herein by reference in its entirety, describes a multistep process for recovering silicon granules from spent wafer-sawing operations. The process described therein can include a 2-stage iodine-catalysed reaction sequence that can operate at temperatures between 800-1300°C to produce a granular silicon product. The purity of silicon recovered can reach 99.9999 wt% (i.e., 6 nines or 6N) and possibly higher levels under certain operating conditions.

[0010] However, for the highest efficiency PV cells in use today it may be preferable to utilize a higher-purity silicon. For instance, it may be desirable to obtain a silicon purity of 8N (i.e., 99.999999 wt%).

[0011] Therefore, there remains a need in the art for commercial operations that can efficiently separate the silicon particles from the remainder of the slurry mixture. Furthermore, there exists a need for ways of converting these fine silicon particles into a useable form for application in the commercial production of semiconductor devices such as photovoltaic solar cells. Also, there remains a need in the art for commercial operations that can recover and/or purify silicon to increased purities (e.g., 8N) from various sources, such as the spent wafer-sawing slurry produced in the PV and ME industries.

SUMMARY OF THE INVENTION

[0012] Embodiments of t~~T~~he invention provides methods, systems, and apparatus for generating and/or recovering one or more silicon-containing products from spent silicon wafer wire sawing slurry. Varying grades of high or increased purity silicon (i.e., up to 7N to 10N and higher) can be produced at high throughputs and low or competitive cost with the processes and apparatus disclosed herein. Various aspects of the invention described herein may be applied to any of the particular applications set forth below or for any other types of silicon purifying applications. The invention may be applied as a standalone system or method, or as part of an integrated silicon product manufacturing process. It shall be understood that different aspects of the invention can be appreciated individually, collectively, or in combination with each other.

[0012a] According to a first aspect of the present invention, there is provided a process for recovering silicon comprising: a) separating iron-containing particles from a cutting slurry using at least one physical separation device, thereby producing a slurry product; b) removing liquid from said slurry product, thereby producing a powder mixture of silicon carbide and silicon; c) providing said powder mixture to a first vessel containing silicon tetra-iodide, thereby producing a vapor comprising silicon di-iodide; and d) providing said vapor comprising silicon di-iodide to a second vessel, wherein said deposited silicon is formed from the silicon di-iodide.

[0012b] According to a second aspect of the present invention, there is provided an apparatus for recovering silicon comprising: a) a physical separation device, wherein said physical separation device removes iron-containing particles from a cutting slurry to produce a silicon and silicon carbide rich stream; b) a cyclone separator for producing a silicon rich stream from the silicon and silicon carbide-rich stream; and c) a vessel for producing deposited silicon from the silicon-rich stream, wherein said vessel comprises a fluidized bed seeded with pure silicon particles.

[0012c] According to a third aspect of the present invention, there is provided a system for recovering silicon comprising: a) a physical separation device, wherein said device creates a magnetic field for separating iron-containing particles from a silicon-containing product; b) a separator, wherein said separation device is a hydro-cyclone or a air-cyclone for separating silicon carbide particles of greater than 10 micrometers in diameter from said silicon-containing product; c) a drying device for drying said silicon-containing product; d) a first vessel configured to receive said silicon-containing product, wherein said first vessel is maintained at a temperature of at least 1000°C; and e) a second vessel configured to receive said silicon-containing product, wherein said second vessel comprises a fluidized bed seeded with pure silicon particles.

[0012d] According to a fourth aspect of the present invention, there is provided a process for recovering silicon comprising: a) providing a silicon-containing material and iodine to a first vessel, thereby producing a silicon tetra-iodide rich composition comprising silicon tetra-iodide; b) providing the silicon tetra-iodide rich composition to a distillation process to form an increased purity silicon tetra-iodide rich composition; and c) providing the increased purity silicon tetra-iodide rich composition to a second vessel, wherein deposited silicon is formed from the silicon tetra-iodide.

[0012e] According to a fifth aspect of the present invention, there is provided a process for recovering a wire-saw cutting slurry comprising: a) subjecting a mixture comprising silicon carbide and PEG to a solid-liquid separation to form a silicon carbide rich composition and a silicon carbide depleted composition; b) subjecting the silicon carbide depleted solution to a filtration separation to form a PEG rich composition; and c) combining the silicon carbide rich composition and the PEG rich composition to form the wire-saw cutting slurry.

[0012f] According to a sixth aspect of the present invention, there is provided an apparatus for recovering silicon comprising: a) a first vessel configured for reacting a silicon-containing material with iodide to form an iodide mixture comprising silicon tetra-iodide; b) a distillation column configured to receive the iodide mixture and produce a high-purity silicon tetra-iodide rich composition; and c) a second vessel configured to form a deposited silicon from the silicon tetra-iodide rich composition.

[0013] Disclosed herein are methods and apparatus for the production of polycrystalline silicon granules and recovery of silicon carbide particles from various sources. The various sources can be spent slurry such as those generated during wire-sawing processes used in the microelectronics (ME) and photovoltaic (PV) industries.

[0014] Some embodiments of the invention provide purification systems and methods that can perform one or more of the following: (1) separation of wire-saw steel particles from the slurry using one or more series of physical separation devices (for example, magnets or electromagnets); (2) recovery of the slurry product and subsequent removal of the liquid phase (either glycol-water or oil) to produce a moist fine powder mixture of silicon carbide and silicon; (3) complete removal of the remaining moisture or oil using a liquid-to-gas phase separation of the powder mixture that can form a dry mixture of silicon and silicon carbide; (4) subjecting a dry mixture of silicon and