molecules within the substrate, and the velocity of the speed of sound within the substrate (assuming a signal applied that is within the audio portion of the spectrum).

[0025] Referring now to a Fig. 2, a uniform-substrate signal propagation graph 200 illustrates an acoustical pulse traveling across a uniform silicon dioxide (SiO_2) plane of a substrate. The uniform-substrate signal propagation graph 200 was simulated in MATLAB® as a 100 by 100 matrix of SiO_2 molecules (boundary conditions were ignored for the simulation). Notice the attenuation of the signal as it propagates along the SiO_2 plane as well as the dispersion of the wave across the entire breadth of the surface. When the interference of the edges of the substrate is accounted for, an entire map can be created of a surface of the substrate. The map can then be used as a baseline for comparison with a measured substrate response in detecting surface or sub-surface abnormalities that could be incurred after the substrate is processed or handled. (While not shown directly, a similar map can be produced to examine bulk defects within the substrate as well.)

[0026] With reference again to Fig. 1, an occurrence of defects within the substrate 101 alters the signal path, thereby altering the plurality of propagated signals 113. The occurrence of defects can cause an impedance mismatch on or in the substrate 101 with regard to the plurality of propagated signals 113 causing one or more of the signals to head back toward the transducer 103. Consequently, non-uniformities occur in a distribution of signals seen by the plurality of distal 107 and proximate 109 sensors. An analysis of the received signal distribution thus provides details as to the relative location of the defect with respect to the plurality of sensors as well as the magnitude of the defect. The relative location is determined upon a known spatial distribution of the plurality of distal 107 and proximate 109 sensors.

[0027] When the integrity of the substrate surface is altered or non-uniform, as a result of a microscopic crack or lattice dislocations, the distance between nodes within at least a portion of the lattice structure is altered. The altered distance shifts both the amplitude and the phase of the signal. Consequently, the signal deviates from the signal response measured on a uniform (i.e., homogeneous) surface. The signal in the non-uniform substrate is also reflected back towards the transducer 103, while the forward propagating signal has an attenuated amplitude (*see* the plurality of propagated signals 113 at Fig. 1).

[0028] With reference now to Fig. 3, a non-uniform-substrate signal propagation graph 300 illustrates an acoustical pulse traveling across a non-uniform SiO_2 plane of a substrate. When the integrity of a surface of the substrate is non-uniform, here an SiO_2 film overlaying the substrate, the surface of the substrate is altered and can produce a microscopic crack. Thus, the distance between nodes within the lattice structure is varied. The variation in the lattice structure causes both the amplitude and phase of an applied signal to shift, deviating from the response of the signal when measured on a

concept testing leads directly to two additional conclusions: (1) for a fixed transducer, a broadband signal response will be a function of the location of a given feature on a surface of the substrate; and (2) the method to identify features on or in the substrate allows both identification of the existence of any surface or molecular variations on or in the substrate as well as the size and location of the surface or molecular variations.

[0036] With reference to Fig. 6, a flowchart 600 depicts an exemplary method for detecting irregularities in a substrate. An operation 601, a substrate, for example a silicon wafer, is placed in contact with the transducer and the plurality of sensors. The transducer and the plurality of sensors will typically be embedded into a portion of the process or metrology tool, as discussed above. A signal is then applied to the transducer, an operation 603, and consequently, to the substrate. As discussed herein, the signal can be a variety of either single-frequency signals, or a broadband signal in the form of, for example, a square wave. Also, depending upon an exact application and the substrate used, the frequency or frequency range can be found in an audio portion of the electromagnetic spectrum, supersonic to the audio spectrum, or any radio frequency range or higher. For certain applications, a frequency or frequency range below the audio spectrum (i.e., subsonic) can also be appropriate.

[0037] After the signal is applied to the transducer, the response on one or more of the plurality of sensors is measured at operation 605. Although not shown explicitly, the response measurement can be repeated as needed to, for example, increase a signal to noise ratio of the measurement operation. Either subsequent to or concurrent with the response measurement process, a baseline response is prepared at operation 607. The baseline response can be prepared in a number of ways. For example, as discussed herein, the baseline response can be based upon a computationally-derived model, a known-good substrate, a moving average of substrate responses, or by a variety of other means known independently to a person of skill in the art upon reading the material disclosed herein.

