement devices configured to take one or more of the of the measurements or readings.
[0125] In some non-limiting embodiments or aspects, the system **105** may not comprise a device for directly measuring a thickness of the at least one coating layer. A direct measuring technique may be one that obtains the coating layer thickness through dimensional measuring as opposed to inferring the thickness through other properties. Examples of direct measuring techniques can include cross-sectional transmission electron microscopy, cross-sectional scanning electronic microscopy, atomic force microscopy, profilometry, and the like.
[0126] With continued reference to FIG. **2**, the control system **110** may communicate with one or more other components of the system **105**. For example, the control system **110** may communicate with at least one of the coating applicators **106**a-**106**c, the user device **112**, and/or the analyzers **114**a-**114**c.
[0127] The control system **110** may receive messages from the coating applicators **106**a-**106**c reporting at least one parameter of the coating applicators **106**a-**106**c and/or providing a control instruction to the control system **110**; the coating applicators **106**a-**106**c may receive messages from the control system **110** reporting at least one parameter of another component of the system **105** and/or providing a control instruction to the coating applicators **106**a-**106**c.
[0128] The control system **110** may receive messages from the user device **112** comprising an input from the user, which the control system **110** may use to control one or more components of the system **105**; the user device **112** may receive messages from the control system **110** to cause the user device **112** to display (on the user interface) at least one message or parameter associated with the system **105** for the user. The at least one message or parameter displayed may comprise at least one control instruction (e.g., the control instruction the control system **110** provided to a component of the system **105**) and/or a request for a control instruction or approval of a control instruction.
[0129] The control system **110** may receive messages from the analyzers **114**a-**114**c reporting at least one parameter of the analyzers **114**a-**114**c and/or a measurement or reading taken by the analyzers **114**a-**114**c and/or providing a control instruction to the control system **110**; the analyzers **114**a-**114**c may receive messages from the control system **110** reporting at least one parameter of another component of the system **105** and/or providing a control instruction to the analyzers **114**a-**114**c (e.g., to take or stop taking readings and/or measurements).
[0130] With continued reference to FIG. **2**, the system **105** may be used for producing coated

substrates **100**. In this non-limiting example, the system **105** may comprise 3 coating applicators **106***a*-**106***c*, 3 analyzers **114***a*-**114***c*, with an analyzer **114***a*-**114***b* between each applicator **106***a*-**106***c* and an analyzer **114***c* after the third applicator **106***c*. The system **105** may produce a coated substrate **100** having a three coating layer stack over a surface of the substrate **102**. It will be appreciated that the number and arrangement of components of the system **105** shown in FIG. **2** is non-limiting and for illustrative purposes only and that variations to the system **105** shown in FIG. **2** are within the scope of the present disclosure.

[0131] In this non-limiting example, the substrate **102** (uncoated) may be moved by the conveyor **108** to the first applicator **106***a*, which may apply a first coating layer over the surface of the substrate **102** to produce the coated substrate **100**. The coated substrate **100** exiting the first applicator **106***a* may be analyzed by the first analyzer **114***a* and subsequently moved by the conveyor **108** to the second applicator **106***b*, which may apply a second coating layer over the first coating layer to produce the coated substrate **100**. The coated substrate **100** exiting the second applicator **106***b* may be analyzed by the second analyzer **114***b* and subsequently moved by the conveyor **108** to the third applicator **106***c*, which may apply a third coating layer over the second coating layer to produce the coated substrate **100**. The coated substrate **100** exiting the third applicator **106***c* may be analyzed by the third analyzer **114***c*. The coated substrate **100** prepared by the system **105** of FIG. **2** may have been prepared according to a target coating profile predetermined for the substrate **102**. The coated substrate **100** prepared by the system **105** may be analyzed by the control system **110**, and the components of the system **105** (e.g., the applicators **106***a*-**106***c*) may be adjusted thereby prior to preparation of a second coated substrate so that the system **105** produces the second coated substrate having an actual coating profile closer to the target coating profile, which is described in detail hereinafter.

[0132] Referring to FIG. **3**, the control system **110** is shown according to some aspects of the disclosure. The control system **110** may comprise at least one of a substrate identifier **116**, a coating profile data database **118**, a coating profiler **120**, a deviation profiler **122**, an experimental data database **124**, a control model **126**, an instruction generator **128**, a communication processor **130**, and/or a color model **132**. The components of the control system **110** shown in FIG. **3** may be separate components as shown, or one or more components shown in FIG. **3** may be combined to form a single component, or a single component shown in FIG. **3** may be subdivided into multiple components.

[0133] The communication processor **130** may be a component of the control system **110** comprising a processor programmed or configured to communicate with other components of the system **105** from FIG. **2**. For example, the communication processor **130** may communicate with at least one of the applicators **106***a*-**106***c*, the conveyor **108**, the user device **112**, and/or the analyzers **114***a*-**114***c*. The communication processor **130** may receive messages from such components and/or the communication processor **130** may transmit messages (e.g. containing control instructions) to such components.

[0134] The substrate identifier **116** may be a component of the control system **110** comprising a processor programmed or configured to identify a substrate **102** and/or coated substrate **100** proceeding through the system **105** (see e.g., FIG. **2**). The substrate identifier **116** may identify the substrate **102** and/or coated substrate **100** using any suitable protocol.

