UDC621. 315. 592

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IMAGE SENSOR ON THE BASIS OF NONIDEAL HETEROJUNCTION WITH RIGID RASTER

The basic requirement to modern solid-state optical image converters is strict geometrical conformity between target video signal and optical image elements. In the given work the design of image sensor on the basis of non-ideal heterojunction and the system of its scanning which enable to exclude raster distortions and instability of raster at image scanning is offered. The maximal resolving ability of scanning system is defined by diffraction focusing limit of light strip by which the image reading is realised.

The basic requirement to modern qualitative solid-state optical image converter (usually it is charge-coupled devices — CCD matrixes) is the strict geometrical conformity between target video signal and optical image elements (rigid raster). This excludes distortions and instability of the raster caused by the given device topology, but not the reading system. Devices with such raster will be better coordinated to the subsequent digital signal processing due to the fact that the coordinates of each image element are rigidly given constants. The raster rigidity raises the accuracy of coordinates measurement up to 0,1 element and higher, and also reduces distortions at inter-exposure processing.

In the given work the optical and X-ray image sensor on the basis of well-known non-ideal heterostructure CdS-Cu_2S developed by us was investigated [1]. The specified sensor works on the principle of modulation in photocurrent by short-wave illumination caused by long-wave illumination. Really, the light from CdS intrinsic absorption region creates non-equilibrium holes in valence band which are localised on deep trap centres in the space charge region of heterojunction. Thus, the field strength at heteroboundary changes and depends on concentration of located non-equilibrium charge. The sensor output signal is photocurrent created by short-wave illumination from Cu_2S intrinsic absorption region. The amplitude of this signal is defined by electric field strength at heteroboundary.

To achieve raster rigidity the following system of scanning and the design of image sensor are offered. If Cu_2S layer as the separate parallel strips is obtained, the photocurrent generated by each strip, can be registered separately, and, switching them serial, a photodetector in the circuit way in the direction perpendicular to Cu_2S strips can be scanned. The reading IR-probe in this case can be prepared as the thin strip of light moving along Cu_2S strips.

The structure for converter of optical image in electric signal made in such way and the principle of its work are shown in fig. 1. The photodetector consists of continuous transparent conducting contact SnO_2 (2), applied on glass substrate (1). Continuous CdS layer (3) is evaporated on SnO_2, and along edges of substrate, SnO_2 small areas are left clean to supply contact. Cu_2S strips (4) are formed on CdS layer. To obtain such strips, $CuCl_2$ was evaporated on CdS in vacuum through the appropriate mask, and then, by substitution reaction in solid phase, Cu_2S layer was formed.

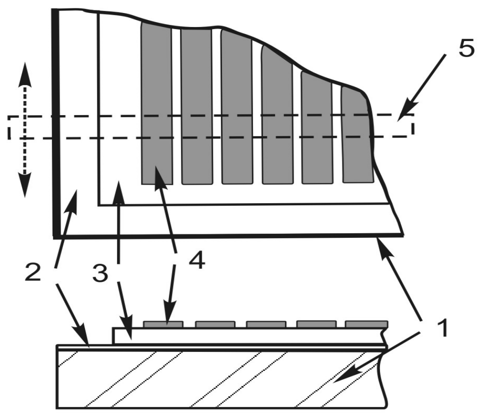

Fig. 1. Structure for converter of optical image in electric signal: *1* — glass substrate; *2* — transparent conducting SnO_2 contact; *3* — continuous CdS layer; *4* — Cu_2S strip, *5* — IR-light reading strip and direction of its movement

Contacts to Cu_2S strips were prepared as follows. The contact platforms of 3—4 mm in length appropriate to each strip with arrangement to connect electric plug were made by photolithography on foil-clad textolite. From fine-dispersed nickel powder and epoxy resin mixed with the hardener, conducting glue was prepared, and it covered the contact panel and edge of photodetector by continuous layer. The contact platforms were carefully combined with copper sulphide strips, and photodetector edge compactly pressed to contact panel. The drying of conducting glue was carried out in strong magnetic field with field lines perpendicular to photodetector plane. The particles of nickel powder in liquid substance generated at that time the chains along the lines of magnetic field. After glue became harden, such structure was conserved and provided good anisotropic conductivity along the normal of structure surface. The short circuit of the adjoined contacts of the made structure was excluded by the special technological methods.

