

## Glossary and Definition of Acronyms

**Absorption Band:** The area of the spectrum in which the absorption coefficient is at maximum.

**Absorption Coefficient:** The internal absorbance of a material; given that the unit transmission of a material is  $t$ , the absorption coefficient is  $a = \log_e t$ .

**Absorption Length:** The depth to which 63% ( $= 1 - e^{-1}$ ) of the photons are absorbed by the material at a specified wavelength.

**Absorption:** The interaction that takes place between the optical electric field of light and the electrons of a solid or gas material; in quantum mechanics, absorption is the interaction between photons and electrons in the presence of the lattice of nuclei.

**A-Center:** Also called an oxygen vacancy or O-V center; a trap that is created when a silicon vacancy interacts with an oxygen atom to form a stable trap defect.

**Amorphous:** A disordered, glassy solid state of a semiconductor (or other substance). Amorphous material does not have long range order; the thermal, optical, electrical, physical, and other properties of amorphous material vary considerably in comparison to the highly ordered crystalline state of the same material.

**Amplifier Sensitivity:** The sensitivity of the output amplifier from electrons to volts ( $V/e^-$ ).

**Angstrom ( $\text{\AA}$ ):** A unit of length commonly used in semiconductor nomenclature; 1  $\text{\AA}$  equals  $10^{-10}$  meters.

**Annealing:** A process wherein a solid material is heated and cooled in order to change its physical, optical, electrical, or thermal properties. UV laser annealing is performed to reverse the damage of the crystal lattices of the semiconductor layers from high energy ion bombardment (ion implantation).

**Antireflection (AR) Coatings:** A coating that is employed to reduce reflection loss; commonly used in backside-illuminated CCDs.

**Aperture:** An on-axis, light-restricting mask or object in an optical system; a circular, square, or other (polygonal) shaped physical object that blocks radiation in an optical system from the object side.

**Attenuation:** A deliberate reduction of the energy or light, generally in an optical system by the insertion of an on-axis element that reflects a portion of the beam from the optical path; attenuation or energy loss occurs (undesirable

or unplanned), when any object or energy-interfering phenomenon scatters, or when standing wave reduces the transmission of light in an optical system; an attenuation will transmit something less than 100% of the light falling on its surface (incident).

**Attenuator:** An optical element which transmits some percentage of a laser beam away from the optical axis or point of incidence.

**Back-Illuminated CCD:** A CCD, also called “backside-illuminated CCD” and “back-thinned CCD”, that is uniformly reduced to a thickness of approximately 10  $\mu\text{m}$  so that an image can be focused on the back of the parallel register (where there is no gate structure); thinned CCDs exhibit a high sensitivity to photons, ranging from the soft X-ray to the near-infrared regions of the spectrum; since light is hitting the silicon directly, instead of passing through the gate structure, this type of CCD has excellent responsivity to blue light; many back-illuminated CCDs also have UV coatings that “down convert” UV light into the visible portion of the spectrum, further increasing the QE.

**Backside Accumulation:** A surface passivation technique required by backside-illuminated CCDs to achieve a high and stable QE.

**Backside Charging:** A QE accumulation technique to induce negative charge on the surface of a backside-illuminated CCD.

**Backside Illumination:** A CCD technology where incident photons enter the back of a sensor to achieve the highest possible QE.

**Backside Well:** A small potential well that develops at the surface of a backside-illuminated CCD after thinning.

**Band-Gap Energy ( $E_G$ ):** The minimum energy that a valence electron must acquire to jump into the conduction band; a characteristic of the semiconductor or insulator material. Band-gap is described as a region between the valence band and the conduction band, devoid of allowed energy states.

**Barrier Phase:** A phase or region in a CCD that exhibits the lowest potential to confine the charge to a collecting phase or region.

**Beam Splitter:** An on-axis optical device to split, in varying percentages, a single beam into two beams; commonly, one beam is reflected from the beam splitter or one is transmitted through the beam splitter.

**Bird’s Beak:** The interface between the gate oxide over the signal channel and the thicker field oxide over the channel stop.

**Birefringent:** A material whose refractive index changes according to the changing polarization states of incident light.