[0135] For example, the substrate **102** and/or coated substrate **100** may comprise a unique identifier physically arranged on the substrate **102** and/or coated substrate **100**. The analyzers **114***a*-**114***c* may read the unique identifier arranged on the substrate **102** and/or coated substrate **100** and transmit a message to the control system **110** that contains the unique identifier read by the analyzers **114***a*-**114***c*. In some non-limiting embodiments or aspects, the unique identifier may comprise a computer-readable unique identifier, and analyzers **114***a*-**114***c* may comprise scanners configured to read the computer-readable unique identifier. Based on the unique identifier, the substrate identifier **116** may identify the substrate **102** and/or coated substrate **100**. The substrate identifier **116** may comprise a database that stores the unique identifier in association with the identity of the substrate **102** and/or coated substrate **100**, such that in response to receiving the unique identifier, the substrate identifier **116** can identify the substrate **102** and/or coated substrate **100**.

[0136] As another non-limiting example, the substrate **102** and/or coated substrate **100** may not comprise a unique identifier physically arranged on the substrate **102** and/or coated substrate **100**, but the substrate **102** and/or coated substrate **100** may have a digitally generated virtual identifier associated therewith and tracked by the control system **110** as the substrate **102** and/or coated substrate **100** proceeds through the system **105**. The virtual identifier may be stored in the database of the substrate identifier **116** in association with the identity of the substrate **102** and/or coated substrate **100**. The substrate identifier **116** may track the substrate **102** and/or coated substrate **100** through the system **105** using the analyzers **114***a*-**114***c* (e.g., comprising a photoelectric sensor, a (video) camera, and the like). The substrate identifier **116** may track the substrate **102** and/or coated substrate **100** through the system **105** based on the speed through which the substrate **102** and/or coated substrate **100** moves (e.g., based on speed of the conveyor **108**, speed of the coating applicators **106***a*-**106***c*, and the like). The substrate identifier **116** may identify a particular substrate **102** and/or coated substrate **100** located in the system **105** by determining the virtual identifier thereof based on the foregoing data (e.g., sensor data, speed data, etc.), and based on the virtual identifier, identify the specific substrate **102** and/or coated substrate **100** based on the association in the database between the virtual identifier and the substrate **102** and/or coated substrate **100**.

[0137] As another non-limiting example, the substrate **102** and/or coated substrate **100** may not comprise a unique identifier physically arranged on the substrate **102** and/or coated substrate **100**, but the substrate **102** and/or coated substrate **100** may be determined based on at least one parameter associated with the substrate **102** and/or coated substrate **100**. For example, the database of the substrate identifier **116** may store a data packet comprising at least one of coating information and/or dimension information, and such information may be store in association with the substrate **102** and/or coated substrate **100**. The analyzer **114***a*-**114***c* may detect coating information and/or dimension information associated with a substrate **102** and/or coated substrate **100** in the system **105** and transmit a message to the control system **110** containing such information. Based on the coating information and/or dimension information in the message, the substrate identifier **116** may determine the specific substrate **102** and/or coated substrate **100** based on the associations in the database.

[0138] While several non-limiting examples of the substrate identifier **116** identifying the substrate **102** and/or coated substrate **100** have been shown and described, it will be appreciated that any other technique of identifying the substrate **102** and/or coated substrate **100** may be employed according to the present disclosure.

[0139] The coating profile data database **118** may be a component of the control system **110** programmed or configured to determine a target coating profile associated with the identified coated substrate **100**. In response to identifying the coated substrate **100** (e.g., with the substrate identifier **116**), the coating profile data database **118** may determine the target coating profile associated with the identified coated substrate **100**. The coating profile data database **118** may comprise a database that stores an association between the coated substrate **100** (e.g., using an identifier thereof) and the target coating profile of the coated substrate. The identifier of the coated substrate **100** may identify the specific coated substrate **100** and/or may identify a type of coated substrate **100** to which the specific coated substrate **100** belongs. The target coating profile may be a predetermined coating profile selected by the system **105** or users thereof to which the system **105** is targeting to apply the coating layer(s) to the substrate **100**. The target coating profile may comprise at least one of, the target number of coating layers, the target materials of the coating layers, the target arrangement of the coating layers, the target thickness of the coating layers, and the like. The target coating profile may provide a target coating thickness for at least one layer of the coated substrate **100** relative to a position on the surface. The target coating profile may be associated in the coating profile data database **118** with a specific coated substrate **100** and/or with a type of coated substrate **100**. Therefore, based on the identified coated substrate **100**, the coating profile data database **118** can determine the target coating profile intended to be applied thereto by the system **105**.

[0140] The coating profiler **120** may be a component of the control system **110** comprising a processor programmed or configured to determine an actual coating profile for the identified coated substrate **100**. The actual coating profile may correspond to the actual coating parameters applied to the coated substrate **100**, which may be different from the target (intended) coating profile. The actual coating profile may comprise at least one of, the actual number of coating layers, the actual materials of the coating layers, the actual arrangement of the coating layers, the actual thickness of the coating layers, and the like. The actual coating profile may provide an actual coating thickness for at least one layer of coated substrate relative to a position on the surface. The coating profiler **120** may determine the actual coating profile of the coated substrate **100** based on receiving a message from the analyzers **114***a*-**114***c* comprising measurements and/or readings of the coated substrate taken thereby. The measurements and/or readings may comprise any of the indirect thickness measurements previously described. The measurements and/or readings may comprise at least one measurement or reading corresponding to a color of the coating layer and/or coated substrate **100**, a material of the coating layer(s), and the like. Based on the received measurements or readings, the coating profiler **120** may generate the actual coating profile of the coated substrate **100**.

