[0028] In the example embodiment, the wire saw 103 is used to slice ingots 102 made of a semiconductor material (e.g., silicon) or a photovoltaic material. The wire saw 103 may also be used to slice ingots of other materials into wafers.

[0029] The wire guides 106 have opposing ends 108, 110, each of which is connected to a frame 112 (only a portion of which is shown in Figure 2) of the wire saw 103 by a bearing 114. The frame 112 includes a fixed bearing sidewall 180 and a free bearing sidewall 182 opposite the fixed bearing sidewall 180.

[0030] Each bearing 114 of the fixed bearing sidewall 180 has a rotating race 116 that is connected to a respective end 108 of the wire guide 106 and a stationary race 118 that is connected to the fixed bearing sidewall 180. The rotating race 116 is best seen in Figure 3. The rotating race 116 rotates as the wire guide 106 to which it is connected rotates. Likewise, the stationary race 118 does not appreciably move as the rotating race 116 and wire guide 106 rotate. In the example embodiment, the bearings 114 are typical roller bearings, although in other embodiments they may be any other suitable type of bearing (e.g., roller bearings).

[0031] As shown in FIG. 4, the frame 112 can thermally deform during the cutting process. Thermal deformation of the frame 112 alters the surface profile resulting in surface defects of the cut ingot. Because the wire guides 106 are connected to the fixed bearing sidewall 180 but are movable relative to the free bearing sidewall 182, the wire guides 106 shift less due to thermal

positioned on an inner surface 202 of the fixed bearing sidewall 180. FIG. 6 illustrates a front view of the heat exchanger 210 positioned on the inner surface of the fixed bearing sidewall 180. The heat exchanger 210 can be positioned near regions that are most susceptible to thermal deformation, and the heat exchanger 210 can be connected to more heat exchangers 210 on the inner surface 202. The heat exchanger 210 is suitably a Peltier cooler, a thermoelectric cooler module or a solid-state heat pump. In some embodiments, the heat exchanger 210 includes a highly conductive thermal plate which abuts the inner surface 202 with a reservoir 206 adjacent to the thermal plate. The reservoir 206 can have fluid passing through it to promote the transfer of heat from the thermal plate to the inner surface 202. In some embodiments, fluid conduits 212 can connect multiple heat exchangers 210 to an external reservoir 206 (not shown) defining a fluid circuit. In some embodiments, the fluid circuit includes a valve or pump connected to a processor as explained in further detail below. In some embodiments, the heat exchanger 210 is a cooling jacket.

[0034] The heat exchanger 210 may also be retrofit onto existing frames 112. By way of example, the heat exchanger 210 can be affixed onto the inner surface 202 of the fixed bearing sidewall 180 and connected to the external reservoir 206 and valve or pump. In some embodiments, the inner surface 202 of the fixed bearing sidewall 180 can include slots sized to receive the heat exchanger 210 such that the heat exchanger 210 is substantially flush with the inner surface 202 of the fixed bearing sidewall 180, thus reducing the footprint of the heat exchanger 210.

[0035] FIGS. 7-10B illustrate embodiments of fluid channels 220 of the temperature regulation system 200. FIGS. 7 and 8 are side and front views, respectively, of an embodiment of the temperature regulation system 200 in which the fluid channels 220 are internal to (or inside) the fixed bearing wall 180. FIG. 9 is a side view of an embodiment of the temperature regulation system 200 in which the fluid channels 220 are external to the fixed bearing wall 180. In the embodiment shown in FIG. 9, the fluid channels 220 may be positioned on the inner surface 202 of the fixed bearing sidewall 180 (shown in FIG. 10A) or the fluid channels 220 may be positioned on the outer surface 203 of the fixed bearing sidewall 180 (shown in FIG. 10B).

[0036] As best shown in FIG. 8, the fluid channels 220 may be internal to or embedded within the fixed bearing wall 180. As best shown in FIG. 10A the fluid channels 220 may be disposed on inner surface 202 of the fixed bearing sidewall 180 and are oriented towards the wire guides 106, and as best shown in FIG. 10B, the fluid channels 220 may be disposed on an outer surface 203 of the fixed bearing sidewall 180, the outer surface 203 opposite the inner surface 202.

[0037] The fluid channels 220 can be positioned near regions that are most susceptible to thermal deformation. As best shown in FIG. 7, in some embodiments, the fluid channels 220 can follow pathways in series or parallel, and as best shown in FIG. 9, the fluid channels 220 can include a single channel. The fluid channels 220 may be connected to an external reservoir 206 (not shown) defining a fluid circuit. In some embodiments, the fluid circuit includes a valve or pump connected to a processor as explained in further detail below.