**Blooming:** A full-well condition of a CCD sensor where the charge escapes a collecting region through a barrier region.

**Bond Strain Gradient (BSG) Model:** The strained region in the  $\text{SiO}_2$  layer near the Si-SiO<sub>2</sub> interface is due to a decrease in the Si-O-Si bond angle as the flexible SiO<sub>2</sub> network is forced to match with the silicon lattice.

**Bulk (or Displacement) Damage:** The damage associated with the displacement of silicon atoms from the lattice structure.

**Bulk Dark Current:** Dark current that is thermally generated in the bulk silicon.

**Bulk Trap:** A defect or impurity in the silicon wafer which traps signal electrons.

**Buried-Channel CCD:** A CCD technology where signal carriers are collected and transferred in a channel, located below and away from the Si-SiO<sub>2</sub> interface.

**CCD (Charged-Coupled Device):** A charge-coupled device is a light-sensitive integrated circuit that stores and displays the data for an image in such a way that each pixel (picture element) in the image is converted into an electrical charge, the intensity of which is related to a color in the color spectrum.

**CCD Gates:** Conductive electrodes that define the pixel boundaries and are blocked to collect and transfer the signal charge.

**CCD Read-Out:** CCDs are analog devices; to obtain a digital signal that is appropriate for doing a quantitative analysis, it is necessary to convert the analog signal to a digital format; when light is gathered on a CCD and is ready to be read out, a series of serial shifts and parallel shifts occurs. First, the rows are shifted in the serial direction towards the serial register. Once in the serial register, the data is shifted in the parallel direction out of the serial register, into the output node, and then into the analog-to-digital (A/D) converter where the analog data is converted into a digital signal.

**Charge Capacity:** The amount of charge that can be held by a pixel before blooming or surface interaction occurs

**Charge Collection Efficiency (CCE):** The efficiency of maintaining signal charge in the target pixel after a charge is generated.

**Charge Generation Efficiency (CGE):** The efficiency of the CCD to intercept incoming photons and generate electron-hole pairs; this efficiency is quantified by the quantum efficiency (QE).

**Charge Transfer Efficiency (CTE):** The fraction of charge successfully transferred per pixel transfer.

**CMOS (Complementary Metal Oxide Semiconductors):** Combination of both p-type channel and n-type channel MOS transistors on the same circuit design; CMOS circuits consume relatively low power.

**Collection Phase:** A high-potential phase that collects the signal electrons.

**Color Centers:** Absorbing sites in the lens element of a laser optical system, induced by repeated exposure to high intensity radiation.

**Compton Effect:** The process of photon scattering off loosely bound electrons in which the photon imparts a portion of its energy to the electron; the magnitude of the energy transfer depends on the scattering angle.

**Conduction Band:** An energy band in a solid in which electrons are freely mobile and can produce a net electric current.

**Conduction Band Electron:** An electron that is free to diffuse within the silicon lattice.

**Current Density:** The current per unit area.

**Damage Threshold:** A specific input energy level, usually radiant laser energy, which produces sufficient absorption in a lens or fiber optical material to cause solarization, color centers, or preablation sites; all of which reduce the transmission of the optical material and are considered as damage.

**Dangling Bond:** An unsatisfied bonding site at the Si-SiO<sub>2</sub> interface which creates traps.

**Dark Signal Non-Uniformity (DSNU):** The spatial variation of the dark signal within an image sensor, commonly expressed in terms of the differences in dark current from pixel to pixel, and specified as a percentage of the average signal.

**Dark Current:** Carriers that are thermally generated under completely dark conditions.

**Dark Spikes:** Isolated pixels that thermally generate dark current at a greater rate than the average dark current floor.

**Deep Trap:** A type of trap whose emission time constant is longer than the shortest clock overlap time period.

**Deep-Depletion CCD:** A custom CCD sensor, fabricated on high-resistivity bulk silicon, to extend the responsivity to the spectral range in the near-IR and hard X-ray regimes.