[0038] At operation 609, the response on one or more of the plurality of sensors is compared to the baseline response. A determination is then made at operation 611 whether the substrate measured response matches the baseline response. If the substrate measured response does not match the baseline response, a disposition of the substrate is determined at operation 613. The disposition can be based on a pre-determined magnitude of the difference between the substrate measured response and the baseline response. A result of the disposition can include ~~can include~~, for example, merely removing the substrate from the process line. Alternatively, the disposition can include returning the substrate for rework in processes earlier in a fabrication line or sending the substrate for ex-situ metrology for root-cause determination of defects detected. Once a

CLAIMS

What is claimed is:

1. A non-destructive signal propagation system to detect one or more defects in a substrate, the system comprising:

a transducer ~~configured~~ to convert one or more frequencies from an electrical signal into at least one mechanical pulse, the at least one mechanical pulse ~~being configured~~ to be coupled to the substrate;

a plurality of sensors to be positioned on the substrate distal to the transducer ~~and configured to be coupled to the substrate~~, the plurality of distal sensors ~~being further configured~~ to detect the at least one mechanical pulse and any distortions to the at least one mechanical pulse received from a bulk of the substrate; and

a signal analyzer coupled to the plurality of distal sensors to compare the detected at least one mechanical pulse and any distortions to the at least one mechanical pulse received from the bulk of the substrate with a baseline response, the baseline response being based on at least one of the following comparison tools where the comparison tools are selectable from a computational model, a known-good substrate, and a moving average of a plurality of substrates.

2. The system of claim 1, further comprising a plurality of sensors positioned proximate to the transducer and coupled to the signal analyzer, the plurality of proximate sensors ~~being configured~~ to be coupled to the substrate to detect any additional distortions to the at least one mechanical pulse received from the substrate.

3. The system of claim 1, wherein the one or more frequencies is within an audio portion of the electromagnetic spectrum.

4. The system of claim 1, wherein the one or more frequencies is above an audio portion of the electromagnetic spectrum.

5. The system of claim 1, wherein the one or more frequencies is provided to the transducer as a single pulse.

6. The system of claim 1, wherein the one or more frequencies is provided to the transducer as a series of pulses.

~~7. The system of claim 1, wherein the baseline response is based on a computational model, a known-good substrate, or a moving average of a plurality of substrates.~~

~~8~~7. The system of claim 1, wherein the system is built into a substrate handling mechanism associated with a piece of semiconductor equipment.

~~9~~8. A non-destructive signal propagation method to detect one or more defects in a substrate, the method comprising:

converting one or more frequencies, in a transducer, from an electrical signal into ~~at least one~~ a series of mechanical pulses;

positioning the transducer on the substrate to couple the ~~at least one~~ series of mechanical pulses to the substrate;

positioning a plurality of distal sensors on the substrate and distal to the transducer~~, the plurality of distal sensors being configured to be coupled to the substrate~~;

detecting the ~~at least one~~ series of mechanical pulses and any distortions to the ~~at least one~~ series of mechanical pulses received from a bulk of the substrate with the plurality of distal sensors; and

comparing the detected ~~at least one~~ series of mechanical pulses and any distortions to the ~~at least one~~ series of mechanical pulses received from the bulk of the substrate with a baseline response to detect the one or more defects, the comparing performed using comparison tools selectable from a computational model, a known-good substrate, and a moving average of a plurality of substrates.

~~10~~9. The method of claim ~~9~~ 8, further comprising positioning a plurality of sensors on the substrate proximate to the transducer~~, the plurality of proximate sensors being configured to be coupled to~~ to detect any additional distortions to the at least one mechanical pulse received from the substrate.

~~11~~10. The method of claim ~~9~~ 8, further comprising selecting the one or more frequencies to be within an audio portion of the electromagnetic spectrum.

