2025年７月１０日、宮坂力先生、昨日はありがとうございました。　　　　　　　　　　萩原良昭、AIPS

もとSONY (1975～2008) の半導体部門に勤務し現在熊本にある崇城大学で教授(2009～現在）として勤務しております。皆さんのスマフォのビデオカメラだけでなく、すべての半導体部品をSONY現役時代に研究開発設計を担当。２６歳の時に発明した超光感度の半導体受光素子の実用化でSONYだけを豊かにしました。これからは、さらに、この賞光感度の半導体部品を太陽電池に応用し、日本を、世界をも豊かにしたいと希望します。この本に関心がある人は萩原良昭にご連絡ください。

hagiwara@aiplab.com　080-2062-5657　萩原良昭

崇城大学　理事長付　特任教授
工学博士、Ph.D.
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合同会社ロコムテック　Locomtec
萩原AIPS研究所　所長

萩　原　良　昭

人工知能パートナーシステム（AIPS）を支えるデジタル回路の世界　｜　青山社

私がはじめてBipolar Transistorの構造と動作原理を学んだのは母校Caltechで大学２年生の時、Feynman の物理の授業でした。

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萩原 良昭 著

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真空管とBipolar Transistorの構造と動作原理の違いの比較

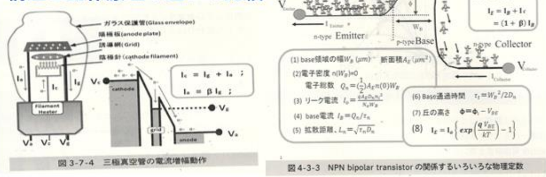
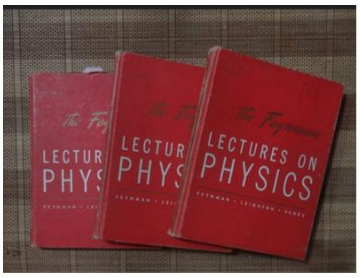
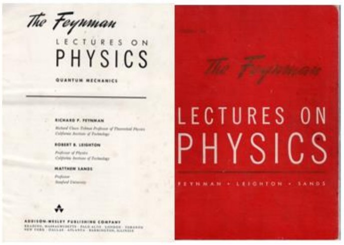
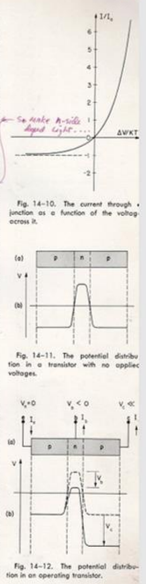


図 3-7-4　三極真空管の電流増幅動作
図 4-3-3　NPN bipolar transistor の関係するいろいろな物理変数

As an undergraduate student at Caltech from Sept 1967 till June 1969, at age 19 to 20, I learned Feynman Physics from Prof. Feynman and Prof. Leighton at Pasadena, California USA.
Yoshiaki Daimon Hagiwara







constant so long as ΔV is not too large. When they approach the barrier, these carriers will still find a downhill potential and will all fall down to the p-side. (If ΔV is larger than the natural potential difference V, the situation would change, but we will not consider what happens at such high voltages.) The net current I of positive carriers which flows across the junction is then the difference between the currents from the two sides:

$$I = I_0(e^{+q\Delta V/kT} - 1). \qquad (14.14)$$

The net current I of holes flows into the n-type region. There the holes diffuse into the body of the n-region, where they are eventually annihilated by the majority n-type carriers—the electrons. The electrons which are lost in this annihilation will be made up by a current of electrons from the external terminal of the n-type material.

When ΔV is zero, the net current in Eq. (14.14) is zero. For positive ΔV the current increases rapidly with the applied voltage. For negative ΔV the current reverses in sign, but the exponential term soon becomes negligible and the negative current never exceeds I_0—which under our assumptions is rather small. This back current I_0 is limited by the small density of the minority carriers on the n-side of the junction.

If you go through exactly the same analysis for the current of negative carriers which flows across the junction, first with no potential difference and then with a small externally applied potential difference ΔV, you get again an equation just like (14.14) for the net electron current. Since the total current is the sum of the currents contributed by the two carriers, Eq. (14.14) still applies for the total current provided we identify I_0 as the maximum current which can flow for a reversed voltage.