[0141] In some non-limiting embodiments or aspects, determining the actual coating profile for the coated substrate **100** may include determining a thickness of a first layer, the determined thickness of the first layer different from a thickness for the first layer from the target coating profile. The at least one control instruction for adjusting the component of the applicators **106***a*-**106***c* may be generated to cause the applicators **106***a*-**106***c* to apply the same (e.g., compositionally) first layer on a second substrate at a different thickness compared to the determined thickness of the first layer from the coated substrate **100**.

[0142] In some non-limiting embodiments or aspects, the coated substrate **100** may include a post-tempered (or otherwise heat treated) substrate having the actual coating profile formed by heating a pre-tempered substrate having a pre-tempered coating profile. Generating the at least one control instruction may comprise the control model **126**: receiving the input comprising the deviation coating profile; analyzing experimental coating control data comprising a plurality of historical pre-tempered coating profiles (e.g., stored in experimental data database **124**); determining a first historical pre-tempered coating profile from the plurality of historical pre-tempered coating profiles; and generating the at least one control instruction for adjusting the component of the applicators **106***a*-**106***c* to cause the applicators **106***a*-**106***c* to apply the first historical pre-tempered coating profile to a pre-tempered second substrate. In this way, the effect of tempering on coating profiles may be considered in the generation of the control instruction.

[0143] In some non-limiting embodiments or aspects, the coated substrate **100** may include a post-tempered (or otherwise heat treated) substrate having the actual coating profile formed by heating a pre-tempered substrate having a pre-tempered coating profile. Generating the at least one control instruction may comprise the control model **126**: receiving the input comprising the deviation coating profile and the pre-tempered coating profile, the deviation coating profile comparing the target coating profile of the post-tempered substrate to the actual coating profile; comparing the pre-tempered coating profile to the actual coating profile; and generating the control instruction for adjusting the component of the applicators **106***a*-**106***c* based on the comparison of the pre-tempered coating profile to the actual coating profile.

[0144] The deviation profiler **122** may be a component of the control system **110** comprising a processor programmed or configured to generate a deviation coating profile for the coated substrate. The deviation coating profile may be generated by comparing the target coating profile (e.g., from the coating profile data database **118**) to the actual coating profile (e.g., from the coating profiler **120**) to determine a difference between the target coating profile and the actual coating profile. The deviation coating profile may comprise at least one of, the difference in the number of coating layers, the materials of the coating layers, the arrangement of the coating layers, the thickness of the coating layers, the thickness gradient of the coating layers, and the like between the target coating profile and the actual coating profile.

[0145] In some non-limiting embodiments or aspects, the deviation profiler **122** may generate the deviation coating profile after a plurality of or all coating layers of the coated substrate **100** have been applied and/or based on data taken by the analyzer **114***a*-**114***c* after a plurality of or all coating layers of the coated substrate **100** have been applied. In some non-limiting embodiments or aspects, the deviation profiler **122** may generate the deviation coating profile after a first layer of the coating stack of the coated substrate **100** is positioned on the surface but before a second layer of the coating stack is positioned over the first layer (e.g., prior to completion of the coated substrate **100**) and/or based on data taken by the analyzer **114***a*-**114***c* after a first layer of the coating stack of the coated substrate **100** is positioned on the surface but before a second layer of the coating stack is positioned over the first layer.

[0146] The experimental data database **124** may be a component of the control system **110** programmed or configured to store historical experimental data. The historical experimental data may comprise data associated with previous substrates coated with one or more coating layers. For example, the historical experimental data may comprise target coating profile data and/or actual coating profile data associated with previously prepared coated substrates. The historical experimental data may comprise data associated with how adjusting a component of the system **105** (see e.g., from FIG. **2**) affected the actual coating profile of coated substrates coated after the adjustment (compared to before the adjustment), such that the impact that adjusting a particular component or combination of components of the system **105** can be quantified. The historical experimental data may comprise data associated with color data of historical coated substrates and/or coating layers thereof and how the color data corresponded to at least one of a coating thickness, coating material, and/or coating layer arrangement. Such historical experimental data may quantify how a color reading from the analyzers **114***a*-**114***c* for a coated substrate corresponds to at least one of a coating thickness, coating material, and/or coating layer arrangement for the coated substrate. These examples of historical experimental data are non-limiting and any other data associated with previously prepared coated substrates may be stored in the experimental data database **124**.

[0147] The control model **126** may be a component of the control system **110** comprising a processor programmed or configured to generate at least one control instruction for adjusting a component of the system **105** (e.g., at least one coating applicator **106***a*-**106***c* thereof) prior to coating a second substrate according to the target coating profile. The control model **126** may comprise any suitable computer-based model. For example, the control model **126** may comprise a machine-learning model, such as an artificial neural network trained on at least a portion of the data from the experimental data database **124**. The training data may comprise at least a portion of the historical experimental data associated with how adjusting a component of the system **105** (e.g., at least one coating applicator **106***a*-**106***c* thereof) affected the actual coating profile of coated substrates coated after the adjustment (compared to before the adjustment) [also referred to herein as experimental coating control data]. For example, the control model **126** may comprise a statistics-based and/or physics-based model generated using data from the experimental data database **124** (e.g., the historical experimental data associated with how adjusting a component of the system **105** (e.g., at least one coating applicator **106***a*-**106***c* thereof) affected the actual coating profile of coated substrates coated after the adjustment (compared to before the adjustment).