~~12~~11. The method of claim ~~9~~ 8, further comprising selecting the one or more frequencies to be above an audio portion of the electromagnetic spectrum.

~~13~~12. The method of claim ~~9~~ 8, further comprising applying the one or more frequencies to the transducer as a single pulse.

~~14. The method of claim 9, further comprising applying the one or more frequencies to the transducer as a series of pulses.~~

~~15. The method of claim 9, further comprising basing the baseline response on a computational model, a known-good substrate, or a moving average of a plurality of substrates.~~

~~16~~13. The method of claim ~~9~~ 8, further comprising determining a disposition of the substrate based on a result that the one or more defects exists in the substrate.

~~17~~14. A non-destructive signal propagation system for detecting one or more defects in a substrate, the system comprising:

a ~~transducer~~ converting means for converting one or more frequencies from an electrical signal into ~~at least one~~ a series of mechanical pulses~~, the at least one mechanical pulse being configured to be~~ that are coupled to the substrate;

a primary sensing means for coupling to the substrate and detecting the ~~at least one~~ series of mechanical pulses and any distortions to the ~~at least one~~ series of mechanical pulses received from a bulk of the substrate, the primary sensing means being located distal to the converting means; and

an analysis means for comparing the detected ~~at least one~~ series of mechanical pulses and any distortions to the ~~at least one~~ series of mechanical pulses received from the bulk of the substrate with a baseline response.

~~18~~15. The system of claim ~~17~~ 14, further comprising a secondary sensing means for detecting any distortion in the ~~at least one~~ series of mechanical pulses received from the substrate due to an impedance mismatch in the substrate.

~~19~~16. A non-destructive signal propagation system to detect one or more defects in a substrate, the system comprising:

a substrate handling mechanism; the substrate handling mechanism including

a transducer ~~configured~~ to convert one or more frequencies from an electrical signal into at least one mechanical pulse, the at least one mechanical pulse ~~being configured~~ to be coupled to the substrate;

a plurality of sensors to be positioned on the substrate distal to the transducer ~~and configured to be coupled to the substrate~~, the plurality of distal sensors ~~being further configured~~ to detect the at least one mechanical pulse and any distortions to the at least one mechanical pulse received from a bulk of the substrate; and

a plurality of sensors to be positioned on the substrate proximate to the transducer ~~and configured to be coupled to the substrate~~, the plurality of ~~distal~~ proximate sensors ~~being further configured~~ to detect the at least one mechanical pulse and to detect any additional distortions to the at least one mechanical pulse received from the bulk of the substrate; and

a signal analyzer coupled to the plurality of distal sensors and the plurality of proximate sensors to compare the detected at least one mechanical pulse and any distortions to the at least one mechanical pulse received from the bulk of the substrate with a baseline response, the baseline response being based on at least one of the following comparison tools where the comparison tools are selectable from a computational model, a known-good substrate, and a moving average of a plurality of substrates.

~~20. The system of claim 19, wherein the baseline response is based on a computational model, a known-good substrate, or a moving average of a plurality of substrates.~~

17. A non-destructive signal propagation system to detect one or more defects in a silicon wafer, the system comprising:

a transducer to convert one or more frequencies from an electrical signal into at least one mechanical pulse, the at least one mechanical pulse to be coupled to the silicon wafer to be propagated along a lattice structure within the silicon wafer;

a plurality of sensors to be positioned on the silicon wafer distal to the transducer, the plurality of distal sensors to detect the at least one mechanical pulse and any distortions to the at least one mechanical pulse received from lattice structure of the silicon wafer; and

a signal analyzer coupled to the plurality of distal sensors to compare the detected at least one mechanical pulse and any distortions to the at least one mechanical pulse received from the lattice structure of the silicon wafer with a baseline response, the baseline response being based on at least one of the following comparison tools where the comparison tools are selectable from a computational model, a known-good substrate, and a moving average of a plurality of substrates.

18. The system of claim 17, further comprising a plurality of sensors to be positioned on the silicon wafer proximate to the transducer and coupled to the signal analyzer to receive any additional distortions to the at least one mechanical pulse received from the silicon wafer.