The voltage-current characteristic of Eq. (14.14) is shown in Fig. 14-10. It shows the typical behavior of solid-state diodes—such as those used in modern computers. We should remark that Eq. (14.14) is true only for small voltages. For voltages comparable to or larger than the natural internal voltage difference V, other effects come into play and the current no longer obeys the simple equation.

You may remember, incidentally, that we got exactly the same equation we have found here in Eq. (14.14) when we discussed the "mechanical rectifier"—the ratchet and pawl—in Chapter 46 of Volume I. We get the same equations in the two situations because the basic physical processes are quite similar.

14-6 The transistor

Perhaps the most important application of semiconductors is in the transistor. The transistor consists of two semiconductor junctions very close together. Its operation is based in part on the same principles that we just described for the semiconductor diode—the rectifying junction. Suppose we make a little bar of germanium with three distinct regions, a p-type region, an n-type region, and another p-type region, as shown in Fig. 14-11(a). This combination is called a p-n-p transistor. Each of the two junctions in the transistor will behave much in the way we have described in the last section. In particular, there will be a potential gradient at each junction having a certain potential drop from the n-type region to each p-type region. If the two p-type regions have the same internal properties, the variation in potential as we go across the crystal will be as shown in the graph of Fig. 14-11(b).

Now let's imagine that we connect each of the three regions to external voltage sources as shown in part (a) of Fig. 14-12. We will refer all voltages to the terminal connected to the left-hand p-region so it will be, by definition, at zero potential. We will call this terminal the *emitter*. The n-type region is called the *base* and it is connected to a slightly negative potential. The right-hand p-type region is called the *collector*, and is connected to a somewhat larger negative potential. Under these circumstances the variation of potential across the crystal will be as shown in the graph of Fig. 14-12(b).

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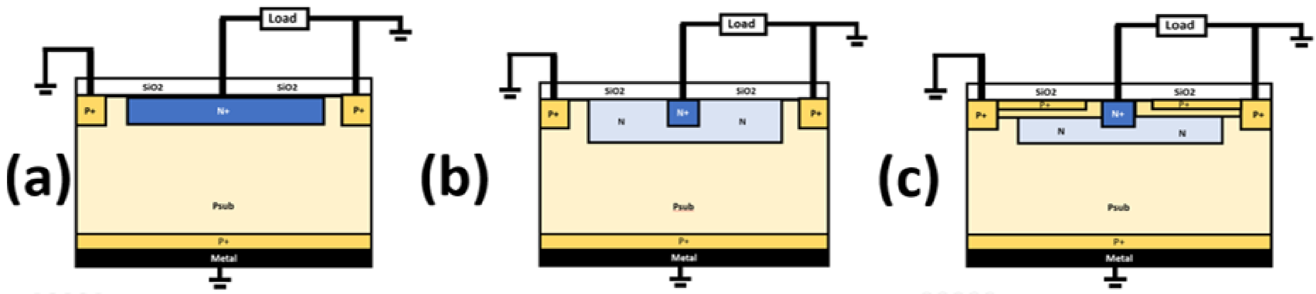
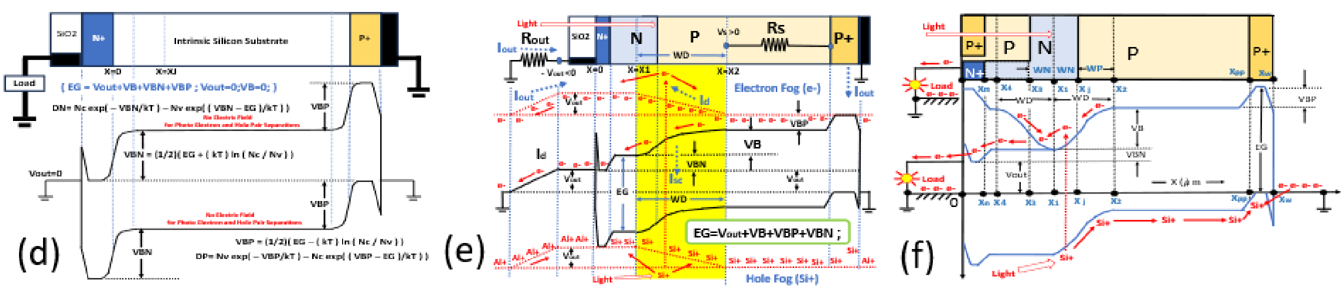
Fig. 14-10. The current through a junction as a function of the voltage across it.

