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Poole et al.

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[45] **Date of Patent: Nov. 10, 1992**

[54] **METHOD FOR MAKING THINNED CHARGE-COUPLED DEVICES**

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[73] Assignee: **Hughes Danbury Optical Systems, Inc.,** Danbury, Conn.

[21] Appl. No.: **670,841**

[22] Filed: **Mar. 18, 1991**

[51] **Int. Cl.^{5}** **H01L 21/58;** H01L 21/339

[52] **U.S. Cl.** **437/53;** 437/226; 437/974; 437/86; 437/225; 148/DIG. 12; 148/DIG. 135

[58] **Field of Search** .... 437/53, 226, 974, 86, 437/225; 148/DIG. 135, DIG. 12

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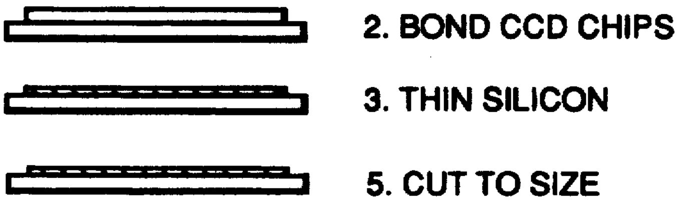
Attorney, Agent, or Firm—W. K. Denson-Low; W. J. Streeter; R. A. Hays

[57] **ABSTRACT**

A standard thick silicon charge-coupled device (FIG. 1A) has its pixel face mounted to a transparent, optically flat glass substrate using a thin layer of thermoset epoxy. The backside silicon of the charge-coupled device is thinned to 10 ±0.5 um using a two-step chemi-mechanical process. The bulk silicon is thinned to 75 um with a 700 micro-grit aluminium oxide abrasive and is then thinned and polished to 10 um using 80 nm grit colloidal silica. Access from the backside to the aluminum bonding pads (36 of FIG. 5) of the device is achieved by photolithographic patterning and reactive ion etching of the silicon above the bonding pads. The charge-coupled device is then packaged and wire-bonded in a structure which offers support for the silicon membrane and allows for unobstructed backside illumination.

18 Claims, 3 Drawing Sheets



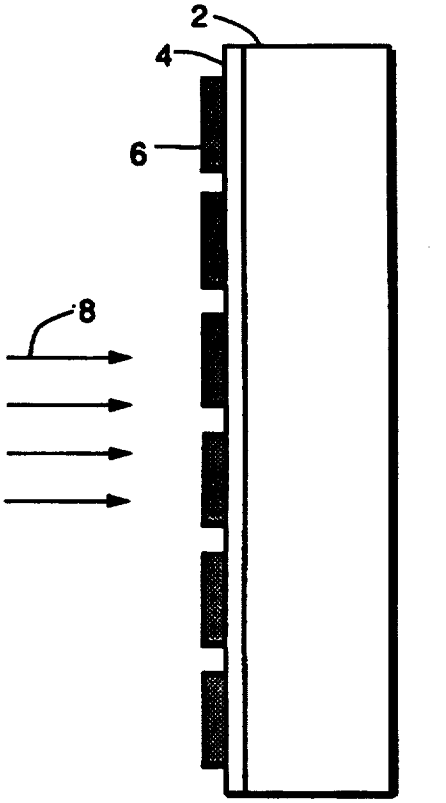


FIG.1a.
(PRIOR ART)

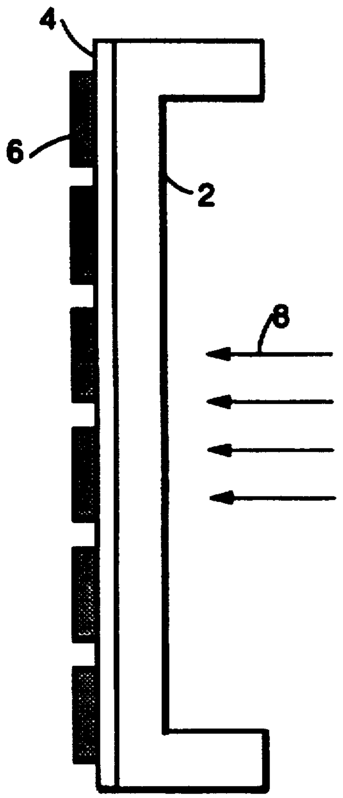


FIG. 1b.
(PRIOR ART)

FIG.5.