[0148] The deviation coating profile (e.g., from the deviation profiler **122**) may be input to the control model **126**. In response to receiving the input, the control model **126** may automatically generate at least one control instruction for adjusting a component of the system **105** (e.g., the applicators **106***a*-**106***c*) prior to coating a second substrate according to the target coating profile. The control instruction may comprise an instruction to cause an adjustor of the at least one of the applicators **106***a*-**106***c* to adjust at least one parameter of the applicators **106***a*-**106***c* (e.g., as described hereinafter in connection with FIGS. **4**A-**5**). The control instruction may comprise an instruction to the conveyor **108** to adjust a parameter thereof (e.g., a conveyor speed thereof, and the like). The control instruction may comprise an instruction to at least one of the analyzers **114***a*-**114***c* to adjust a parameter thereof (e.g., a frequency and/or timing for taking a measurement or reading, and the like). The control instruction may comprise an instruction to the user device **112** to cause the user to effect an adjustment to the system **105** or to request user input for adjusting the system **105**.

[0149] In some non-limiting embodiments or aspects, inputting the deviation coating profile into the control model **126** may include inputting coating profile data associated with a first layer of the plurality of layers and a second layer of the plurality of layers of the coated substrate **100**. The control instruction for adjusting a component of the applicators **106***a*-**106***c* may be generated to cause the applicators **106***a*-**106***c* to apply a first layer of a plurality of layers on the next substrate based on the coating profile data associated with the first layer of the plurality of layers and the second layer of the plurality of layers.

[0150] In some non-limiting embodiments or aspects, the control model **126** may automatically generate a control instruction after the production of each coated substrate **100** so that adjustments can be made to the system **105** so that the next coated substrate produced has an actual coating profile closer to the target coating profile (a reduced deviation coating profile). In some non-limiting embodiments or aspects, the control model **126** may automatically generate a control instructions periodically (e.g., after a predetermined time period, after a predetermined number of coated substrates have been produced, and the like) so that adjustments can be made to the system **105** so that the next coated substrate produced has an actual coating profile closer to the target coating profile (a reduced deviation coating profile) for the next coated substrate produced. When multiple coated substrates **100** have been produced between executions of the control model **126**, the deviation profiles input to the control model **126** may include all of or a subset or a combination of the deviation profiles of the multiple coated substrates **100** that have been produced between executions of the control model **126**. A combination of deviation profiles may comprise an average, a weighted average, or other statistical function applied to the deviation profiles being input to the control model **126**.

[0151] In some non-limiting embodiments or aspects, the control model **126** may generate the control instruction in response to determining that at least a portion of the deviation coating profile input to the control model satisfies a threshold. This feature enables the system **105** to only adjust a component thereof when a deviation from the target coating profile satisfies a threshold. The threshold being satisfied may comprise the number of coatings, thickness of coatings, material of coatings, arrangement of coatings, and the like deviating from the target coating profile by more than a predetermined deviation threshold. For example, the threshold may be satisfied by an actual coating thickness deviating by more than a predetermined amount, percent, or the like from the target coating thickness.

[0152] In some non-limiting embodiments or aspects, the coated substrate **100** comprises a plurality of coating layers applied by a plurality of applicators **106***a*-**106***c* (e.g., the first through third applicators **106***a*-**106***c*), with each applicator **106***a*-**106***c* applying a different coating layer of the coating stack applied thereto (see e.g., FIG. **2**). In generating the control instruction, the control model **126** may determine at least one applicator (e.g., the first coating applicator **106***a*) of the plurality of applicators **106***a*-**106***c* requiring adjustment to obtain the target coating profile based on the deviation coating profile. Based on the determination, the control model **126** may generate at least one control instruction for the first applicator **106***a*, which may be transmitted to the first applicator **106***a* to cause adjustment thereof to obtain the target coating profile. In some non-limiting embodiments or aspects, a plurality of applicators **106***a*-**106***c* may require adjustment.

[0153] In some non-limiting embodiments or aspects, the system **105** may automatically identify at least one parameter of the at least one applicator **106***a*-**106***c* and/or a parameter of a coating process for coating the substrate **102**. For example, the at least one parameter may comprise a parameter of the applicators **106***a*-**106***c*, such as an aging condition of the applicators **106***a*-**106***c* and/or at least one component thereof. For example, the at least one parameter may comprise a glass quality parameter (e.g., a breakage parameter, a present periodic gas composition change parameter, and the like). The at least one parameter of the at least one applicator **106***a*-**106***c* and/or a parameter of a coating process may be input to the control model **126**, and the control instruction generated by the control model **126** may be based at least partially on the parameter input to the control model **126**.

[0154] In some non-limiting embodiments or aspects, the control model **126** may determine that a component of the applicators **106***a*-**106***c* is malfunctioning or satisfies a limit based on the deviation coating profile. A malfunctioning component may refer to a component that is at least partially broken and/or operating in a manner different from the intended operation of the component. A component that satisfies a limit may refer to a component that is operating at an actual and/or theoretical limit such that allowing the component beyond the limit is not possible and/or would be expected to cause the component to malfunction. For example, a component that alters gas flow that is closed such that gas flow is **0** may satisfy a limit because the component cannot be more closed since it already fully prevents the flow of gas. For example, a component made of a material having a theoretical stress/strain curve and/or modulus of elasticity and/or other relevant material property may have a theoretical property limit of the material that, if exceed, would be expected to cause the material to fail.

[0155] In response to determining that the component of the applicators **106***a*-**106***c* is malfunctioning or satisfies a limit based on the deviation coating profile, the component may be maintenanced. Maintenancing the component may be completed in any suitable manner. For example, maintenancing the component may comprise replacing the component with a different (e.g., new) component. Maintenancing the component may comprise fixing the component. The component may be maintenanced by an operator or may be automatically maintenanced (e.g., by the adjustor). A control instruction may be generated by the control model **126** to notify the operator that the component should be maintenanced. A control instruction may be generated by the control model **126** to cause the component to be automatically maintenanced.