Fig. 14-11. The potential distribution in a transistor with no applied voltages.

Fig. 14-12. The potential distribution in an operating transistor.

14-11





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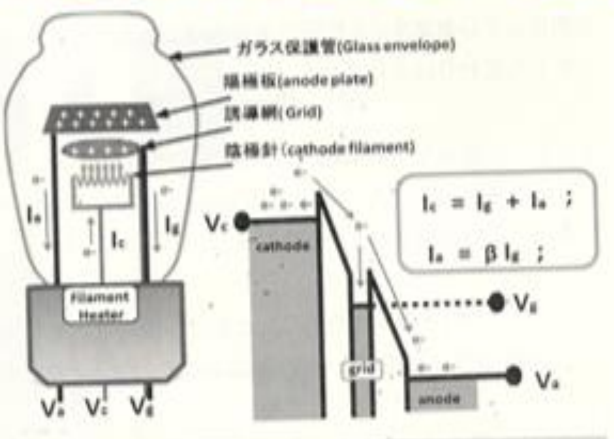

図 3-7-4 三極真空管の電流増幅動作

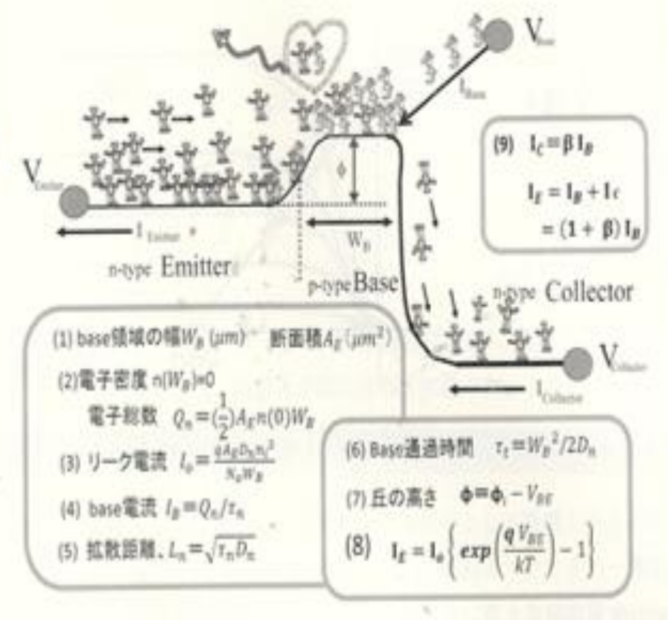

図 4-3-3 NPN bipolar transistor の関係するいろいろな物理定数

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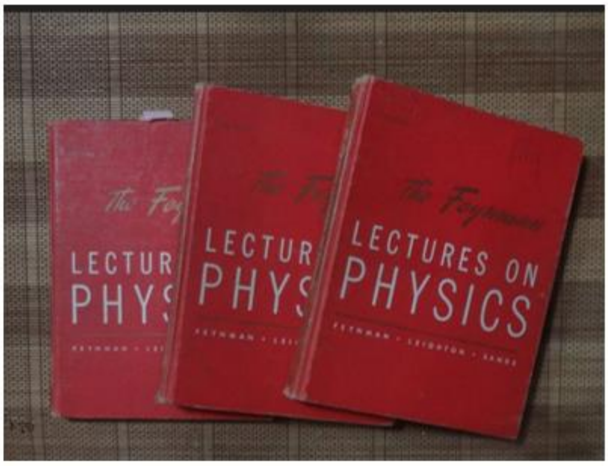