In contrast to the various photodiode matrixes where photosensitive elements are located on crossing of switching electrodes, in the given device, the image element is formed on crossing of Cu_2S strips (stretched photosensitive element) and the reading light strip perpendicular to them and being not an electrode which scanning photoconverter.

When the projection of object is switched off, owing to storage effect its image can be read from photoconverter during 5 minutes. If necessary (for example, during transmission of moving image), after each exposure the image may be erased by application of the positive bias to all elements (strips) of photoconverter (under the positive bias ~ 1 V, the barrier in such structure disappears). One can erase the image also by short-time illumination of heterojunction with powerful pulse of IR-light which ejected holes, accumulated in traps, into valence band. Under application of holes accumulation effect on holes centers in SCR, the device can detect the image at very low integral illumination (10^{-4} lx). But in this case, the time interval between exposures increases significantly.

If one makes the reading strip movement discrete (for example, to do scanning by consecutive switching of matrix linear elements) such converter will provide the rigid raster on both coordinates, as well as detecting devices on the CCD basis. However, in contrast to CCD matrixes which dimensions do not exceed 1x1 cm, the given photoconverter is easy to obtain with rather large sizes as the used evaporation process of layers does not set any restrictions on its dimensions. In this connection, the obtained sensor can be used to register images in rather large area, for example, in astronomical observation with big telescopes. The maximum resolving ability of device is defined by diffraction focusing limit of light strip by means of which the image reading is realised and it is ~ 1 micron.

The testing of considered sensor with rigid raster made on the base of $CdS—Cu_2S$ non-ideal heterojunction was carried out in simple demonstration set (Fig. 2). The set allowed to obtain image of test-object at oscillograph screen with the help of such sensor. The process to obtain the image takes place as follows. The image of test-object was projected on the line photoconverter (PC) through the light filter with transmission area $\lambda < 520$ nm. The system of rotating mirrors helped the reading strip of IR-light ($\lambda > 950$ nm) to move in the direction along photosensitive strips (in Figs. 1 and 2 this direction is marked by arrows).

The frame scan is carried out as follows. When the reading strip crosses photodiode 1, located before photoconverter, it generates signal, that after amplification by amplifier A1 starts the generator G1, forming the synchropulse. The latter starts vertical scanning generator G3 (made on the base of C3-93 oscillograph), and also starts the commutator that begins to switch in series the linear photosensitive elements (Cu_2S strips) to video-intensifier (made on the base of differential amplifier), carrying out the line scanning. Commutator operates continuously in iterative way, and the number of channels in the period is limited by the number of strips (this value was 30 for converter made during our work). At the end of each cycle the commutator generates the synchro-pulse, that is applied to synchronization input of C8-17 oscillograph (used to visualize video-signal, generated by photoconverter) and provides the start of line, carrying out the line synchronization. Frame scan is carried out by sawtooth voltage which is applied from generator G3 to input of Y oscillograph. Video-signal from A3 amplifier is applied to input of Z oscil-

