SURFACE RECOMBINATION VELOCITY MEASUREMENTS ON SURFACES OF n-TYPE GERMANIUM SUBJECTED TO VARIOUS GAS CYCLES

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By measuring the surface recombination velocity influenced by gas cycles on Ge samples, the produced type of surface conductivity was determined for various etchants.

In previous publications we have dealt with the dependence of surface recombination velocity (s) on various surface treatments using the flying spot method [1]. In the present work we employ the so-called MANY-bridge method [2, 3] to detect the variations of s during the stabilization process of etched Ge surfaces. Changes in surface potential were produced by usual gas cycles. The aim of the investigations was to detect the basic feature, *i.e.* the conductivity type of the surface layer produced by various etches.

It is well-known that in the small signal case

$$s \equiv \frac{(K_n K_p)^{1/2} N_t (n_b + p_b)}{2n_i \{\cosh[(E_t^f - E_i)/kT - u_0] + \cosh(u_s - u_0)\}}, \qquad (1)$$

$$u_0 \equiv \frac{1}{2} \ln \frac{K_p}{K_n},$$

where $u_s = q\Phi_s/kT$ denotes the dimensionless form of the surface potential Φ_s (q the charge on the electron, k the Boltzmann constant, T the absolute temperature), E_t^f the effective energy and N_t the density of surface centres. The δn_b and δp_b ($\delta n_b \equiv n_b^* - n_b = \delta p_b \equiv p_b^* - p_b$) are the excess carrier densities in the bulk, which depend on the equilibrium and non-equilibrium densities, n_b, p_b and n_b^*, p_b^*, respectively. K_n and K_p denote the capture cross-sections, and n_i the intrinsic carrier concentration. From inspection of the above equation, it is obvious that $s_{\max}$ belongs to the case $u_s = u_0$ and s decreases for large values of $|u_s - u_0|$. Thus, from the dependence of s on successive etching processes followed by rather quick gas-cycles, the conductivity type of the surface can be deduced, provided these influences do not practically affect the other parameters of the surface [4—6].

Results

The experimental set-up (Fig. 1.) was similar to that used by MANY and his co-workers [2, 7]. Because of the high sensitivity of the bridge, little changes in the effective lifetime (τ_e), *i.e.* in s, could also be detected.
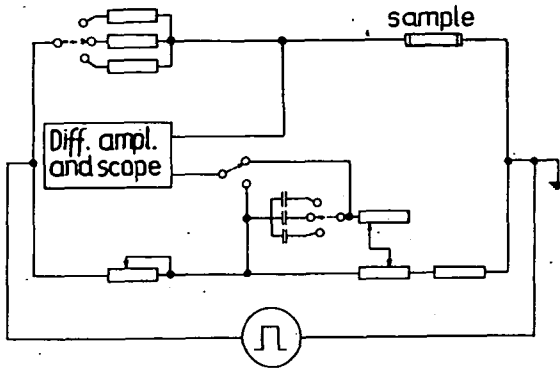
Fig. 1

Samples ($20 \times 6 \times 0.5 \text{mm}^3$) were made of n-type Ge of 22 ohm cm resistivity. Two contacts, one ohmic and one slightly injecting, were soldered onto the samples. The injection ration of the latter was about 0,7. The value of s was calculated by the following expression:

$$\frac{1}{\tau_e} = \frac{1}{\tau_b} + \frac{2s}{d}, \qquad (2)$$

where τ_b denotes bulk lifetime and d the sample thickness.

The previously polished samples were etched in the following etches:
1. CP4 ($3HF : 5 HNO_3 : 3 CH_3COOH : 0.06 Br_2$), 25°C, 120 seconds,
2. CP4A ($3 HF : 5HNO_3 : 3 CH_3COOH$), 25°C, 90 seconds,
3. CPI ($5 HF : 10 HNO_3 : 11 CH_3COOH : 0.3 I_2$), 25°C, 120 seconds,
4. Superoxol ($1 H_2O_2 : 1 HF : 4H_2O$), 25°C, 180 seconds,
5. alkaline peroxide ($125 H_2O_2 : 1 KOH$ of 25%), boiling, 10 minutes,
6. WAg ($2 HF : 1 HNO_3 : 2 AgNO_3$ of 5%), 25°C, 90 seconds.