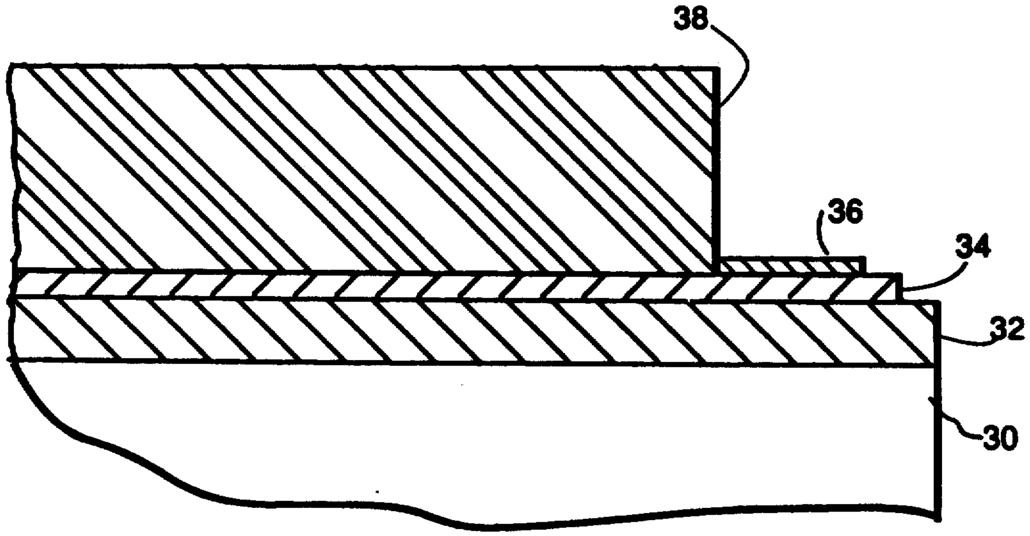


FIG. 2a.

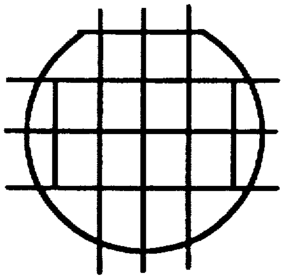


FIG. 2b.

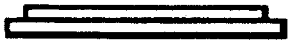


FIG. 2c.

FIG. 2d.

FIG. 2e.

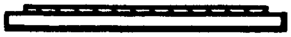


FIG. 6.