[0156] In response to determining that the component of the applicators **106***a*-**106***c* is malfunctioning or satisfies a limit based on the deviation coating profile, the control model **126** may automatically be updated based on the malfunctioning or satisfaction of the limit. The control model **126** may be updated by generating a control instruction that distributes an adjustment to a remainder of components of the applicator(s) **106***a*-**106***c* (e.g., to compensate for the malfunctioning component).

[0157] The instruction generator **128** may be a component of the control system **110** comprising a processor programmed or configured to generate the message comprising the control instruction generated by control model **126**. The communication processor **130** may communicate the message comprising the control instruction to one or more components of the system **105** (e.g., the coating applicators **106***a*-**106***c*) to cause the components to execute the adjustment specified by the control instruction.

[0158] In some non-limiting embodiments or aspects, the communication processor **130** may communicate the message containing the control instruction directly to the components of the system **105** to which the control instructions require adjustment. In some non-limiting embodiments or aspects, the communication processor **130** may first communicate the message containing the control instruction directly to the user device **112** to display the proposed control instruction to the user. The user may approve or decline the control instruction by providing a user input to the user device **112**. In response to the user approving the control instruction, the communication processor **130** may communicate the message containing the control instruction to the components of the system **105** to which the control instructions require adjustment.

[0159] In some non-limiting embodiments or aspects, in response to transmission of the message comprising the control instruction, at least one component of the system **105** may be automatically adjusted prior to preparation of a second coated substrate having the same target coating profile. For example, in response to transmission of the message comprising the control instruction, at least a component of at least one of the applicators **106***a*-**106***c* may be automatically adjusted prior to preparation of a second coated substrate having the same target coating profile. After adjustment of the at least one component, the system **105** may apply one or more coating layers using the adjusted at least one component to a surface of a second substrate according to the target coating profile. Based on the adjustment made to the system, the deviation coating profile of this second coated substrate may be reduced compared to the deviation coating profile of the first coated substrate (e.g., the actual coating profile thereof be closer to the target coating profile).

[0160] The color model **132** may be a component of the control system **110** comprising a processor programmed or configured to contribute to generating the actual coating profile of the coated substrate **100**. In some non-limiting embodiments or aspects, the actual coating profile may be generated based at least in part based on color data of the coated substrate **100** (as a whole or of one or more coating layers thereof). The analyzers **114***a*-**114***c* (e.g., spectrometer, spectrophotometer, colorimeter, and the like) may take a color reading and/or measurement at one or more locations in the system **105** producing the coated substrate **100**. The color reading and/or measurement may be transmitted from the analyzer **114***a*-**114***c* to the control system **110** and input to the color model **132**.

[0161] The color model **132** may comprise any suitable computer-based model. For example, the color model **132** may comprise a machine-learning model, such as an artificial neural network trained on at least a portion of the data from the experimental data database **124**. The training data may comprise at least a portion of the historical experimental data associated with color data of historical coated substrates and/or coating layers thereof and how the color data corresponded to at least one of a coating thickness, coating material, and/or coating layer arrangement [also referred to herein as historical experimental color data, which includes experimental color to thickness data]. For example, the color model **132** may comprise a statistics-based and/or physics-based model generated using data from the experimental data database **124** (e.g., the historical experimental color data).

[0162] For the color model **132** to contribute to generating the actual coating profile of the coated substrate **100**, at least one of the analyzers **114***a*-**114***c* (e.g., a measurement device) may take at least one color measurement of the coated substrate (e.g., in its partially completed and/or completed form), which may be transmitted to the control system **110**. The color measurement may be input to the color model **132**. The color model **132** may generate the actual coating profile based at least in part on the input color measurement.

[0163] Referring to FIGS. **4**A-**4**B, an adjustable magnet bar coating applicator **135** (e.g., a vacuum coating applicator) is shown, according to some aspects of the disclosure. FIG. **4**A shows the adjustable magnet bar coating applicator **135** in a first position, and FIG. **4**B shows the adjustable magnet bar coating applicator **135** in a second position.

[0164] In FIGS. **4**A-**4**B, a substrate **102** of glass is coated to form a coated substrate **100**. The adjustable magnet bar coating applicator **135** may deposit at least one coating layer to the surface of the substrate **102**. The glass is moved beneath the adjustable magnet bar coating applicator **135** to coat the glass. The adjustable magnet bar coating applicator **135** may comprise a target material holder **134** holding a target material **136**, the target material **136** used to coat the glass. The adjustable magnet bar coating applicator **135** may comprise a remotely adjustable magnet bar **138** comprising a plurality of nodes **140**. The nodes **140** of the magnet bar **138** may be moved up or down to adjust the distance of the magnet bar **138** from the target surface of the glass. The nodes **140** of the magnet bar **138** may be adjusted in response to receiving a control instruction from the control system **110** (see e.g., FIGS. **2-3**), so that the coating layer deposited on the subsequent substrate is according to the target coating profile. The control instruction may cause all nodes **140** of the magnet bar **138** to be adjusted in height or may cause only a subset of the nodes **140** to be adjusted in height.

