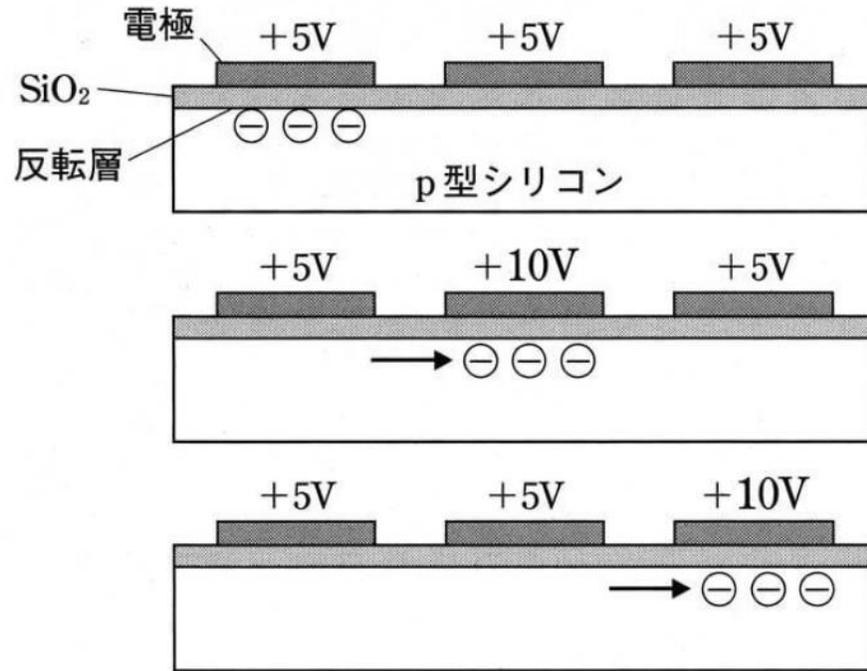


4 Explain what is meant by "inverted" operation. Why is inverted operation of a CCD advantageous?

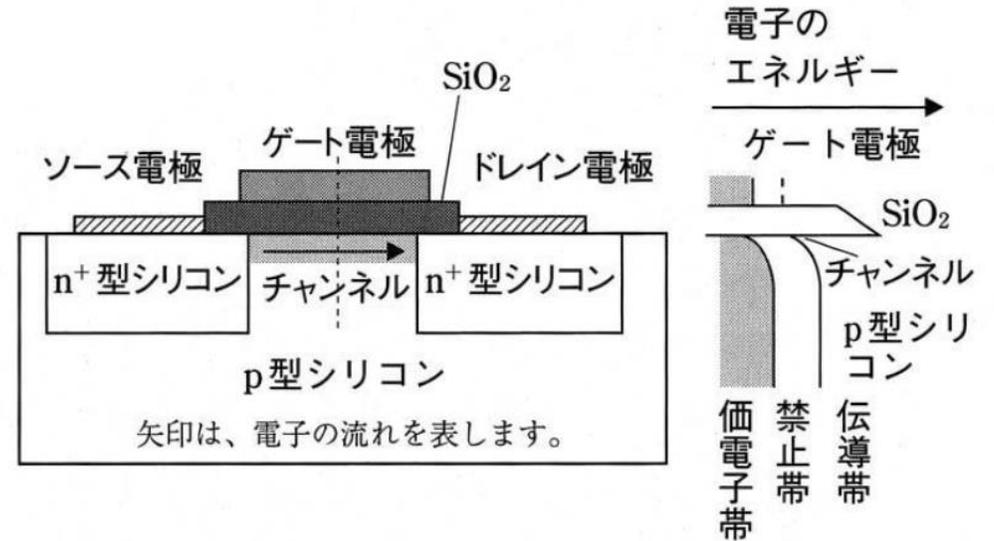
- Explain what is meant by "inverted" operation.
 - A mode where the surface of the CCD, at the silicon-silicon dioxide (Si-SiO_2) interface, is brought into an "inverted" state by applying a negative voltage to the gate electrodes.
 - The CCD can be operated in "inversion" mode then holes from the channel stop regions migrate to populate the interface states below the inverted gate and thereby eliminate surface dark current (by filling the hopping sites).
- Why is inverted operation advantageous?
 - Reduction of dark current → less noisy:

A significant portion of this dark current originates at the Si-SiO_2 interface, where electrons can "hop" from the valence band to interface states and then to the conduction band, creating unwanted charge in the CCD pixels. In inversion state, this hopping is suppressed. By suppressing surface dark current, inverted operation leads to cleaner images with less thermal noise, which is especially important for scientific imaging where faint signals need to be detected with high precision.



CCDでは、隣接する電極に順番に強いプラスの電圧をかけることによって、電子を引きつけて、移動させます。

図 6-18 CCDの基本構造



左図の破線部分の電位分布を表したのが右図です。ゲート電極に電圧をかけると、p型シリコンの電位が曲がり、SiO₂に隣接して、電位の溝（チャンネル）ができます。この溝を、ソースのn⁺シリコンから供給された電子がドレインまで移動します。電圧をかけるのをやめると、溝は消え、ソースからドレインへの電子の流れは止まります。

図 5-15 MOS トランジスタの構造

10. Describe the orthogonal transfer (OT) CCD and explain its application to provide tip/tilt corrections over a large field of view.

An Orthogonal Transfer CCD (OTCCD) is a specialized CCD that allows charge to be shifted in multiple directions (up, down, left, right) in real time. This enables tip/tilt correction by moving the collected charge to follow the motion of an object caused by atmospheric turbulence, keeping the image sharp during long exposures.

- Key Benefits

- Real-time motion correction: Tracks and compensates for image shifts, reducing blur.
- Large field of view adaptability: Different OTCCD units can apply independent corrections in wide-field systems, like in Pan-STARRS.
- Minimal blurring: Keeps charge shifts small (under 0.5 pixels), limiting image distortion.
- OTCCDs improve image quality by reducing blur caused by atmospheric conditions over large fields of view.