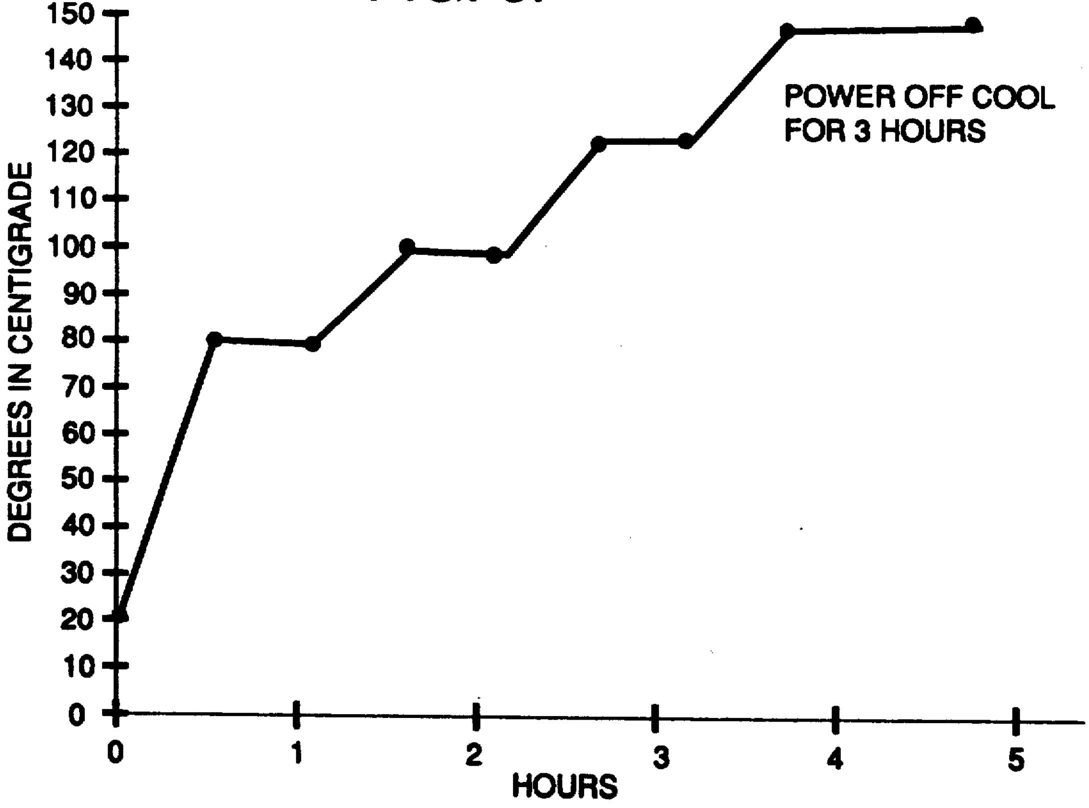


FIG. 3.