[0165] As shown in FIG. **4**A, the nodes **140** may all be the same distance from the target surface, or as shown in FIG. **4**B, the nodes **140** of the magnet bar **138** may be different distances from the target surface. Adjusting the height of the nodes **140** may fine tune the local deposition of the target material **136** onto the glass to improve uniformity control of the coating layer thickness (e.g., adjusting components so that a uniform (or more uniform) coating layer is applied as opposed to a non-uniform coating layer). Therefore, the height of the nodes **140** may be individually adjusted to adjust the height of a section of the nodes **140** of the magnet bar **138**.

[0166] The target material **136** may be applied to the glass by applying a magnetic field (e.g., by the magnet bar **138**) to deposit the target material **136** to the glass. The magnetic field strength **142** generated by the magnetic bar may be adjusted based on the height of the nodes **140** to yield the desired coating thickness gradient **144** (e.g., a coating profile).

[0167] For example, the magnet bar **138** having the nodes **140** all at a same height from the glass may exhibit a uniform magnetic field strength **142** across the glass, but may result in a coating thickness gradient **144** thicker at the ends of the glass and thinner in the middle of the glass, as shown in the non-limiting example of FIG. **4**A. In contrast, adjusting the height of the nodes **140** so that the magnetic field strength **142** exhibited by the magnet bar **138** is stronger in the middle and weaker on the ends may provide for a uniform coating thickness gradient **144**, as shown in the non-limiting example of FIG. **4**B.

[0168] Referring to FIG. **5**, a trim gas coating applicator **145** is shown, according to some aspects of the disclosure. The trim gas coating applicator **145** may comprise a process gas feed tube **148** for providing a sputtering gas **156**. The trim gas applicator **145** may comprise at least one cathode **162** and at least one anode **160**. A target platform **152** containing target material **154** may be arranged, and target material **154** may be used to coat a substrate **102** to form a coated substrate **100**. The target platform **152** may be arranged on the cathode **162**.

[0169] The sputtering gas **156** may be flowed through the process gas feed tube **148** and toward the target platform **152**. The sputtering gas **156** may be an inert (e.g., non-reactive) or reactive gas. The control system **110** (see e.g., FIGS. **2-3**) can automatically adjust the local flow rate of both types of process gases (e.g., non-reactive and reactive gases at different locations across the substrate **102** and/or coated substrate **100**). The sputtering gas **156** may be an inert gas. In another embodiment, the sputtering gas **156** may contain a reactive gas. In reactive sputtering, the deposition rate and deposition mode may be affected and determined by the reactive gas concentration, which is a function of the reactive gas flow rate. Upon the sputtering gas **156** colliding with the target material **154** on the target platform **152**, the target material **154** may be ejected through a plasma **155** and toward the substrate **102** to coat the substrate **102**.

[0170] Parameters of the sputtering gas **156** may be adjusted in response to receiving a control instruction from the control system **110**, so that the coating layer deposited on the substrate **102** is according to the target coating profile. For example, the flow rate of the sputtering gas **156** may be adjusted (e.g., increased or decreased) to adjust the deposition of the target material **154** on the substrate **102** in response to receiving the control instruction.

[0171] A single process gas feed tube **148** or a plurality of process gas feed tubes **148** may be provided. The control instruction may cause the flow rate of the sputtering gas **156** to be adjusted to all process gas feed tubes **148**, or the control instruction may cause the flow rate of the sputtering gas **156** to be adjusted to a subset of the process gas feed tubes **148**.

[0172] Referring to FIG. **6** (and FIGS. **2-3**), a process **600** is shown for automatically controlling a component of a coating applicator, according to some aspects of the disclosure.
[0173] At a step **602**, the process **600** may include identifying a first coated substrate comprising a substrate comprising a surface over which at least one coating layer is positioned, the at least one coating layer positioned over the surface using at least one applicator **106***a*-**106***c*. The first coated substrate may be identified based on at least one of the substrate **102** and/or coated substrate **100**, data from at least one of the analyzers **114***a*-**114***c*, and using the substrate identifier **116** of the control system **110**.
[0174] At a step **604**, the process **600** may include, in response to identifying the first coated substrate, determining, with at least one processor, a target coating profile corresponding to the first coated substrate. The target coating profile may be determined based on the identified first coated substrate using the coating profile data database **118** of the control system **110**.
[0175] At a step **606**, the process **600** may include determining, with at least one processor, an actual coating profile for the first coated substrate. The actual coating profile may be determined based on the coated substrate **100**, data from at least one of the analyzers **114***a*-**114***c* and using the coating profiler **120** of the control system **110**.
[0176] At a step **608**, the process **600** may include generating, with at least one processor, a deviation coating profile for the first coated substrate by comparing the target coating profile to the actual coating profile. The deviation coating profile may be generated by the deviation profiler **122** of the control system **110**.
[0177] At a step **610**, the process **600** may include inputting, with at least one processor, the deviation coating profile into a model based on experimental coating control data. The deviation coating profile may be input to the control model **126** of the control system **110**.
[0178] At a step **612**, the process **600** may include generating, with the model, at least one control instruction for adjusting at least one component of the at least one applicator based on the deviation coating profile prior to coating a second substrate according to the target coating profile. The control model **126** may generate the at least one control instruction.
[0179] Referring now to FIG. **7**, shown is a diagram of example components of a device **700** according to non-limiting embodiments or aspects. Device **700** may correspond to at least one applicator **106***a*-**106***c*, control system **110**, user device **112**, and/or analyzer **114***a*-**114***c* in FIG. **2** and/or at least one of control system **110**, substrate identifier **116**, coating profile data database **118**, coating profiler **120**, deviation profiler **122**, experimental data database **124**, control model **126**, instruction generator **128**, communication processor **130**, and/or color model **132** in FIG. **3**, as an example. In some non-limiting embodiments or aspects, such systems or devices in FIGS. **2-3** may include at least one device **700** and/or at least one component of device **700**. The number and arrangement of components shown in FIG. **7** are provided as an example. In some non-limiting embodiments or aspects, device **700** may include additional components, fewer components, different components, or differently arranged components than those shown in FIG. **7**. Additionally, or alternatively, a set of components (e.g., one or more components) of device **700** may perform one or more functions described as being performed by another set of components of device **700**.
[0180] As shown in FIG. **7**, device **700** may include bus **702**, processor **704**, memory **706**, storage component **708**, input component **710**, output component **712**, and communication interface **714**. Bus **702** may include a component that permits communication among the components of device **700**. In some non-limiting embodiments or aspects, processor **704** may be implemented in hardware, firmware, or a combination of hardware and software. For example, processor **704** may include a processor (e.g., a central processing unit (CPU), a graphics processing unit (GPU), an accelerated processing unit (APU), programmable logic controller (PLC), etc.), a microprocessor, a digital signal processor (DSP), and/or any processing component (e.g., a field-programmable gate array (FPGA), an application-specific integrated circuit (ASIC), etc.) that can be programmed to perform a function. Memory **706** may include random access memory (RAM), read only memory