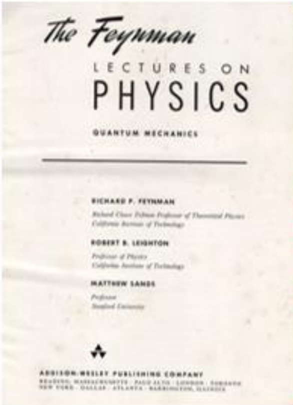

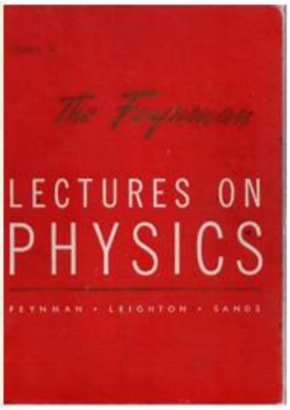

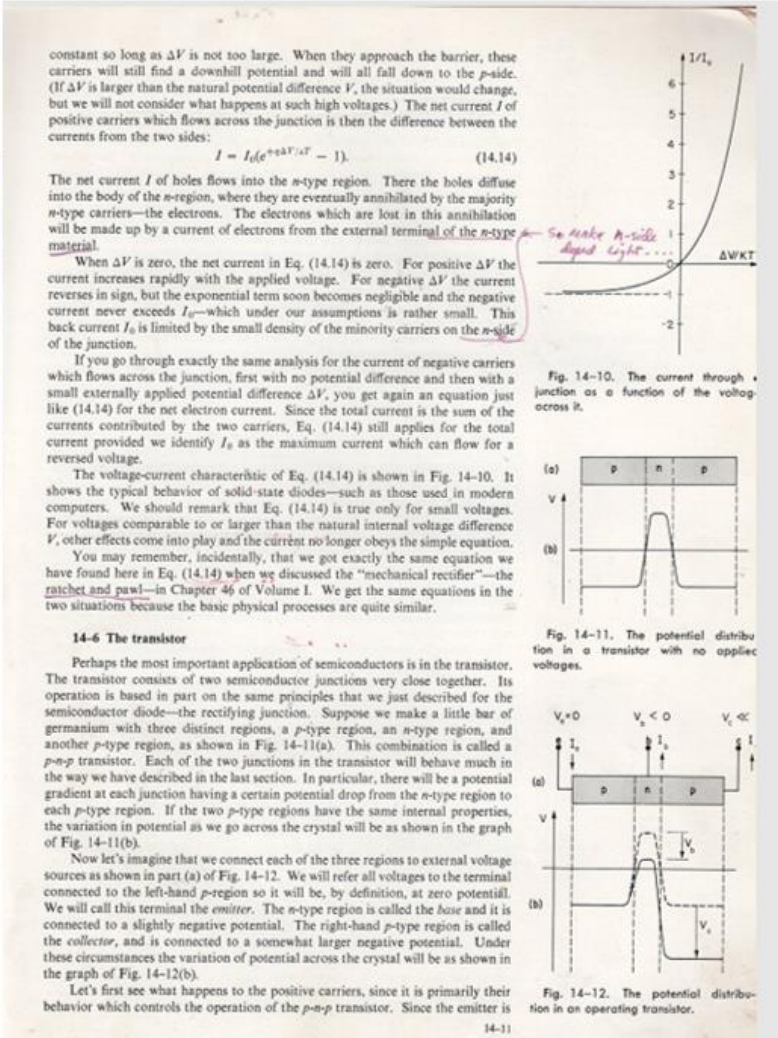

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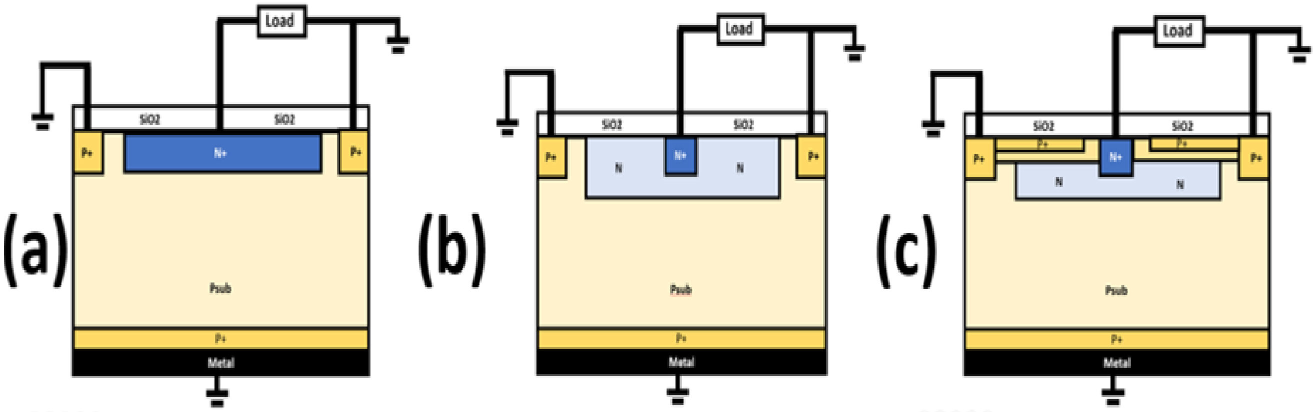