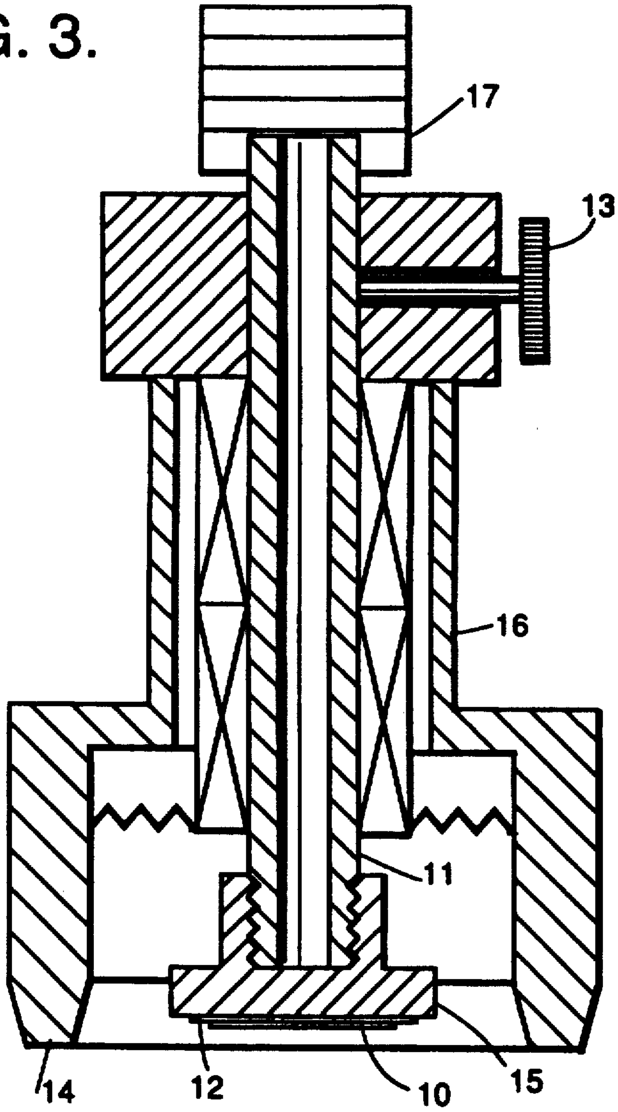

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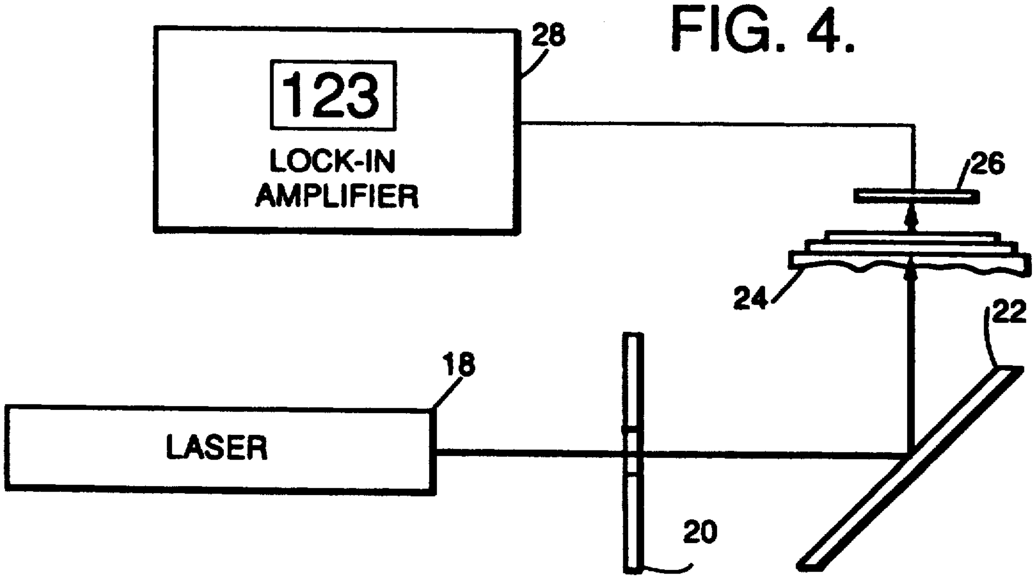
FIG. 4.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LOCK-IN AMPLIFIER
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22
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LASER
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METHOD FOR MAKING THINNED CHARGE-COUPLED DEVICES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to charge-coupled devices and in particular, such devices which are thinned to allow illumination of the backside of the device to improve quantum efficiency and UV spectral response. The invention is particularly directed towards an improved method for thinning such charge-coupled devices.

2. Description of the Prior Art

Charge-coupled devices are typically made of silicon and are used as solid-state imagers by taking advantage of the properties of a silicon crystal lattice. In the crystalline form, each atom of silicon is covalently bonded to its neighbor. Energy greater than the energy gap of about 1.1 eV is required to break a bond and create an electron hole pair. Incident electromagnetic radiation in the form of photons of wavelength shorter than 1 um can break the bonds and generate electron hole pairs.

The wavelength of incoming light and the photon absorption depth are directly related, the shorter the wavelength, the shorter the penetration depth into the silicon. Silicon becomes transparent at a wavelength of approximately 1100 nm and is essentially opaque to light at wavelengths shorter than 400 nm. High energy particles, X-rays and cosmic rays can break many thousands of bonds; therefore, excessive exposure can cause damage to the crystal lattice. Bonds can also be broken by thermal agitation. At room temperature, approximately 50 bonds per second per um^3 are broken and recombined on a continuous basis. The rate of electron hole pair generation due to thermal energy is highly temperature-dependent and can be reduced arbitrarily through cooling.