**Deep-UV (DUV):** The portion of the ultraviolet (UV) spectrum from approximately 180 nm to 280 nm, so-called because it is the deepest area of the UV where practical UV imaging is routinely done. It is also the deepest part of the UV spectrum, where irradiation work can be done in atmosphere conditions without side efforts. In this book, 157 nm is also considered as DUV.

**Defect Cluster:** A region where several radiation damage defects are closely grouped.

**Delta Doping:** An accumulation technique that grows a very thin highly doped epitaxial layer on the back surface of a CCD to obtain the QE-pinned condition.

**Depletion Dark Current:** The dark current generated thermally in the depletion region.

**Depletion Region:** The region in the CCD where dopant atoms are ionized by applied gate and channel voltages that generate a potential well.

**Dielectric:** A material having a relatively low electrical conductivity, such as an insulator; a substance that contains few or no free electrons (e.g., silicon dioxide (SiO<sub>2</sub>) and silicon nitride).

**Diffusion Dark Current:** Dark current carriers that diffuse from regions outside the depletion region.

**Displacement Damage:** See “Bulk Damage”.

**Divacancy:** A trap defect caused by two adjacent vacancies in the silicon lattice.

**Dose:** See “Radiation Absorbed Dose”.

**Dynamic Range:** The ratio of the CCD signal at full-well condition to the read noise.

**E' Center:** A relaxed oxygen vacancy in SiO<sub>2</sub>, represented as ≡Si•; the E' center is an oxygen-related point defect and constitutes a trivalent silicon atom that has an unpaired electron in a dangling orbital and is back-bonded to three oxygen atoms.

**Elastic Interaction:** An elastic scattering interaction of a high-energy ion and the coulomb potential, presented by the target ion that can result in displacement damage.

**Electromagnetic (EM) Spectrum:** The entire range of radiation extending in frequency from approximately 10<sup>23</sup> Hz to 0 Hz or, in corresponding wavelengths, from 10<sup>-13</sup> cm to infinity and including, in order of decreasing frequency, cosmic-ray photons, gamma rays, X-rays, ultraviolet radiation, visible light, infrared radiation, microwaves, and radio waves.

**Electron:** The signal carrier generated, collected, transferred, and measured in n-channel CCDs.

**Electron-Hole (e-h) Pair:** A carrier pair, produced when a photon or particle photoelectrically interacts with a silicon atom.

**Emission Time Constant:** The time period for a signal electron to escape from a trap thermally.

**Epitaxial Layer:** A high-quality layer of silicon, grown on a substrate where all the CCD functions take place.

**Epitaxial Silicon:** A type of silicon wafer, used in making high-performance CCDs.

**Excimer:** An acronym for "excited dimer"; a molecule consisting of generally two atoms (e.g., krypton and fluorine) which are strongly bound in the excited or upper energy level state, and dissociate in the ground state; an excited complex of two molecules.

**Excimer Lasers:** Chemical lasers that are capable of generating very short wavelength UV radiation; e.g., KrF (248 nm), ArF (193 nm), and F<sub>2</sub> (157 nm); commonly used as a source of UV radiation in very-high resolution photolithography.

**Exposure Time:** The length of time that a CCD is accumulating the charge.

**Extreme Ultraviolet (EUV):** The spectral range that covers wavelengths of 10 nm to 100 nm.

**Field-Assisted Emission:** A process by which electrons are emitted from a trap and accelerated by an electric field.

**Field Oxide:** A relatively thick oxide (typically 100 nm to 500 nm) formed to passivate and protect semiconductor surface outside of active device area, and to provide lateral isolation between adjacent device structures. The field oxide layer is common in MOS structures, but does not participate in device operation.

**Fixed Charge:** The type of charge in a Si-SiO<sub>2</sub> structure, located in the oxide layer in the immediate vicinity of Si surface; the fixed charge does not

move and does not exchange charge with Si, but has an electrical influence on the characteristics of a Si-SiO<sub>2</sub> structure.

**Fixed Pattern Noise (FPN):** An image noise that results from sensitivity differences between the pixels; also called “pixel nonuniformity”.

**Flatband Voltage ( $V_{FB}$ ):** A voltage, in MOS devices, at which there is no electrical charge in the semiconductor and, therefore, no voltage drop across it; in the energy band diagram, the energy bands of the semiconductor are horizontal (flat).