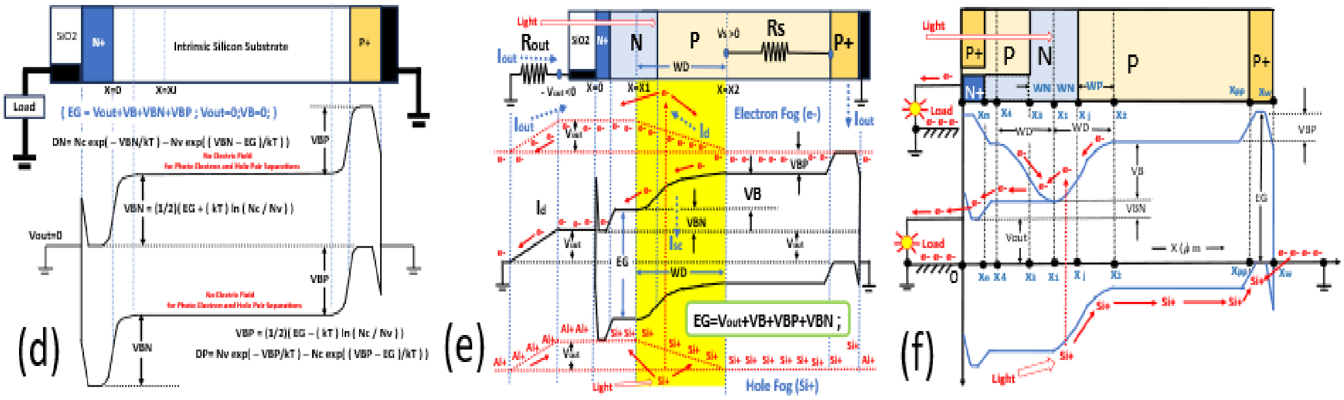

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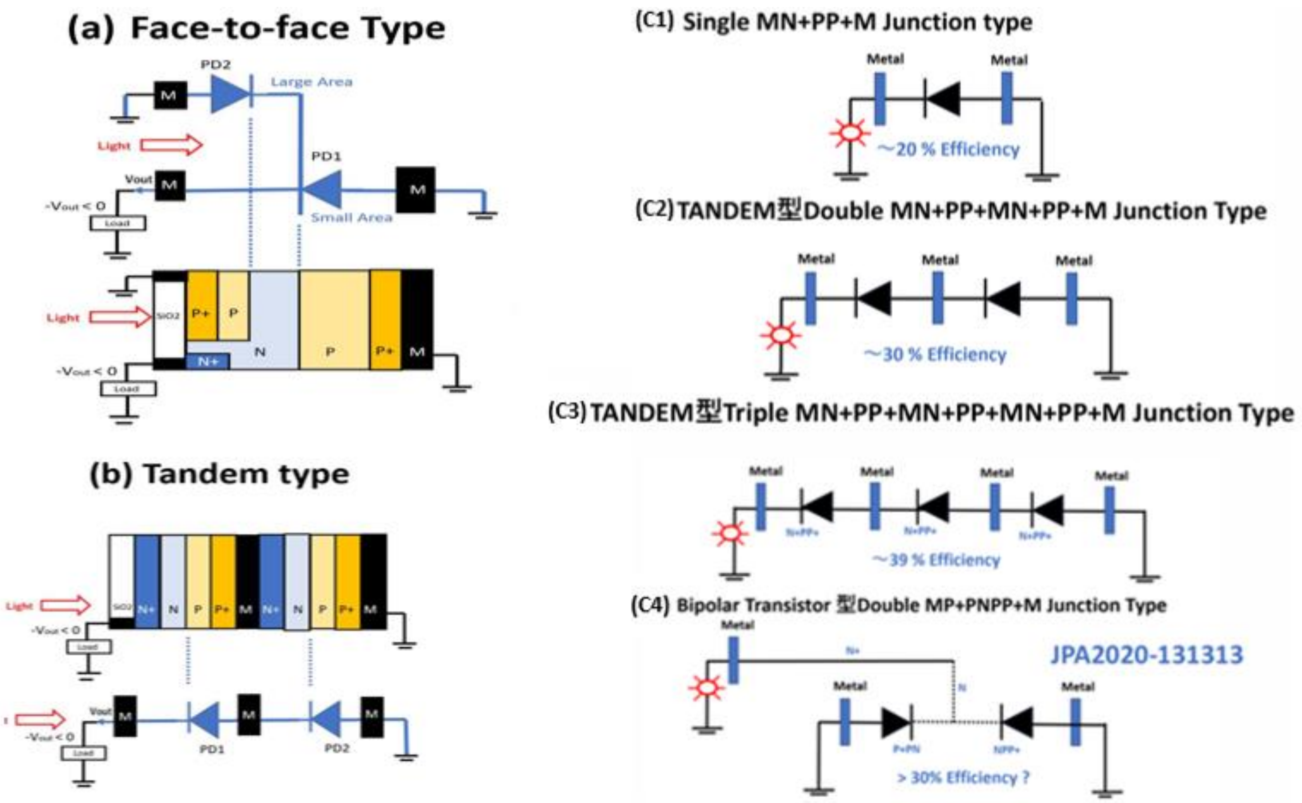
Hagiwara_Paper_for_Journal_of_ Electronics_and_Signal_Processing