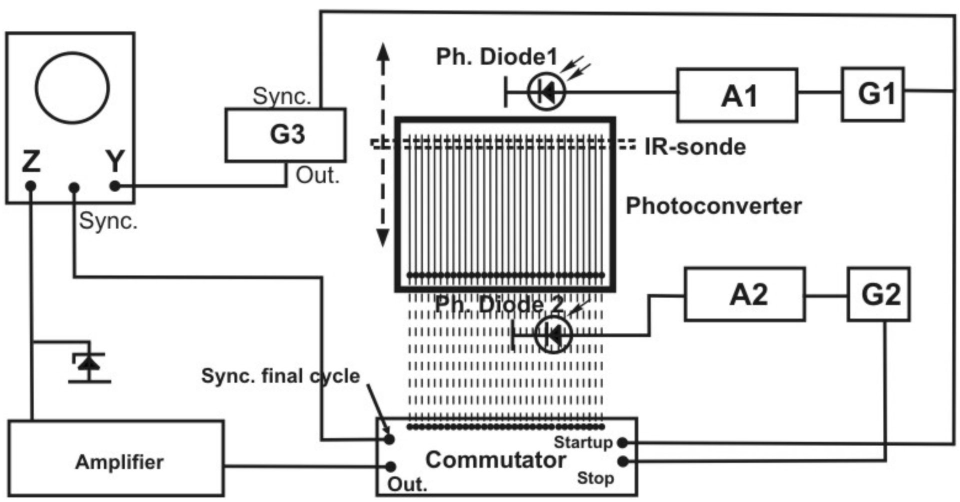

Fig. 2. The set to obtain the image by converter of optical image into electrical signal
(the explanations are in the text)

lograph and modulates the brightness of beam (Z-input is protected from overload by stabilitron, that does not allow the amplitude of videosignal to overcome the legitimate value for Z-input of the given oscillograph — 10 V). When the frame is finished, the reading strip hits on the window of photodiode 2, which signal after amplification by amplifier A2 forms with the help of G2 the synchro-pulse, stopping the commutator, and then the line scanning.

When the test-object projection is finished, owing to storage effect, its image can be read from photoconverter during 5 minutes. If necessary (e. g. at transmission of moving objects image) after each frame the image can be erased by application of positive bias (~ 1 V) to all elements of photoconverter. Short-term exposure of heterojunction by powerful pulse of IR-light can also result in the initial state of heterojunction. Really, IR-light of high intensity with quantum energy which is higher or equal to $E_t \approx 0.38$ eV, ejects all holes, accumulated in traps, into valence band, and at the same time they are removed by internal field from SCR, and heterostructure returns to equilibrium condition.

It should be noted that application of the effect to accumulate holes in trapping centers in SCR is possible. At the account of this, the device can be used in registration of images with very weak integral illumination intensity.

So, the applied construction of image sensor and the reading set allowed, firstly, to obtain the image with rigid raster, and secondly, at the expense of application of image electronic scanning along one of coordinates, to accelerate considerably the process of image scanning — scanning time for sensor of such construction was 0.04 sec, that allowed to carry out the transmission of moving images.

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СЕНСОР ИЗОБРАЖЕНИЯ НА ОСНОВЕ НЕИДЕАЛЬНОГО ГЕТЕРОПЕРЕХОДА С ЖЕСТКИМ РАСТРОМ

Основным требованием к современным твердотельным преобразователям оптического изображения является строгое геометрическое соответствие между выходным видеосигналом и элементами оптического изображения. В данной работе разработан сенсор изображения на основе неидеального гетероперехода и системы его сканирования, которые позволяют исключить растровые искажения и нестабильность растра при сканировании изображения. Максимальная разрешающая способность системы сканирования определяется дифракционным пределом фокусировки считывающей полосы.

УДК 621.315.592

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СЕНСОР ЗОБРАЖЕННЯ НА БАЗІ НЕІДЕАЛЬНОГО ГЕТЕРОПЕРЕХОДУ З ЖОРСТКИМ РАСТРОМ

Основною вимогою до сучасних твердотільних перетворювачів оптичного зображення є сувора геометрична відповідність між вихідним відеосигналом і елементами оптичного зображення. У даній роботі розроблено сенсор зображення на основі неідеального гетеропереходу та система його сканування, яка дозволяє виключити растрові перекручування і нестабільність растру при скануванні зображення. Максимальна розподільна спроможність системи сканування визначається дифракційною межею фокусування смуги, що зчитує.