**Fluence:** The total concentration of the irradiated particles that impinge on a device; given in particles/cm<sup>2</sup>.

**Fractional Yield:** The fraction of holes that remain in the gate dielectric after initial recombination and electron migration, after being generated by ionizing radiation.

**Frenkel Pair:** The atom-vacancy pair formed when an atom is dislocated from its position in a lattice by high-energy particles.

**Frontside Illumination:** A CCD technology where incident photons enter on the gate side of the sensor.

**Full Well:** The maximum charge level that a pixel can hold and transfer; also referred to as the “well capacity”.

**Fused Silica:** Silicon dioxide (SiO<sub>2</sub>) that is highly purified; also known as “vitreous silica”.

**Gate Structure:** The polysilicon structure that is located on the parallel register in a traditional CCD; polysilicon gates are transparent at long wavelengths, but become opaque at wavelengths shorter than 400 nm.

**Glass:** A supercooled liquid composed of silica (SiO<sub>2</sub>) and impurities; highly purified silica glass will transmit UV.

**Hard CCD:** A CCD in which custom fabrication process steps are used to reduce the effects of radiation damage.

**Hole:** The signal carriers generated, collected, and measured in p-channel CCDs.

**Hopping Conduction:** A dark current generation process where valence electrons transit through interface and bulk states into the conduction band.

**Horizontal Shift Register:** The register responsible in shifting the signal charge horizontally to the output amplifier; also referred to as the “serial register”.

**Hydrogen Passivation:** The process by which hydrogen atoms are introduced to a CCD during processing, to passivate dangling bonds at the Si-SiO<sub>2</sub> interface.

**Impact Ionization:** A process in which a high-energy electron interacts with the silicon lattice, breaking the Si-Si covalent bonds, and generating electron-hole pairs.

**Indium Tin Oxide (ITO):** A material used in some CCD gates to provide a higher QE, particularly in the blue-green region of the spectrum.

**Inelastic Interaction:** An interaction typically involving a high-energy particle, and a silicon nucleus that results in displacement damage.

**Infrared (IR):** Invisible radiation with wavelengths from  $0.7\ \mu\text{m}$  to  $15\ \mu\text{m}$ .

**Integrated Circuit (IC):** A chip etched or imprinted with a network of electronic components such as transistors, diodes and resistors along with their interconnections.

**Integration:** The act of accumulating signals or charges on a CCD.

**Interface State:** Mid-band energy states found at the Si-SiO<sub>2</sub> interface that are responsible for dark current generation and charge trapping; also referred to as “interface traps”.

**Interstitial:** The atom in an atom-vacancy pair, produced when an atom is dislocated from its position in a lattice; see also “Frenkel Pair”.

**Ionization Damage:** The damage caused by the generation of electron-hole pairs within the gate dielectric.

**Ionization:** The process by which neutral atoms become electrically charged, either positively or negatively, by the loss or gain of electrons.

**Ionizing Radiation:** Radiation sources that produce ionizing particles that damage the gate dielectric of the CCD.

**Laser:** An acronym for “Light Amplification by the Stimulated Emission of Radiation”; a stimulated emission device that produces intense, highly coherent, monochromatic optical radiation.

**Light Shield:** A metal layer deposited over regions of the CCD to shield them from incoming light.

**Lithography:** The transfer of a pattern from one medium to another, for example, transferring a pattern from a mask or reticle to a wafer.

**Local Oxidation of Silicon (LOCOS):** Oxidation of selected areas of a silicon wafer by masking off the oxidation reaction from other regions. A thin uniform SiO<sub>2</sub> layer is initially formed (known as pad oxide) and then a layer of silicon nitride, Si<sub>3</sub>N<sub>4</sub>, is deposited. The Si<sub>3</sub>N<sub>4</sub> is photolithographically patterned and then a relatively thick SiO<sub>2</sub> layer is grown in the openings in the Si<sub>3</sub>N<sub>4</sub>. Oxidation is inhibited at regions with Si<sub>3</sub>N<sub>4</sub>. Following oxidation the Si<sub>3</sub>N<sub>4</sub> layer is stripped off the wafer. The thin pad oxide layer is used to help relieve stress from direct contact between Si and Si<sub>3</sub>N<sub>4</sub>. LOCOS is widely used to isolate MOSFETs.