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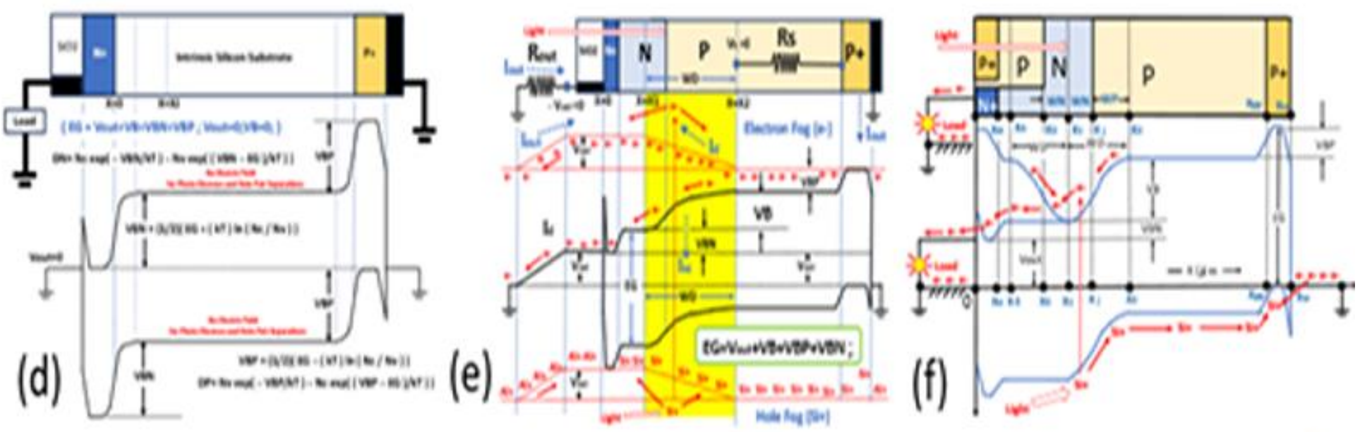

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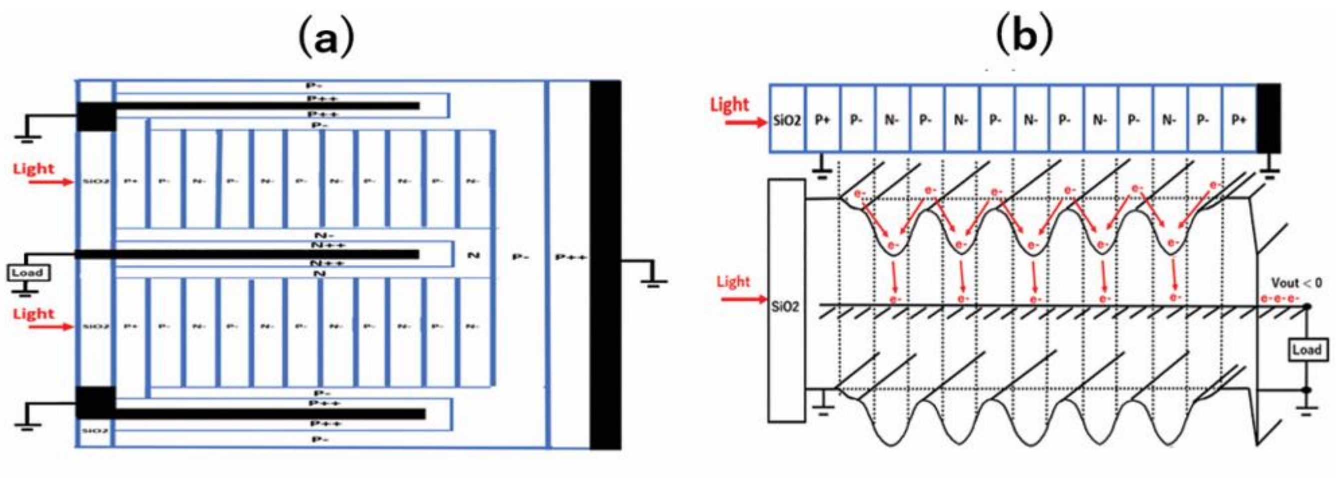


