ELECTRON-BEAM IRRADIATION-BASED RECORDING ON ORGANIC DYE FILMS

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Thin organic films have rapidly evolved as potentially important materials in microelectronics. They are promising candidates for high density optical memories due to their optical and structural properties. Also they can be used as master disks for CD and DVD ROM replication because film pit shape possesses all properties needed for super high density compact disks. In this work we present the experimental results showing the effects of electron-beam heat process on the information recording parameters in dye films. Dye composite films were obtained by vacuum deposition method. The changes in the optical properties and the surface structure were studied. In our experiments we have irradiated organic dye films by electron beam at different time to modify the structure and morphology of the surface. The changes observed in the structural properties have been studied by high-resolution electron microscopy. The one main broaden ring is observed for amorphous dye film in initial state on the diffraction pattern. Annealing the dye films by electron-beam irradiation during 2-5 sec leads to grain formation whose size varies between 2 and 5 nm. It was found that organic dye films have hexagonal structure in the grains formed after annealing process by electron beam. The threshold energies necessary for the modification of the dye film surface structure after electron beam irradiation were estimated. The obtained results give possibility for the study of dye layer behaviour as an electron beam assisted recording medium.

Introduction

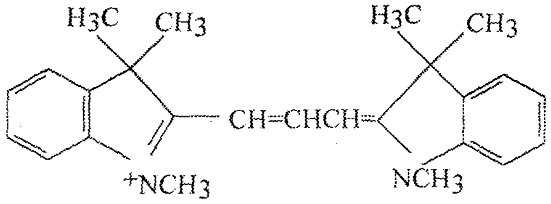
Thin organic dye based films attract great scientific interest in order to provide the best material for high-density laser recording. Intensive search of new dye classes for information recording by means of laser irradiation in blue and ultraviolet spectral region is carried out. The density of information recording in this region is much more higher then in visible because the diameter of laser beam is proportional to the wavelength $d \approx 0.61\frac{\lambda}{NA}$, were NA is the numerical aperture of recording microobjective.

As it is known, the dye films have much more high-resolution ability than widely used photoresistive systems [1]. That is why the organic dye based films can be used as recording media for information registration in UV region by means of electron beam irradiation method as well as by laser beam irradiation.

In this connection it should be interesting to investigate the organic dye films such as pyrosolines by means of high resolution electron beam microscopy method to characterize the structural peculiarities of these films and to determine the processes of electron beam influence on the organic film.

Experimental

The samples of dye recording media were prepared by thermal vacuum evaporation at the background pressure of about 10^{-3} Pa on glass discs 160 mm in diameter and 2.1 mm in thickness in the commercially available vacuum chamber having resistive thermal evaporators. The chemical formula of pyrosoline is [2]:



The films were investigated by means of high resolution electronic microscopy IEOL 4000 EX (with the resolution ability point-to- point 0.16 nm) with the maximum accelerating voltage 3000 V. The dye films were deposited on the net copper substrates that were surrounded by copper rings of 3.05 mm in diameter and were of a standard size for installation in measured cell. The film thickness was about of 100 nm.

Using tunnel microscopy method we have demonstrated the posibility of laser recording on dye layers.

Results and discussion

The results of investigation of the electron beam influence on the organic dye film (pyrosoline) atomic structure are presented in Figs. 1–3. In Fig. 1(a, b) the amorphous structure of organic film in the initial state (before the influence of electron beam) is represented. The general view of the film structure is shown in Fig.1a. In the diffraction pattern (Fig.1b) one can observe almost homogeneous halo, the diffraction rings are absent.

The electron beam irradiation during 3–5 s led to cluster formation with the characteristic sizes of 2-3 nm (Fig.2a, b). Considering the fact that this crystalline phase is enclosed in an amorphous matrix, we may suppose that this new phase is an intermediate phase between amorphous phase and stable crystalline structure similar to [3].