**Lumogen:** A phosphor coating, applied to the CCD, to extend the QE response into the UV and EUV spectral regimes.

**Microlithography:** The science of imaging micron and submicron structures onto silicon wafers and other substrates by using a photomask with patterns of the image and a photoresist coating on the substrate onto which the mask pattern is formed.

**Micron:** Short for micrometer ( $10^{-6}\ \text{m}$ ), a unit of measure that is 1 millionth of a meter, or 1 thousandth of a millimeter.

**Multi-Pinned Phase (MPP):** A multiphase CCD technology that suppresses surface dark current generation.

**MOS (Metal-Oxide-Semiconductor):** A three layer structure in which the concentration of charge carriers in the semiconductor's sub-surface region (or the current flowing in semiconductor in the direction parallel to its surface) is controlled by the potential applied to a metal contact, or in other words, by the field-effect; the core of the MOS field-effect transistors (MOSFET).

**MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor):** A FET with a MOS structure as a gate, where the channel is created by inverting the semiconductor surface underneath the gate.

**Mobile Charge:** Electrically charged species which can move in the MOS gate oxide under the influence of an electric field, and can cause instability in the MOS device's characteristics;  $\text{Na}^+$  ions are the most common mobile charges in  $\text{SiO}_2$ .

**Non-Bridging Oxygen (NBO):** Non-bridging oxygen refers to an oxygen atom that fails to bridge one  $\text{SiO}_4$  tetrahedral to another tetrahedral in the  $\text{SiO}_2$  network; the NBO can be represented by  $\equiv \text{Si} - \text{O}^\bullet$ , and is a source of intrinsic point defects; when the NBO captures a hole, it is referred to as an oxygen-hole center (OHC) or a non-bridging oxygen hole center (NBOHC,  $\equiv \text{Si} - \text{O}^\bullet$ ).

**Non-Bridging Oxygen Hole Center (NBOHC):** Represented as  $\equiv \text{Si} - \text{O}^\bullet$ ; see also "Non-Bridging Oxygen".

**Nonlinear Absorption:** The process wherein the attenuation coefficient becomes a function of the light intensity.

**Open-Pinned-Phase (OPP):** A high-QE frontside-illuminated CCD technology that has a portion of the pixel open to incident photons.

**Output Amplifier:** A MOSFET amplifier that provides an output voltage for each pixel.

**Output Node:** The location on a CCD (often a single pixel, adjacent to the serial register) where the charge is collected as a discrete picture element for a CCD read-out; the data enters the output node from the serial register and exits through the analog-to-digital (A/D) converter.

**Output Transfer Gate (OTG):** The last gate of the horizontal register which is used for the charge injection and the clock isolation between the sense node and output summing well.

**Overflow Drain:** A drain on the opposite edge of the device that keeps the thermally generated charge from entering the device; the overflow drain is used for CCDs with only one horizontal register.

**Oxygen-Deficient Center (ODC):** An oxygen vacancy which is classified into two variants: ODC(I) and ODC(II); the structural origin of ODC(I) in  $\text{SiO}_2$  is attributed to the  $\equiv \text{Si} - \text{Si} \equiv$  homobond; ODC(II) is assigned to an unrelaxed neutral oxygen vacancy which is less stable than the  $\equiv \text{Si} - \text{Si} \equiv$  bonds.

**Pair Production:** A process in which a high-energy photon collides with a target atom and creates an electron-positron pair.

**Phase-Shift Mask:** A chrome-on-quartz or surface-etched quartz with patterns to shift the phase of the light in selected areas so as to permit a better overall patterning fidelity and to compensate for the proximity effects and other nonlinear geometry-related patterning effects.

**Phosphor:** A chemical substance that fluoresces when excited by X-rays, an electron beam, or UV radiation; phosphors are composed of rare earth oxides or halides (e.g., gadolinium, lanthanum, and yttrium) and usually emit green light with decay times that range from hundreds of nanoseconds to a few milliseconds.