(ROM), and/or another type of dynamic or static storage device (e.g., flash memory, magnetic memory, optical memory, etc.) that stores information and/or instructions for use by processor **704**.

[0181] With continued reference to FIG. **7**, storage component **708** may store information and/or software related to the operation and use of device **700**. For example, storage component **708** may include a hard disk (e.g., a magnetic disk, an optical disk, a magneto-optic disk, a solid state disk, etc.) and/or another type of computer-readable medium. Input component **710** may include a component that permits device **700** to receive information, such as via user input (e.g., a touch screen display, a keyboard, a keypad, a mouse, a button, a switch, a microphone, etc.). Additionally, or alternatively, input component **710** may include a sensor for sensing information (e.g., a global positioning system (GPS) component, an accelerometer, a gyroscope, an actuator, etc.). Output component **712** may include a component that provides output information from device **700** (e.g., a display, a speaker, one or more light-emitting diodes (LEDs), etc.). Communication interface **714** may include a transceiver-like component (e.g., a transceiver, a separate receiver and transmitter, etc.) that enables device **700** to communicate with other devices, such as via a wired connection, a wireless connection, or a combination of wired and wireless connections. Communication interface **714** may permit device **700** to receive information from another device and/or provide information to another device. For example, communication interface **714** may include an Ethernet interface, an optical interface, a coaxial interface, an infrared interface, a radio frequency (RF) interface, a universal serial bus (USB) interface, a Wi-Fi® interface, a cellular network interface, and/or the like.

[0182] Device **700** may perform one or more processes described herein. Device **700** may perform these processes based on processor **704** executing software instructions stored by a computer-readable medium, such as memory **706** and/or storage component **708**. A computer-readable medium may include any non-transitory memory device. A memory device includes memory space located inside of a single physical storage device or memory space spread across multiple physical storage devices. Software instructions may be read into memory **706** and/or storage component **708** from another computer-readable medium or from another device via communication interface **714**. When executed, software instructions stored in memory **706** and/or storage component **708** may cause processor **704** to perform one or more processes described herein. Additionally, or alternatively, hardwired circuitry may be used in place of or in combination with software instructions to perform one or more processes described herein. Thus, embodiments described herein are not limited to any specific combination of hardware circuitry and software. The term “programmed or configured,” as used herein, refers to an arrangement of software, hardware circuitry, or any combination thereof on one or more devices.

[0183] It will be readily appreciated by those skilled in the art that modifications may be made to the invention without departing from the concepts disclosed in the foregoing description. Accordingly, the particular embodiments described in detail herein are illustrative only and are not limiting to the scope of the invention, which is to be given the full breadth of the appended claims and any and all equivalents thereof.

Claims

1. A computer-implemented method for automatically controlling a component of a coating applicator, comprising: identifying, with at least one processor, a first coated substrate comprising a substrate comprising a surface over which at least one coating layer is positioned, the at least one coating layer positioned over the surface using at least one applicator; in response to identifying the first coated substrate, determining, with at least one processor, a target coating profile corresponding to the first coated substrate; determining, with at least one processor, an actual coating profile for the first coated substrate; generating, with at least one processor, a deviation coating profile for the first coated substrate by comparing the target coating profile to the actual coating profile; inputting, with at least one processor, the deviation coating profile into a model based on experimental coating control data; and generating, with the model, at least one control instruction for adjusting at least one component of the at least one applicator based on the deviation coating profile prior to coating a second substrate according to the target coating profile.

2. The computer-implemented method of claim 1, further comprising: automatically adjusting, with at least one processor, the at least one component of the at least one applicator based on the at least one control instruction.

3. The computer-implemented method of claim 1, wherein the substrate comprises glass.

4. The computer-implemented method of claim 1, wherein the first coated substrate comprises the surface over which a coating stack comprising a plurality of coating layers is positioned.

5. The computer-implemented method of claim 4, wherein the deviation coating profile is determined after a first layer of the coating stack is positioned on the surface but before a second layer of the coating stack is positioned over the first layer.

6. The computer-implemented method of claim 4, wherein the deviation coating profile is determined after the plurality of coating layers of the coating stack are positioned over the surface.