従来型のN+NPP＋シングル接合型太陽電池と
萩原提案のP+PNPPダブル接合型シリコン太陽電池は
最初のWAFERの準備が違うだけで製法は同一である。

●まず、P型の高抵抗シリコンWAFERを用意する。

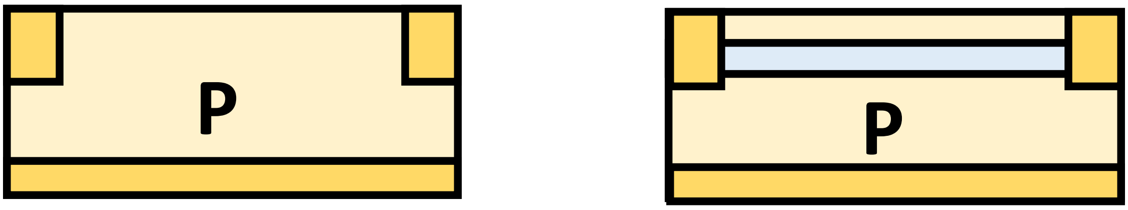
(A1) 高エネルギーイオン打ち込み装置で、りんイオンを全面に
深く打ち込み、埋め込みN型BASE領域を形成する。

(A2) 次に、低いエネルギーイオン打ち込み装置で、ボロンイオンを全面に
深く打ち込み、受光表面近傍をP型領域に形成する。

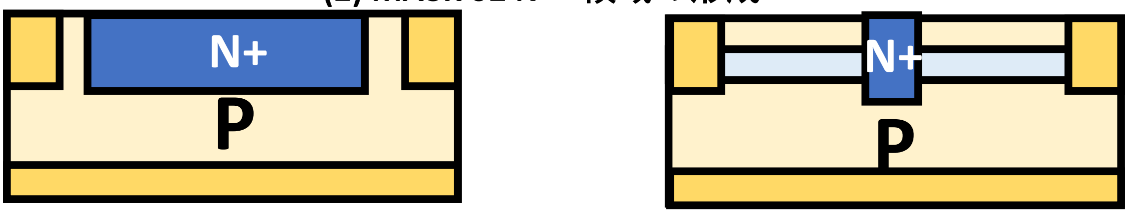
(A3) その後は、シングル接合型と同一で、熱拡散工程の４枚マスクとなる。

(a) 従来のシングル接合型　　(b) 萩原提案のダブル接合型

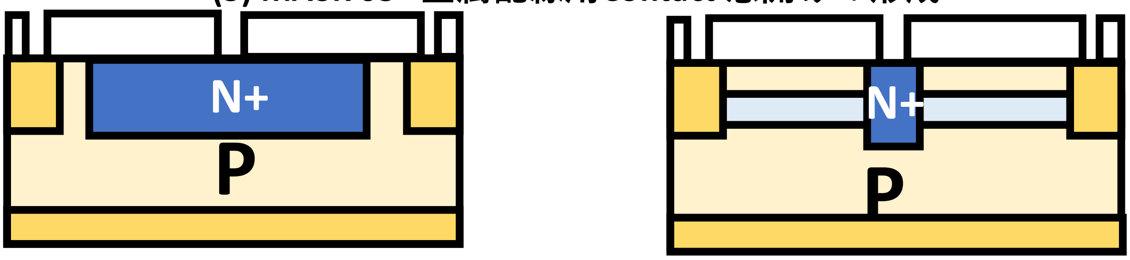
(1) MASK 01 P+　領域の形成



(2) MASK 02 N+　領域の形成



(3) MASK 03　金属配線用Contact 窓開けの形成



(4) MASK 04　金属配線の形成で完成である。