**Photo-Response Non-Uniformity (PRNU):** The spatial variation of the photo-induced signal generating process within an image sensor.

**Photoelectric Effect:** A process in which valence band electrons are injected into the conduction band by a photon interaction.

**Photoelectron:** An electron that has been ejected from its parent atom by the interaction between that atom and a photon.

**Photoemission:** The process by which interacting photons stimulate the emission of electrons from one material into another material (e.g., the photoemission of electrons in the silicon layer into the SiO<sub>2</sub> layer).

**Photolithography:** The process of defining the polysilicon and gate dielectric layers and implants for CCD and MOS integrated circuits; light is used to transfer a pattern or image from one medium to another such as from a mask to a wafer; microlithography refers to the process that is applied to image with features in the micrometer range.

**Photon:** An elementary particle, or quantum, of radiant energy that stimulates the CCD and generates electron-hole pairs provided that the photon has sufficient energy.

**Peroxy Linkage (POL):** Represented as  $\equiv\text{Si}-\text{O}-\text{O}-\text{Si}\equiv$ , a defect in the SiO<sub>2</sub>.

**Peroxy Radical (PR):** Represented as  $\equiv\text{Si}-\text{O}-\text{O}^\bullet$ , an excess-type defect in the SiO<sub>2</sub>.

**Pinning Implant:** A highly concentrated, shallow boron p-type doped layer that pins the surface potential to the substrate potential.

**Pinning:** A bias condition that occurs when the signal channel is driven into inversion and pins the Si-SiO<sub>2</sub> surface potential to the substrate potential.

**Pixel Nonuniformity:** Variations in the pixel sensitivity to incident photons.

**Pixel:** A picture element; the smallest resolved area or object in a given image.

**Point Defects:** Highly localized imperfections of a crystalline structure, including vacancies, interstitials, and substitutional defects; point defects affect the periodicity of the crystal mostly in, or around, one unit cell.

**Polysilicon:** Highly doped, semitransparent, semiconductive, noncrystalline silicon used to form the gates of a CCD.

**Potential Maximum:** The highest potential within the potential well.

**Potential Well:** The potential distribution in the signal channel, which is responsible for the charge collection and the charge transfer.

**Process Traps:** Charge transfer efficiency (CTE) traps that result as the CCD is processed.

**P-V Center:** A phosphorus-vacancy center that traps a single electron induced when the CCD is exposed to high-energy particles.

**Quantum Efficiency (QE):** The number of electrons generated per incident photon.

**Quantum Yield:** The number of electrons generated per interacting photon.

**Radiation Absorbed Dose (RAD):** The standard unit of radiation dose, equivalent to the deposition of 100 ergs of energy per gram of material in the form of electron-hole pairs.

**Radiation Events:** Charge generated by energetic ions interacting with the CCD.

**Radiation Hard:** Describes devices that are able to withstand a higher-than-normal dose of ionizing radiation within the specified limits of performance degradation.

**Radiation Shield:** A shield, usually made of aluminum or tantalum, placed near a CCD to reduce the dose received by the CCD.

**Radiation Traps:** Charge transfer efficiency (CTE) traps induced when the CCD is exposed to high-energy particles.

**Resolution:** The smallest image that can be clearly discerned with the instrument and technique used, in terms of either space (spatial resolution), time (temporal resolution), or intensity.

**Responsivity:** The absolute QE given in units of amps per watt.

**Reverse Annealing:** The process by which an irradiated CCD's dark current and flat-band shift continue to increase long after the initial exposure.

**Saturation:** The absolute maximum signal level possible in the device; it is usually determined by factors such as the onset of clipping, (e.g., with anti-blooming), charge spreading (e.g., in non-antibloomed devices), or gross non-uniformity.

**Scientific-Grade CCD:** A high-performance CCD that offers fewer defects than commercial-grade CCDs. Scientific-grade CCDs produce better spatial resolution, have lower noise, and enable the user to accurately measure the intensity differences between the objects.

**Sense Node:** The region where the signal charge is dumped from the horizontal register, allowing the measurement of the charge packet size as a voltage; it is also called the "floating diffusion" or "output diode".

