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SYSTEMATIC STUDY OF THE INFLUENCE OF CONTACTS ON CPM RESULTS

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The constant photocurrent method (CPM)[1] is now widely used for the basic characterization of amorphous hydrogenated silicon (a-Si:H). For detailed deconvolution procedures[2] reliable data are of great importance. We therefore studied the influence of different contacts on the measured spectra of identical samples. Undoped a-Si:H samples were covered with coplanar contacts made from NiCr, Ag, or Ti. Different contact spacings were used to investigate the influence of scattering in the samples[3]. An additional n^+ layer between a-Si:H and metal was used on some samples to ensure good ohmic contacts as a reference. The influence of SF_6 plasma etching (necessary for removal of the n^+ layer) was also tested.

We found that for all the above arrangements, the subbandgap shoulder increases with increasing distance of coplanar contacts[3]. However, significant differences were found in the magnitude and slope of the shoulder for different contact metals. These differences are not related to contact ohmicity (addition of n^+ layer has negligible influence). The preliminary results indicate that this effect can be at least partially explained by the reflection of light at the contact edges, whose height and shape can be critical in the subbandgap region.

1. INTRODUCTION

The constant photocurrent method (CPM)[1] is now widely used for the basic characterization of amorphous hydrogenated silicon (a-Si:H). CPM allows the spectral dependence of the optical absorption coefficient α to be found, by deconvoluting the midgap density of states (DOS) and the slope of the broader (valence) band tail.

In the standard deconvolution procedure, the shape of the midgap DOS is preselected (mostly Gaussian)[1]. Jensen[2] suggested a new deconvolution procedure in which there is no assumption about the DOS shape and which allows fine details of the DOS to be studied, related to the degradation, for example. Recently, small but systematic changes of the CPM results in response to changes in the coplanar contact distance have been used for the study of light scattering[3].

The reliability and reproducibility of CPM results is necessary for the interpretation of fine CPM differences[2,3].

For the study of light scattering, the coplanar contact distance is changed and the applied electric field (≈10V/mm) is kept constant. The coplanar contacts are basically two barriers, placed adjacent to each other. Part of the applied voltage can remain on the reverse biased metal contact. This means that for smaller distances (≈0.1mm) a substantial part of the applied voltage (about 1V) can remain on the barrier and the condition of constant electric field may not be fulfiled. That is why in this paper we have concentrated on studying the influence of different contact metals.

2. EXPERIMENTAL

2μm thick undoped, device quality a-Si:H was deposited at 275°C onto Corning 7059 glass substrates. On part of the samples an additional PH_3 doped n^+ layer was also deposited. On each sample a set of 10mm wide rectangular contacts was sputtered with varying spacing, similar to that used by Favre et al.[3]. The distances were L=5mm, 1.5mm, 0.5mm, and 0.15mm. Standard contact metal was NiCr but Ag and Ti were also

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used for comparison.

To enable CPM measurement of the intrinsic film on samples where an n^+ layer was used for guaranteed ohmic contact, the n^+ layer had to be removed between the electrodes. This was done by plasma etching of the samples in SF_6, for which the NiCr contacts act as a mask. One sample without an n^+ layer was also treated in the SF_6 plasma to investigate the influence of the etching itself. Instead of n^+ contacts, Mg ohmic contacts have also been widely used[4] but they are unstable when annealed in excess of 100°C.

The CPM measurements were carried out in the photon energy range 1.0 - 1.8eV with a conventional setup described elsewhere[1]. The absolute magnitude of the absorption coefficient was adjusted to values deduced from direct transmission measurements.

3. RESULTS AND DISCUSSION

In Fig.1 it is shown that the different contact metals can lead to very different CPM spectra in the subbandgap region. In fact, this result led to the writing of this paper.

The simplest explanation which came into consideration was that one of the metal contacts, i.e. Ag, is non-ohmic. That is why we decided to compare the CPM spectra of two samples with NiCr contacts, one of them with and the other without an n^+ layer below NiCr. For the CPM measurements, the n^+ layer between the metal contacts had to be etched off. To guarantee identical conditions, both samples (with and without n^+) were etched.

