Dependence on Light Intensity and Wavelength of Microwave Photoconductivity in Silver Bromide Emulsion Microcrystals

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Abstract

The microwave photoconductivity signals of silver bromide emulsion microcrystals (cubic, edge length: 0.33 μ m) were measured at room temperature with the incident light of various intensity and wavelength. Two decay components with first-order kinetics were observed. The decay time constant of the fast component increased from ~40 to ~80 ns when the light intensity increased from ~150 to ~4,000 photons/grain in absorbed photons by a microcrystal. For larger intensity, that decreased gradually until that reached asymptotically to ~40 ns. This feature of the intensity dependence was same in all light wavelengths used for measurements (250 to 440 nm).

At 250 nm photoelectrons and photoholes are excited beneath the crystal surface, and at 440 nm they are excited all over the volume. Therefore the fact that it was independent of wavelengths suggests photoelectrons move around the crystal volume before they are captured at trapping sites on the surface. On the one hand amplitude of the signals showed a tendency to saturate for higher light intensity than that at the maximum decay time constant. It was shown that the different decay kinetics became superior to the other depending on the light intensity.

Introduction

Most latent image specks in silver bromide cubic microcrystals are formed on the surface. This fact is owing to the surface crystal defects that exist abundantly. In unsensitized microcrystals, the latent image specks are formed at the defects that function as electron trap. So, it is considered that the information of the latent image formation process is included in the photoelectron decay kinetics.

In this study we measured the microwave photoconductivity of silver bromide emulsion microcrystals at room temperature with the incident light of various wavelength and intensity. With short wavelength photocarriers are excited just beneath the crystal surface and with long wavelength they are excited all over the crystal. Under high intensity light exposure excessive carriers for latent image formation are excited, which is the case in usual microwave photoconductivity measurements. In this case it is supposed that the recombination process with holes becomes much predominant over the latent image process.

The purpose of this study is to find experimentally how the intensity and the wavelength of exposure light affect the photoconductivity phenomenon in silver bromide emulsion microcrystals.

Experimental

Monodisperse, cubic silver bromide microcrystals with an edge length of 0.33 μm were prepared for this investigation. These microcrystals were precipitated in gelatin and were coated on a polyester base with a mono-grain layer. The photoconductivity measurements reported here were made at room temperature.

The light source (Fig. 1) was a pulsed tunable solid-state optical parametric amplifier pumped by a Nd:YAG laser. The output frequency of the laser was doubled by a second harmonic generation unit. The width of the light pulse was about 3 ns.

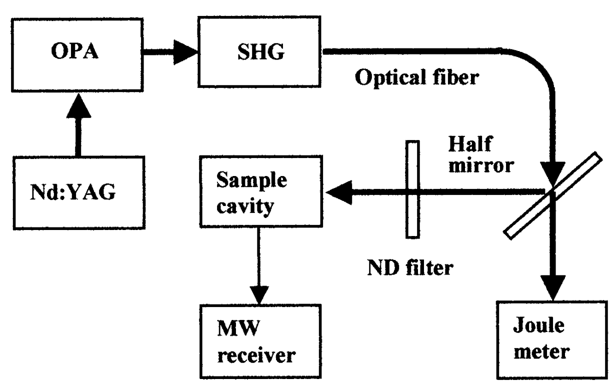


Figure1. Schematic diagram of light source

A schematic diagram of the microwave photoconductivity measurement apparatus is shown in Fig. 2. X-band homodyne receiver with a reentrant-type sample cavity and a microwave low noise preamplifier is used as a high sensitive and high-speed detector. The rise time of the system was 7.5 ns.

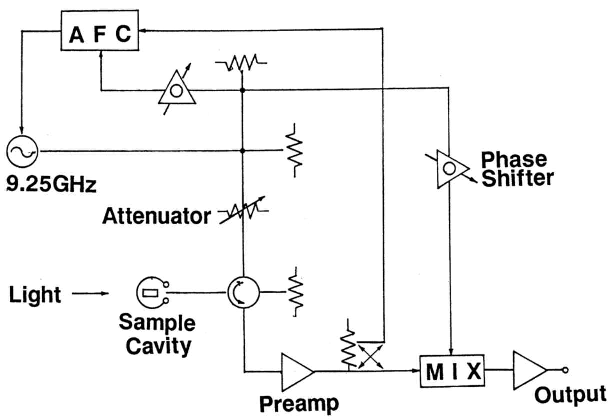


Figure 2. Schematic diagram of microwave apparatus

Results and Discussion

Photoelectron decay times were estimated from semilogarithmic plots of the photoconductivity decay curves. Any decay curve in this investigation consisted of a fast component and a slow component. In this study, only the fast components are analyzed.