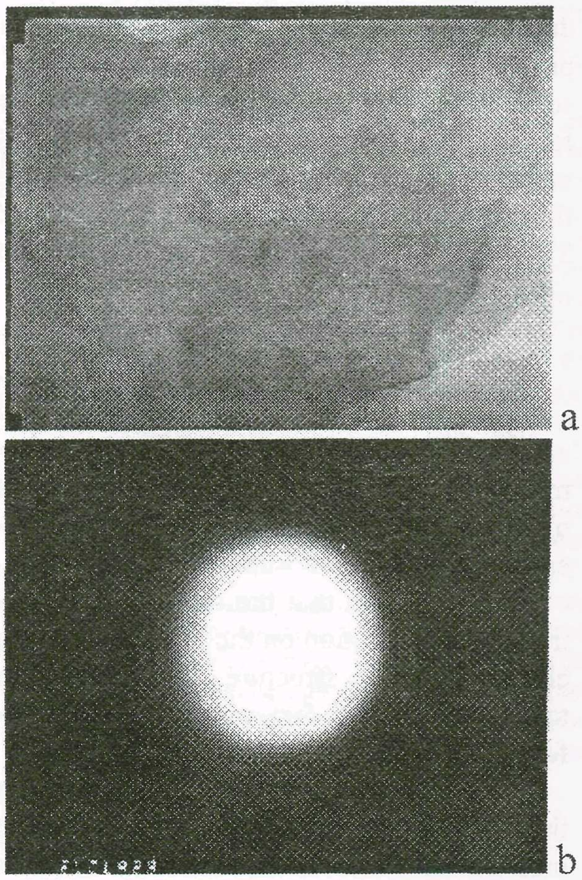


Fig.1. TEM (bright-field) plan view image of the amorphous dye films (a) and diffraction pattern of the film before the electron beam influence (b)

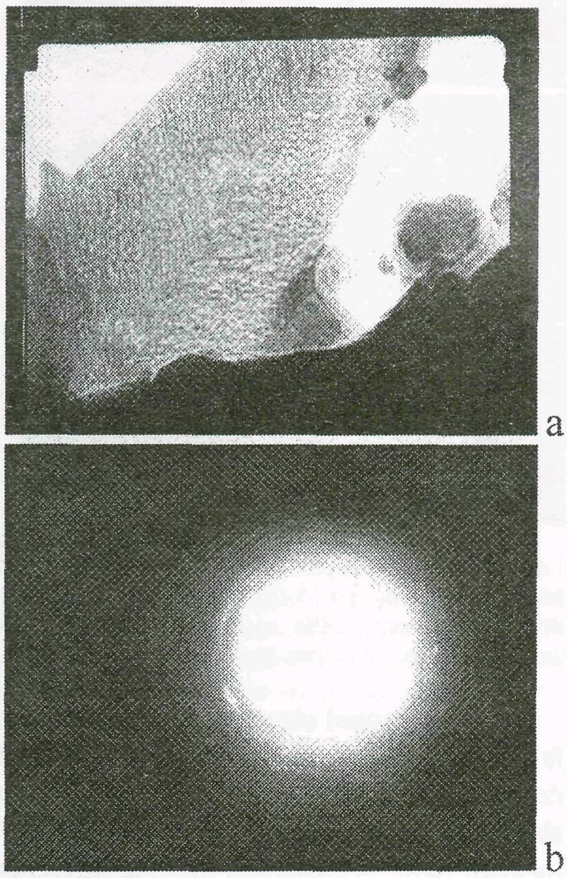
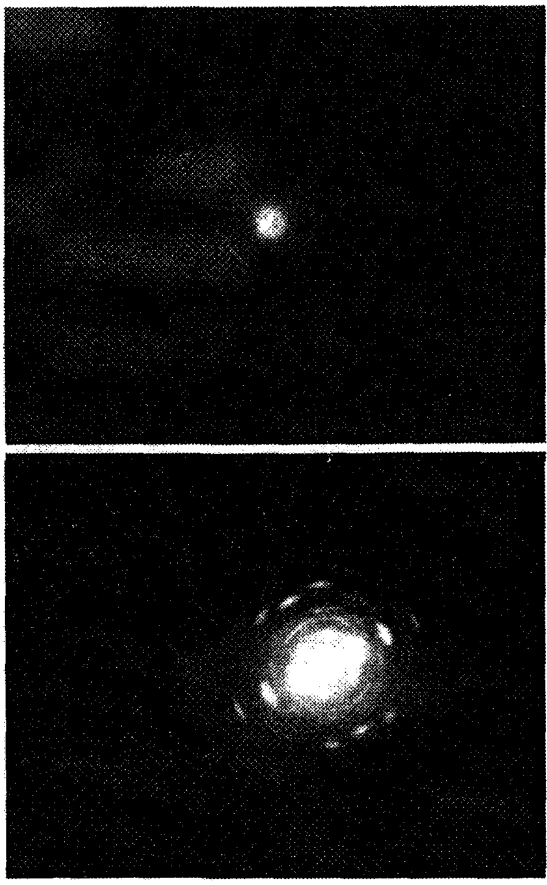