7. The computer-implemented method of claim 1, wherein determining the actual coating profile comprises: taking, with at least one processor, at least one color measurement of the first coated substrate; inputting, with at least one processor, the at least one color measurement to a second model based on experimental color to thickness data; and generating, with the second model, the actual coating profile based on the at least one color measurement.

8. The computer-implemented method of claim 1, wherein the target coating profile and/or the actual coating profile provide a target and/or actual coating thickness for at least one layer of the at least one coating layer relative to a position on the surface.

9. The computer-implemented method of claim 1, wherein the at least one applicator comprises a vacuum coating applicator.

10. The computer-implemented method of claim 9, wherein the vacuum coating applicator comprises at least one gas inlet through which at least one reactive or non-reactive gas is flowed to deposit the at least one coating layer on the surface, wherein the at least one control instruction comprises a control instruction for adjusting a flow rate of the gas through the at least one gas inlet for depositing a coating layer on the second substrate according to the target coating profile.

11. The computer-implemented method of claim 9, wherein the vacuum coating applicator comprises a magnet bar arranged at a height above the surface to deposit the at least one coating layer on the surface, wherein the at least one control instruction comprises a control instruction for adjusting the height of the magnet bar above the surface for depositing a coating layer on the second substrate according to the target coating profile.

12. The computer-implemented method of claim 11, wherein the magnet bar comprises a plurality of nodes configured to adjust a height of a section of the magnet bar above the surface, wherein the at least one control instruction comprises a control instruction for only a subset of the plurality of nodes to adjust the height of a corresponding section of the magnet bar above the surface for depositing a coating layer on the second substrate according to the target coating profile.

13. The computer-implemented method of claim 1, wherein the first coated substrate comprises the surface over which a coating stack comprising a plurality of coating layers is positioned, wherein a plurality of applicators are provided, each applicator of the plurality of applicators configured to apply a different layer of the plurality of layers of the coating stack, wherein generating the at least one control instruction comprises: determining, with the model, at least one applicator of the plurality of applicators requiring adjustment to obtain the target coating profile based on the deviation coating profile; and generating, with the model, the at least one control instruction for at least one component of the at least one applicator of the plurality of applicators requiring adjustment to obtain the target coating profile.

14. The computer-implemented method of claim 4, wherein inputting the deviation coating profile into the model comprises inputting coating profile data associated with a first layer of the plurality of layers and a second layer of the plurality of layers, wherein the at least one control instruction for adjusting the at least one component of the at least one applicator is generated to cause the at least one applicator to apply a first layer of a plurality of layers on the second substrate based on the coating profile data associated with the first layer of the plurality of layers and the second layer of the plurality of layers.

15. The computer-implemented method of claim 1, wherein determining the actual coating profile for the first coated substrate comprises determining a thickness of a first layer of the at least one coating layer, the determined thickness of the first layer of the at least one coating layer different from a thickness for the first layer of the at least one coating layer from the target coating profile, wherein the at least one control instruction for adjusting the at least one component of the at least one applicator is generated to cause the at least one applicator to apply a first layer of at least one coating layer on the second substrate at a different thickness compared to the determined thickness of the first layer of the at least one coating layer from the first coated substrate.

16. The computer-implemented method of claim 1, wherein the first coated substrate comprises a post-tempered substrate having the actual coating profile formed by heating a pre-tempered first substrate having a pre-tempered coating profile, wherein generating the at least one control instruction comprises the model: receiving the input comprising the deviation coating profile; analyzing experimental coating control data comprising a plurality of historical pre-tempered coating profiles; determining a first historical pre-tempered coating profile from the plurality of historical pre-tempered coating profiles; and generating the at least one control instruction for adjusting the at least one component of the at least one applicator to cause the at least one applicator to apply the first historical pre-tempered coating profile to a pre-tempered second substrate.

17. The computer-implemented method of claim 1, further comprising: determining, with the model, that the at least one component of the at least one applicator is malfunctioning or satisfies a limit based on the deviation coating profile; and maintenancing the at least one component of the at least one applicator.

18. The computer-implemented method of claim 17, further comprising: in response to determining that the at least one component of the at least one applicator is malfunctioning or satisfies a limit based on the deviation coating profile, automatically updating the model based on the malfunctioning or satisfaction of the limit by generating a control instruction that distributes an adjustment to a remainder of components of the at least one applicator.

19. The computer-implemented method of claim 1, wherein the first coated substrate comprises a post-tempered substrate having the actual coating profile formed by heating a pre-tempered first substrate having a pre-tempered coating profile, wherein generating the at least one control instruction comprises the model: receiving the input comprising the deviation coating profile and the pre-tempered coating profile, the deviation coating profile comparing the target coating profile of the post-tempered substrate to the actual coating profile; comparing the pre-tempered coating profile to the actual coating profile; and generating the at least one control instruction for adjusting the at least one component of the at least one applicator based on the comparison of the pre-tempered coating profile to the actual coating profile.

20. A system for automatically controlling a component of a coating applicator, comprising: at least one applicator configured to prepare a first coated substrate comprising a substrate comprising a surface over which at least one coating layer is positioned; and a control system comprising at least one processor programmed or configured to: identify the first coated substrate; in response to identifying the first coated substrate, determine a target coating profile corresponding to the first coated substrate; determine an actual coating profile for the first coated substrate; generate a deviation coating profile for the first coated substrate by comparing the target coating profile to the actual coating profile; input the deviation coating profile into a model based on experimental coating control data; and generate, with the model, at least one control instruction for adjusting at least one component of the at least one applicator based on the deviation coating profile prior to coating a second substrate according to the target coating profile.