In order to measure the electronic charge produced by incident photons, it was required to provide a means for collecting this charge. Thus, the potential well concept was developed, wherein a thin layer of silicon dioxide is grown on a section of silicon, and a conductive gate structure is applied over the oxide. The gate structure is formed in an array of columns and rows, thus making it possible by applying a positive electrical potential to various gate elements to create depletion regions where free electrons generated by the incoming photons can be stored.

By controlling the electrical potential applied to adjacent gates, the depletion region, or well, containing the free electrons can be caused to migrate along a column or row, so that the signal may eventually be output at the edge of the array.

Typically, the gate structure is arranged with multiple phases, particularly three phases, so that the potential wells may be easily migrated through the silicon to an output device.

In reality, the wells and the migration of the wells is not carried out along the surface of the silicon-silicon dioxide interface, but takes place in a buried channel below the surface. The buried channel is free of interference from interface states and thus assures effective charge transfer from well to well. The operation of a charge-coupled device is somewhat analogous to that of a bucket brigade circuit commonly used to delay electrical signals.

Because the charge from the wells located far from an output amplifier must undergo hundreds of transfers, the charge transfer efficiency of a charge-coupled device is most important, as is the quantum efficiency and the spectral response. These considerations are particularly important when extremely low light levels are to be sensed.

Light normally enters the charge-coupled device by passing through the gates in the silicon dioxide layer. The gates are usually made of very thin polysilicon, which is reasonably transparent to long wavelengths but becomes opaque at wavelengths shorter than 400 nm. Thus, at short wavelengths, the gate structure attenuates incoming light.

In an effort to overcome this difficulty, it has become the practice to uniformly thin a charge-coupled device to a thickness of approximately 10 um, using acid etching techniques. Using a thinned charge-coupled device, it then becomes possible to focus an image on the backside of the charge-coupled device, where there is no gate structure that will attenuate the incoming light. Thinned charge-coupled devices exhibit high sensitivity to light from the soft X-ray to the near-infrared region of the spectrum.

FIG. **1A** illustrates schematically a cross-section of a typical thick-bodied charge-coupled device. The device includes a silicon body **2**, a silicon dioxide layer **4** and a gate array **6** formed on the silicon dioxide layer. Incoming light is illustrated by arrows **8** as illuminating a front side of the silicon **2**. FIG. **1B** illustrates a cross-section of a thinned charge-coupled device with light illuminating a backside. The thinned charge-coupled device, having a thickness of approximately 10 um, has improved quantum efficiency and UV spectral response.

Conventional charge-coupled device thinning was performed using chemical etchants, such as an acid mixture of hydrofluoric, nitric and acetic (HNA) acids, or potassium hydroxide; however, these reagents leave the silicon surface roughened with variations of approximately 500Å and frequent etch pits. The resulting surface was severely wrinkled, and if flattened by attaching to a support structure, significant non-planarity remained. Such non-planarity degraded performance, especially when used in fast (small f number) optical systems. With this thinning technique a thick (500 um) border region or hoop structure is required for device handling and for wire bonding to the device's electrical contacts, since the thinned material is much too fragile for either of these operations. The hoop region, therefore, is purposely marked off during device processing to prevent its being etched or thinned. Potassium hydroxide is an anisotropic etchant and therefore only etches the silicon directly behind the pixels, which results in a rectangular membrane attached to a rectangular hoop of silicon, as illustrated in FIG. **1B**. This structure does not require mechanical support for thinning; however, it results in a somewhat buckled, non-planar charge-coupled device silicon membrane.

In general, the chemical etchants are extremely strong and have varying reaction rates, thereby making it difficult to control the rate of etching, resulting in very poor yields.

The techniques used for wet etching with the chemical etchants required that the pixel face of the charge-coupled device be protected during the chemical etching; typically, the pixel face of the charge-coupled device is waxed to a support substrate, while the back is etched. Thereafter, the charge-coupled device is trans-

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