[0038] The fluid channels 220 may also be retrofit onto existing frames 112. For example, the fluid channels

relative to the outlet of the system due to heat absorbed throughout the temperature regulation system 200.

[0044] The temperature sensors 134, 136 are communicatively connected to the processor 140 (discussed in greater detail below) by any suitable communication system (e.g., a wired and/or wireless network).The processor, shown schematically in Figures 2 and 3 and indicated generally at 140, is communicatively connected to the temperature sensors 134, 136, the displacement sensors 130, 132, and the temperature regulation system 200. Generally, and as discussed in greater detail below, the processor 140 is configured for receiving an input from a user identifying a desired wafer nanotopology profile or shape of wafers sliced from the ingot. Alternatively, the processor 140 is configured to maintain the temperature at a set level to reduce deformation. Based on this input and the measured temperature of the fluid, the processor 140 communicates instructions to the temperature regulation system 200 to control (i.e., adjust, alter or change) the temperature of the fluid.

[0045] The flow rate is maintained generally constant. The temperature of the fluid can be controlled by activating heaters or chillers (not shown) connected to the reservoir 206. The reservoir 206 has a sufficient volume such that the fluid circulated through the reservoir 206 is uniformly heated or cooled. Alternatively, fluid can be partially expelled from the reservoir 206 and fresh fluid can be added to the reservoir 206. The fresh fluid having the target temperature such that the reservoir 206 reaches the target temperature.

[0046] This change in temperature of the fixed bearing sidewall 180 alters their displacement and that of the wire guides 106 and wires 104. Control of the displacement of the wire guides 106 and wires 104 controls the shape of the surfaces of the wafers, which in turn controls the nanotopology of the surfaces.

[0047] The operation of the processor 140 and system 100 are now described in greater detail. An input device 160 as shown in FIG. 11 is communicatively connected to the processor 140 and may be used to receive the input identifying the desired wafer nanotopology or wafer shape from a user. In other embodiments, the processor 140 may receive this input from another computer system communicatively connected to the processor.

[0048] Once this input is received by the processor 140, the processor retrieves a recipe associated with the input from a memory 150. The memory is described in greater detail below. The recipe specifies a temperature set point (i.e., a desired temperature) of the fixed bearing sidewall 180 and/or temperature-controlling fluid associated with the recipe. The recipe may also include displacement measurements for the bearings in addition to or in substitution for the temperature set points of the bearings and/or fluid. Adherence to the temperature and/or displacement measurements contained in the recipe during cutting of the ingot 102 by the saw 103 will generally yield wafers having characteristics the same or similar to those as the input. The recipe may be referred to interchangeably as a “temperature profile”, a “displacement profile”, and/or a “temperature displacement profile”. The processor sends a

system 200 and the temperature control of the reservoir 206 control the temperature of the fixed bearing sidewall 180, which in turn controls displacement of the fixed bearing sidewall 180. Moreover, the instructions generated by the processor 140 may also be based at least in part on one or more recipes stored in the memory 150.

[0061] In one example, the processor 140 may determine temperature set point based on the measured displacement of the fixed bearing sidewall 180 or portions thereof. The processor then communicates instructions to the temperature regulation system 200 to cool the fluid based on the measured displacement of the fixed bearing sidewall 180 or portions thereof. The reduction in temperature of the fluid reduces the temperature of the fixed bearing sidewall 180, which in turn reduces or eliminates their displacement. The temperature sensors 134, 136 may also be used to measure the temperature of the fluid and/or fixed bearing sidewall 180 and communicate these temperature measurements to the processor 140. These temperature measurements function as feedback for the processor 140.

[0062] In another example, only the temperature of the fluid is controlled and the displacement of the fixed bearing sidewall 180 is not measured during slicing of the ingot 102. In these embodiments, the temperature regulation system 200 controls the temperature of the fluid to control the temperature of the fixed bearing sidewall 180 according to a temperature set point. This temperature set point may be retrieved from a recipe as described above. Alternatively, it may be received as an input to the system 100 from a user or other computer system. The system 100 may measure the temperature of the fluid with the respective

CLAIMS:

1. A system for controlling the surface profile of wafers sliced from an ingot in a wire saw comprising:

a wire saw base including a fixed bearing sidewall and a free bearing sidewall opposite the fixed bearing sidewall;

a wire guide assembly for supporting wires, the wire guide assembly including rollers having a first end connected to the fixed bearing sidewall and a second end supported by the free bearing sidewall, wherein a wire guide rotates on a bearing, wherein thermal deformation of the fixed bearing sidewall from a first state to a second state corresponds to a change in a cutting surface profile of a cut wafer from a first cutting surface profile to a second cutting surface profile;

a temperature regulation system attached to the fixed bearing sidewall for controlling thermal deformation of the fixed bearing sidewall;

a control system for controlling the temperature of the fixed bearing sidewall including a temperature sensor for measuring the temperature of the fixed bearing sidewall; and,

a processor connected to the temperature regulation system and the control system, the processor configured to control the temperature of the fixed bearing sidewall at a desired temperature by activating the temperature regulation system.