From Fig.2 it is seen that the difference between both curves is negligible, which means that NiCr itself is ohmic enough and an n^+ layer is not necessary.

However, for a given distance L of the coplanar electrodes the sample with NiCr (without n^+) which was etched (Fig.2) has an absorption coefficient α in the shoulder region (1-1.4eV) about twice as high as the unetched sample (Fig.1) ! A detailed comparison of these two

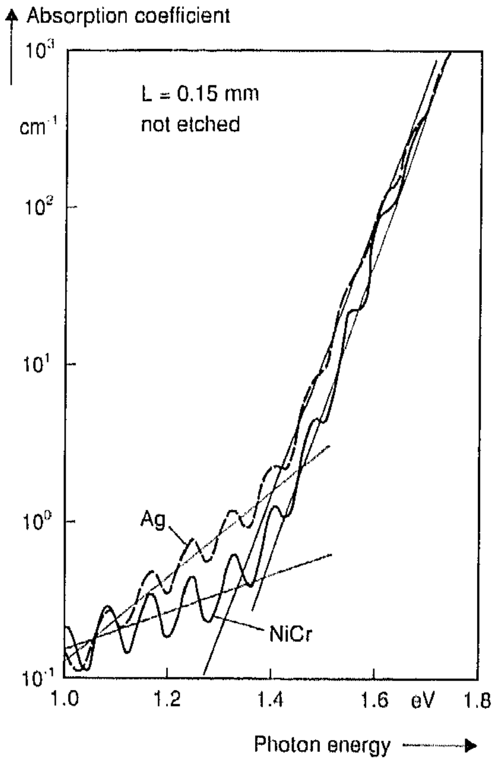

FIGURE 1
Absorption coefficient vs. photon energy of two a-Si:H samples with Ag or NiCr contacts.

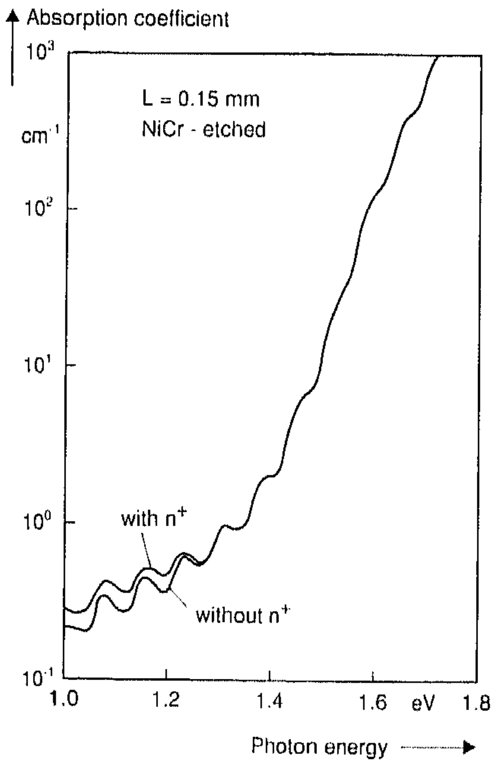

FIGURE 2
Absorption coefficient vs. photon energy of two a-Si:H samples with n^+ and without n^+ contacts.

samples with NiCr contacts for different values of L is seen from Fig.3 and 4.