**Shallow Trap:** A type of trap whose emission time constant is shorter than the shortest clock overlap time period.

**Silicon Dioxide (SiO<sub>2</sub>) or Silica:** Exists in crystalline or amorphous form, and occurs naturally in impure forms such as quartz and sand; in semiconductor technology, SiO<sub>2</sub> is used in the form of amorphous thin films, and is the most common insulator in MOS devices; very high quality films are

obtained by the thermal oxidation of silicon which forms an excellent interface with the silicon; single crystal  $\text{SiO}_2$  is known as quartz, and amorphous  $\text{SiO}_2$  is sometimes referred to as glass.

**Soft CCD:** A CCD in which no special effort has been made in the design and the fabrication to lessen the effects of radiation damage on the performance.

**Solid-State:** Refers to the electronic properties of crystalline material, as opposed to vacuum and gas-filled tubes that transmit electricity; compared with earlier vacuum-tube devices, solid-state components are smaller, less expensive, more reliable, use less power, and generate less heat.

**Surface Dark Current:** Thermally generated dark charge produced at the Si- $\text{SiO}_2$  interface.

**Surface-Channel CCD:** An early CCD technology where a charge is collected and transferred at the Si- $\text{SiO}_2$  interface.

**Thermal Anneal:** A process by which the radiation traps are thermally annealed.

**Thin Gate:** A frontside-illuminated CCD technology that uses an ultrathin ( $<400 \text{ \AA}$ ) gate as one of the phases for a high QE response.

**Total Dose:** The ionizing radiation dose received by a device. See also “radiation absorbed dose”.

**Transparent Gate:** A frontside CCD technology that can deliver high QE, where one of the polygate electrodes is replaced by an optically transparent conducting gate material.

**Trap:** An undesired region in the signal channel where electrons are deferred.

**Ultraviolet (UV):** Wavelengths in the electromagnetic spectrum that begins at the end of the “violet” portion of the visible spectrum (400 nm), and extends down to where the X-ray region begins (10 nm).

**UV Flooding:** A backside charging technique used to accumulate and negatively charge the surface of a backside-illuminated CCD.

**UV Lamp:** A lamp that emits a sizable quantity of UV radiation; examples are mercury arc and xenon or deuterium lamps which are enclosed by a quartz envelope; the lamps can contain “dupont” gases to increase the spectral output in the UV region.

**UV Laser:** A laser such as an excimer laser, quadrupled Nd:YAG laser, or He:Ne laser, that emits radiation in the UV region.

**Vacancy:** A defect that is produced when a silicon atom is displaced from its position in the lattice; a missing ion in a lattice point.

**Vacuum Ultraviolet (VUV):** The region of the ultraviolet spectrum between 200 nm and the shortest end of the UV spectrum, about 10 nm; VUV radiation generally requires the use of a vacuum environment to prevent the absorption of the VUV energy by gas (air) molecules.

**Valence Band:** The highest occupied energy level in a solid crystal semiconductor or insulator that is occupied by electrons at  $T = 0 \text{ K}$ .

**Vertical Shift Register:** The register responsible for shifting the signal charge vertically to the horizontal shift register; also referred to as “parallel register”.

**Via:** A small opening in an insulative layer which is filled with a metallic conductor to permit an ohmic contact with the underlying silicon semiconductor device; multiple layers of semiconductor devices are connected with via metallization.

**Virtual Phase CCD:** A single-phase frontside-illumination CCD technology that exhibits high UV sensitivity.

**Visible Light:** The region of the electromagnetic spectrum, with wavelength from 400 nm to 700 nm, that can be perceived by the eye or the human retina.

**Wafer:** A semiconductor substrate, sliced from a crystalline ingot of silicon or gallium arsenide or sapphire, and polished on one side to an optical finish; the wafers are then cleaned, patterned with a resist layer, etched, and doped. After several such operations and the final metallization steps, the wafers are cut into individual dies.

**Wavelength:** The physical distance covered by one cycle of a sinusoidal wave of electromagnetic radiation; or the distance between the phase maxima or wave peaks in a light beam.

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