The etching procedure was followed by dilution with doubly distilled water. The measurements were begun within 2 minutes after etching.

Fig. 2 shows the influence on s of gas cycling in the case of various etches. Empty signs in the figure represent measurements just after etching, full triangles show results on a surface stabilized for 48 hours in room atmosphere. By inspection it is to be seen that alkaline peroxide produces a depletion layer, while all others produce accumulation layers. We also have investigated the effect of successive surface treatments on the type of surface conductivity (Fig. 3). With the above results, using Eq. (1), it is possible to determine the conductivity type produced by an etch by employing it successively after an etch of known effect.

As a conclusion drawn from the above experiments, it can be stated that the effect of various etches on surface Fermi level can be characterized by a scheme which is similar to that proposed by HARTEN for the case of silicon [8]. Accordingly, Fig. 4 gives a qualitative information on surface Fermi levels, *i.e.* the types of surfcae
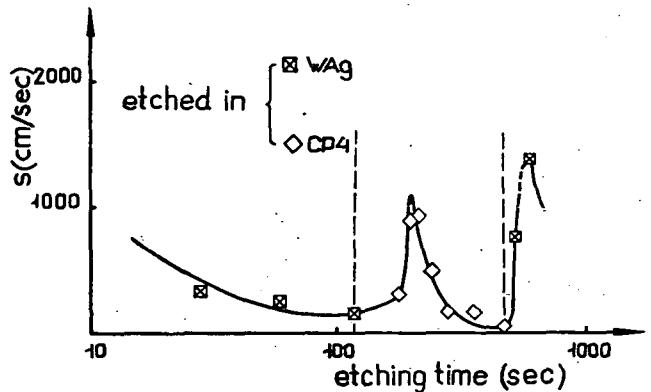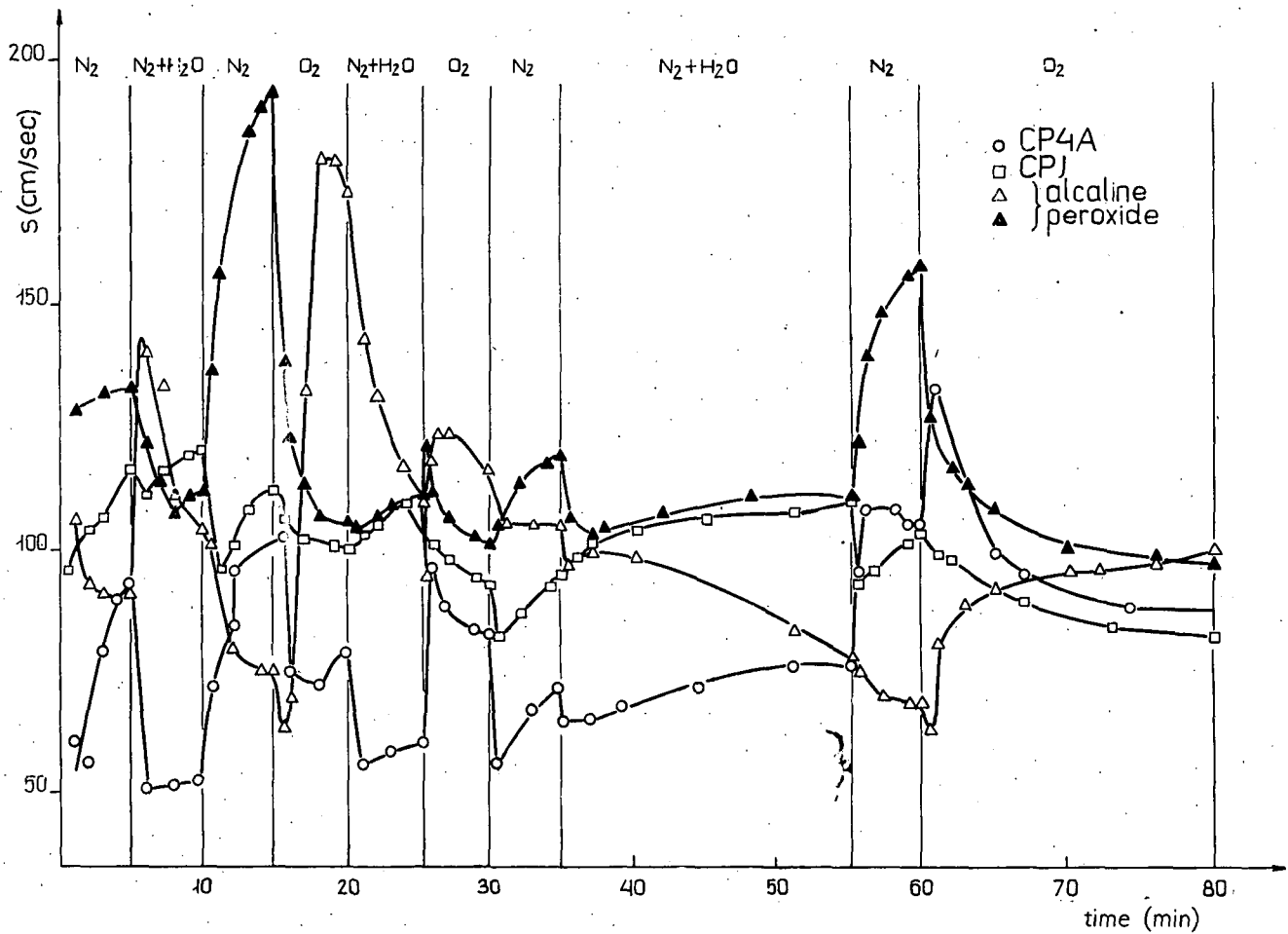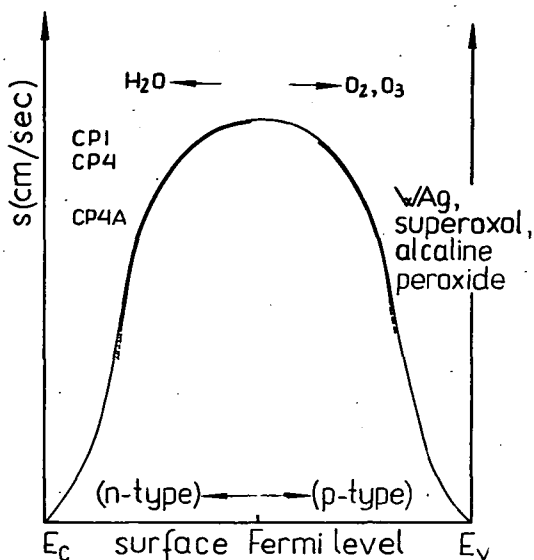

Fig. 3

Fig. 2

Fig. 4

conductivity produced by various etching procedures on bulk *n*-type Ge samples. Fig. 4 shows that the surface Fermi level for etches CPI and CP 4 is near to the midgap. This is consistent with the fact that the effect of gas cycles in this case is not definite. This might have been the cause of the contradiction between early observations of STEVENSON and KEYES [9] and the results of RZHANOV [10], the surfaces investigated by them being different as regards the degree of stabilization.

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ИЗМЕРЕНИЕ СКОРОСТИ ПОВЕРХНОСТНОЙ РЕКОМБИНАЦИИ НА ПОВЕРХНОСТИ ГЕРМАНИИ n-ТИПА ПОД ВЛИЯНИЕМ РАЗНЫХ АТМОСФЕР

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Измерялось скорость поверхностной рекомбинации на поверхности германии под влиянием разных атмосфер. Определялось, возникающий под влиянием различных травителей, тип проводимости на поверхности германии.