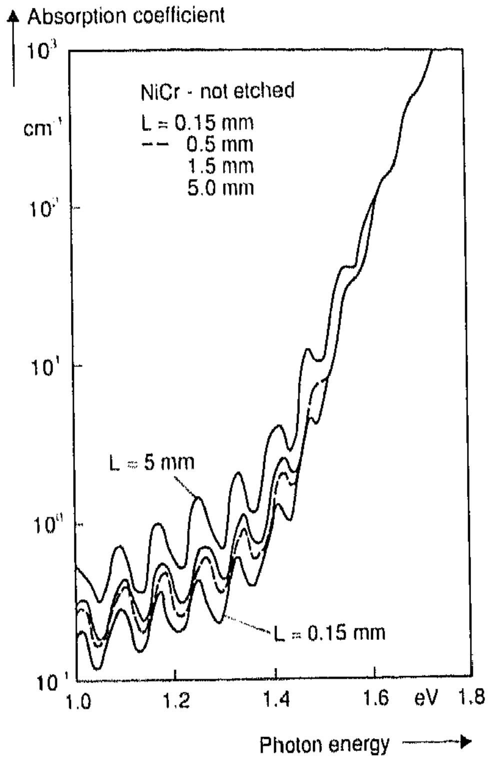

FIGURE 3
Absorption coefficient vs. photon energy of four a-Si:H samples with NiCr contacts. The contact spacing is varied from 5mm to 0.15mm.

It is seen in both cases (etched and unetched), according to ref.3, that the measured subbandgap α increases with increasing L. However, not only are the absolute values of α of etched samples higher but the ratio of α at 1.1eV for L=5mm to α for 0.15mm is also about twice as high for the etched sample (Fig.4) as the same ratio for the unetched sample (Fig.3), i.e. about 4 instead of 2. This means that in addition to scattering in a volume of a-Si:H, described in ref.3, there is an "additional scattering" mechanism of unknown origin.

Etching-induced surface roughness seems unlikely because the surface after etching (as illustrated in Fig.5) is even smoother than before etching. The only difference is the higher edge step, induced by etching of a-Si:H.

A detailed study of the sample with Ag contacts was essential for clarifying the problem. As illustrated in Fig.6, in this case too the

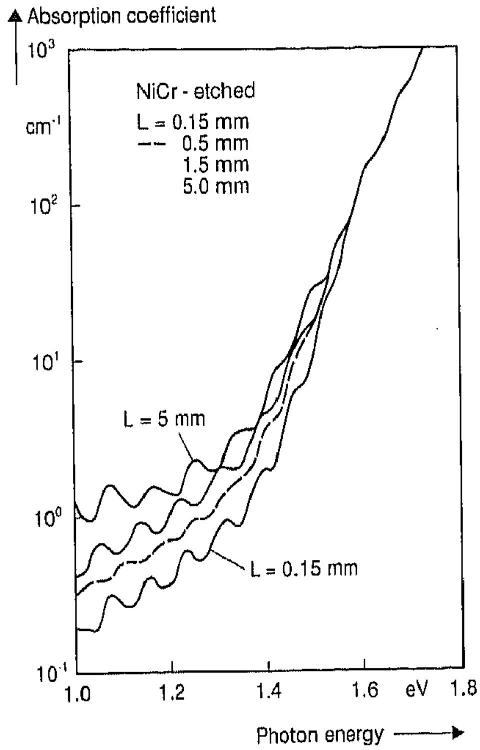

FIGURE 4
Absorption coefficient vs. photon energy of four a-Si:H samples as in Fig.3. The samples were etched in an SF_6 plasma.

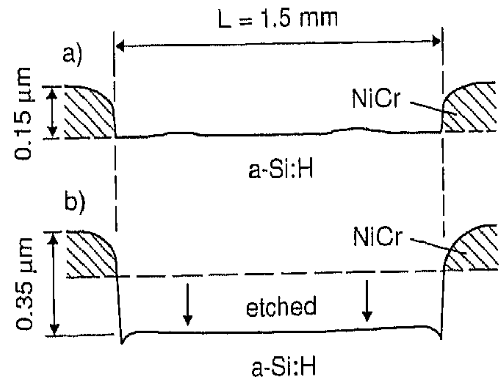

FIGURE 5
Cross section of an a-Si:H sample with NiCr gap electrodes. Measured depth profile a) prior and b) after plasma etching.

subbandgap shoulder height is a function of the distance of the coplanar contacts. However, surprisingly the CPM curve for L=0.5mm is below the 0.15mm curve. The fact that this anomaly is observed for L=0.5mm not only in CPM curves but also in contact height profiles, displayed in Fig.7 (no sharp Ag edge for 0.5mm gap), led us to the explanation illustrated schematically in Fig.8.