Fig.2. TEM (bright-field) plan-view image of the polycrystalline dye film showing grain sizes 2–3 nm (a) and electron diffraction pattern for dye film annealed by electron beam during 3–5 seconds (b)

The diffraction pattern of organic dye film after the electron beam influence during 15-20 sec is shown in Fig.3a. We can observe the structural changes and appearance of the ordered structure characterized by diffraction rings. *The diffraction pattern of* electron beam focused on a single granule for dye film annealed by electron beam during 15-20 seconds is presented in Fig. 3b.



a

b

Fig.3. Diffraction pattern of the film after the electron beam influence during 15–20 seconds (a) and electron diffraction pattern on the single granule for dye film annealed by electron beam during 15–20 seconds (b)

The hexagonal structure is observed that is why it could be inferred that the film has definite direction and its optical properties should depend on the polarization state of incident light. We can see that the influence of electron beam leads to structure state change and creation of the news phases. This effect can be used for super high recording on the organic dye films. The size of recording bit by electron beam is about of several nanometers. The threshold energies necessary for the recording bit on the surface of dye film during electron beam irradiation were estimated. This value is about 6.5 10^{-15} J/μm^2.

On the other hand it is possible to realize the information recording by means of laser beam irradiation method. The information in a pit form is recorded on pyrosoline dye film by using the second harmonic radiation of Nd-laser (λ=532 nm) or Ar+ (λ=488 nm) and appropriate recording surface structure of this film was probed by scanning tunnel microscope after the laser irradiation with power of 4 mWt. The ring-like pits correspond to 3τ impulse extent of laser irradiation as well as the ellipse-like ones are determined by its 11τ impulse extent at τ=231 ns accepted as a standard for compact disk during information registration. The depth is proved to be equal to the thickness of pyrosoline dye film and the process of a hole formation consists of three phases: 1) maximum heating of the absorbing film; 2) initiation of the microhole formation in the film; 3) characteristic rim formation around the microholes [4–5].

Conclusions

In this work it was shown that the information recording might be realized by means of two methods such as electron beam process and laser beam irradiation.

It was shown that the influence of electron beam irradiation on the organic dye film changes the film structure from amorphous *to crystalline: this fact can be used for in*formation recording.

The experiments of laser recording on the disc consisted of pyrosoline as recording medium have shown that the most efficient optical recording of the information in a pit form for such kind of dye films could be realized by using second harmonic radiation of Nd laser with power of the order of 4mW at 3τ pulse extent.

References

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ЗАПИС НА ПЛІВКАХ ОРГАНІЧНИХ БАРВНИКІВ НА ОСНОВІ ОПРОМІНЕННЯ ЕЛЕКТРОНАМИ

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Тонкі органічні плівки швидко стали потенційно важливим матеріалом у мікроелектроніці. Завдяки своїм оптичним і структурним властивостям вони перспективні для створення оптичної пам'яті високої щільності. Їх також можна використовувати як матриці для реплікації CD- і DVD-ROM дисків, оскільки форма ямок відповідає вимогам, необхідним для компакт-дисків надвисокої щільності. Нами представлено експериментальні результати, що показують вплив нагрівання електронним пучком на параметри запису інформації у плівках барвника. Композитні плівки барвника було отримано методом вакуумного напилення. Вивчаються зміни оптичних властивостей і структури поверхні. Ми опромінювали плівки органічного барвника електронним пучком при різній тривалості опромінення, щоб змінити структуру і морфологію поверхні. Зміни, що спостерігались у структурі, досліджувались електронним мікроскопом з високою роздільною здатністю. Максимальне збільшення ширини спостерігається для аморфної плівки барвника на початковій стадії дифракційної картини. Відпал плівок барвника електронним пучком протягом 2–5 с веде до утворення зерна, розмір якого змінюється від 2 до 5 нм. Виявлено, що плівки органічного барвника мають гексагональну структуру зерен, утворених після відпалу електронним пучком. Оцінено порогові енергії, необхідні для зміни структури поверхні плівки барвника при опроміненні електронним пучком. Отримані результати дають змогу вивчення поведінки шарів барвника як середовища для запису інформації за допомогою електронного пучка.