2. The system of claim 1, wherein the processor is configured to maintain the temperature of the fixed bearing sidewall at a first desired temperature, the first desired

temperature corresponding to the first cutting surface profile of the cut wafer.

3. The system of claim 1, wherein the processor is configured to raise the temperature of the fixed bearing housing to a second desired temperature, the second desired temperature corresponding to the second cutting surface profile of the cut wafer.

4. The system of claim 1, wherein the processor is configured to lower the temperature of the fixed bearing housing to a third desired temperature, the third desired temperature corresponding to a third cutting surface profile of the cut wafer.

5. The system of claim 1, wherein the control system further comprises a memory for storing temperature profiles, each temperature profile associated with a cutting surface profile and defining a temperature set point for the fixed bearing sidewall, the processor configured to retrieve the associated temperature set points from the memory, the processor configured for communicating instructions to the control system to control the temperature regulation system.

6. The system of claim 1, wherein the temperature regulation system includes fluid channels and a valve in fluid connection with the fluid channels, the processor connected to the valve, the processor configured to maintain the temperature of the fixed bearing sidewall at a desired temperature by activating the valve.

7. The system of claim 6, wherein the fluid channels are internal to the fixed bearing sidewall.

8. The system of claim 7, wherein the fluid channels are on an inner surface of the fixed bearing sidewall.

9. The system of claim 6, wherein the fluid channels are on an outer surface of the fixed bearing sidewall.

10. The system of claim 1, wherein the temperature regulation system includes a heat exchanger, the processor communicatively connected to the heat exchanger, the processor configured to maintain the temperature of the fixed bearing sidewall at a desired temperature by activating the heat exchanger.

11. The system of claim 1 further comprising a sensor connected to the fixed bearing sidewall for measuring thermal displacement of the fixed bearing sidewall.

12. The system of claim 1 wherein the control system is connected to a valve of the temperature regulation system for controlling a flow rate of fluid of the temperature regulation system.

13. A system for controlling a cutting surface profile of wafers cut from an ingot by a wire saw, the system comprising:

a temperature regulation system attached to a fixed bearing sidewall of a wire saw base for controlling thermal deformation of the fixed bearing sidewall;

a control system for controlling the temperature of the fixed bearing sidewall including a temperature sensor for measuring the temperature of the fixed bearing sidewall and a displacement sensor for measuring thermal deformation of the fixed bearing wall; and,

a processor in communication with the temperature regulation system and the control system, the processor configured to control the temperature of the fixed bearing sidewall at a desired temperature by activating the temperature regulation system.

14. A method for slicing an ingot into wafers using a wire saw, the method comprising:

receiving an input from a user, the input including a desired wafer surface profile corresponding to a temperature set point of a fixed bearing sidewall of a wire saw base;

activating a temperature regulation system attached to the fixed bearing sidewall for controlling thermal deformation of the fixed bearing sidewall, the thermal deformation of the fixed bearing sidewall corresponding to the desired wafer surface profile; and,

initiating a slicing operation such that wires supported by a wire guide assembly cut wafers from the ingot, the wire guide assembly including rollers having a first end connected to the fixed bearing sidewall and a second end supported by a free bearing sidewall of the wire saw base, wherein the wire guide rotates on a bearing, wherein thermal deformation of the fixed bearing sidewall from a first state to a second state corresponds to a change in a cutting surface profile of a cut wafer from a first cutting surface profile to a second cutting surface profile.

15. The method of claim 14 further comprising maintaining the temperature of the fixed bearing sidewall at a first desired temperature, the first desired temperature corresponding to the first cutting surface profile of the cut wafer.

16. The method of claim 14 further comprising raising the temperature of the fixed bearing housing to a second desired temperature, the second desired temperature corresponding to the second cutting surface profile of the cut wafer.

17. The method of claim 14 further comprising lowering the temperature of the fixed bearing housing to a third desired temperature, the third desired temperature corresponding to a third cutting surface profile of the cut wafer.

18. The method of claim 14, wherein wafer surface profiles are stored in memory connected to a processor, the processor connected to the temperature regulation system, each of the wafer surface profiles associated with temperature set points of the fixed bearing sidewall.

19. The method of claim 18 further comprising retrieving, by the processor, wafer surface profiles from the memory, wherein the processor is configured for communicating instructions to a control system to control the temperature regulation system.

20. The method of claim 14, further comprising activating a valve of the temperature regulation system for controlling temperature of the fixed bearing sidewall.