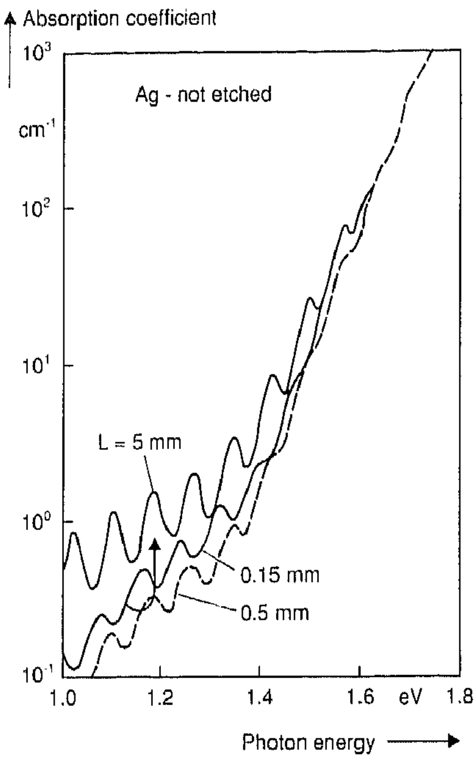

FIGURE 6
Absorption coefficient vs. photon energy of three a-Si:H samples with Ag contacts. The contact spacing is varied from 5mm to 0.15mm. The α spectra show an anomalous sequence.

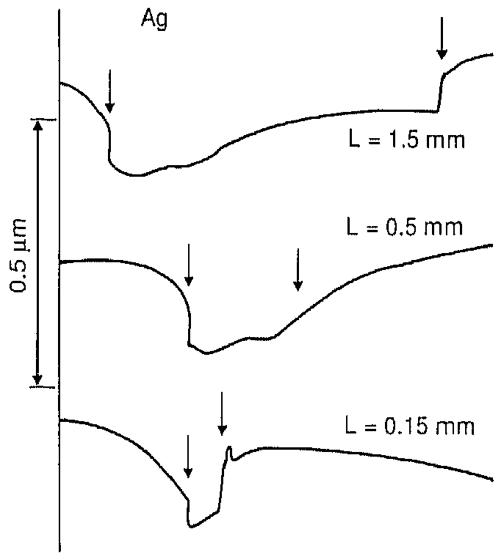

FIGURE 7
Cross section of an a-Si:H sample with Ag gap electrodes. Measured depth profiles for three different contact spacings.

The basic idea is that with increasing L the subbandgap α can be increased not only by the increased optical path of the light scattered in the volume[3] but also by the increased optical path of the light reflected from the rounded metal contacts or even from the etching-induced a-Si:H step.

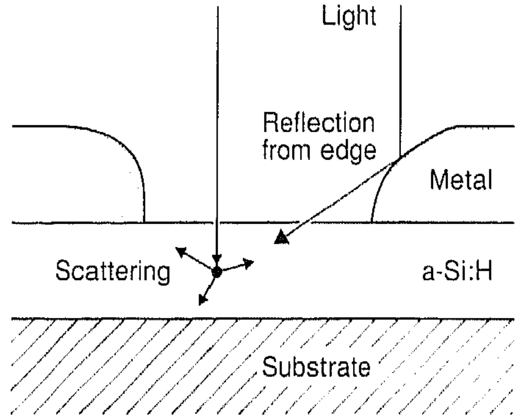

FIGURE 8
Cross section of a sample with gap electrodes. Sketch indicating volume scattering of incoming light and light reflected from electrode edges.

4. CONCLUSIONS

The study of fine changes or details of CPM spectra requires extreme care. We found that NiCr or Ti contacts are sufficiently ohmic so that the n^+ layer is not necessary. In accordance with ref.3, we can confirm the existence of the volume light scattering in a-Si:H. However, the shape or height of the contact metal (and a-Si:H) edge, especially for Ag, can strongly influence the CPM spectra. The simplest solution is to use bottom instead of top illumination, as this produces no reflection into the a-Si:H.

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