Figure 3 shows the light intensity dependence of the photoelectron decay time at the wavelength of 355 nm. The decay time increase rapidly to the maximum and then decrease gradually to a constant value with the increase of light intensity. These features of the light intensity dependence and the values of decay time were same in other measurements with different wavelengths: 250 to 440 nm. The decay time at the minimum intensity of 150 absorbed photons per grain was about 40 ns and the maximum was about 80 ns at 4,000 absorbed photons per grain. The constant values at the intense light region were about 40 ns.

Figure 4 shows the light intensity dependence of the maximum photoconductivity signal height V_o at the wavelength of 355nm. At first V_o increases linearly with the increase of light intensity and then reaches saturation. These features and the saturated maximum value of V_o were same in other wavelengths. The tendency of the saturation appeared at 4,000 absorbed photons per grain in any wavelength.

The densities of the developed samples that were exposed with the light for photoconductivity measurements are shown in Fig. 5 along with the photoelectron decay times. It is shown that the density corresponds to the shoulder portion of the characteristic curve when the decay time is the maximum at the light intensity of 4,000 absorbed photons per grain. This feature was same in any wavelength, too.

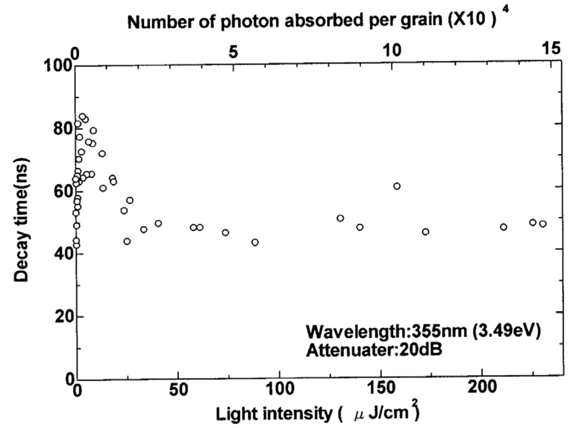
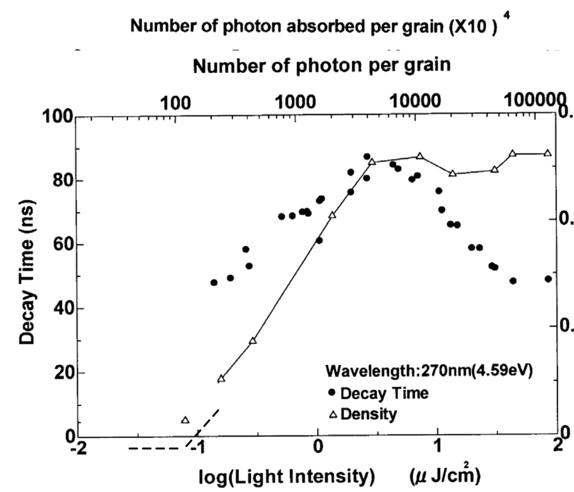


Figure 3. Light intensity dependence of photoelectron decay time

Figure 4. Light intensity dependence of the maximum photoconductivity signal height

Figure 5.Photoelectron decay time and densities of developed samples

All the features of light intensity dependence in the photoelectron decay time, the maximum photoconductivity signal height and the developed density were same in any wavelength used for the measurements. In the shortest wavelength (250 nm), the depth of light penetration (the thickness of the crystal in which the transmitted light intensity decreases to 1/e of the incident light intensity) is calculated to be 0.016 μm from the absorption coefficient of silver bromide crystal. On the other hand, in the longest wavelength (440 nm) that is 26 μm. Independence of the above mentioned features on these wavelengths implies that the excitations of photocarriers beneath the crystal surface



or all over the volume both results in the same effects. This fact can be understood by considering that the electron-trapping process is controlled by reaction-limited kinetics: photoelectrons move around the crystal volume and only some fraction of them arriving at the grain surface is captured at the surface crystal defects[1)].

The light intensity dependence of the photoconductivity phenomenon in silver halide microcrystals became evident. The decrease of photoelectron decay time after the maximum at 4,000 absorbed-photons per grain might show the presence of inefficient process for latent image formation. The analysis of the mechanism is considered to be useful for the clarification of latent image formation process and for the development of high sensitive microcrystals.

References

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Biography

Akira Hasegawa received his B.S. (1965) and Ph.D. (1988) degrees in Electronics from the Shizuoka University. He is a professor in the department of information and image science of Chiba University. He has been carrying out research on photophysics of silver halide microcrystals using microwave photoconductivity measurement technique. He is a member of the IS&T.