

Optical recording mechanisms in undoped titanosillenite crystals

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Abstract

We characterized undoped titanosillenite $\text{Bi}_{12}\text{TiO}_{20}$ (BTO) crystals using holographic recording at higher than room temperature (RT). Our results show that photoconductivity is due to electron donor centers, as already well known, but dark conductivity is not due to holes but to positive ions, possibly H^+ , at least in the 30-120°C explored temperature range. The activation energy of the ionic charge carriers is 0.85 eV

Introduction.

Holography is largely employed to characterize photosensitive materials and volume recording media [1] and is particularly useful for photorefractive crystals[2,3]. Holographic erasure after recording is particularly interesting because it is not affected by environmental perturbations and provides a direct measure of the material response time τ that, on its turn, is inversely proportional to the conductivity (in the dark) or photoconductivity (under illumination) σ

$$\tau \propto K\varepsilon_0 / \sigma$$

where K is the dielectric constant and ε_0 is the electric permittivity of vacuum. In this communication we report on the use of holographic erasure techniques for the research on the recording mechanisms in undoped BTO.

Experiment.

Preliminary experiments on the undoped BTO sample under research have shown that two different holograms do appear in this material: a fast photosensitive one, probably arising from electron-donor centers and a slow non-photosensitive hologram, probably due to positive ions, possibly H^+ .

The sample was placed in a temperature-controlled vacuum chamber (**Fig.1**) with monomode optical fibers guided light to record the hologram on the sample. The recording light is from an Ar^+ laser at 514.5 nm. The recording was carried out at fixed temperatures from 30 to 120°C, for about 1 min. This time was found to be enough to record the photosensitive electronic-based fast grating without allowing for the slower compensation grating to be buildup. After recording, the sample was kept in the dark and, from time to

time, the evolution of the diffraction efficiency was measured using a very short (5 ms) pulse of light (from one of the recording beams), and the corresponding exponential time constant τ_{Fd} was computed. The procedure was repeated for different temperatures in the 30-70°C temperature range in order to plot the Arrhenius curve for τ_{Fd} as shown in **Fig.2**, leading to an activation energy of 0.87 eV.

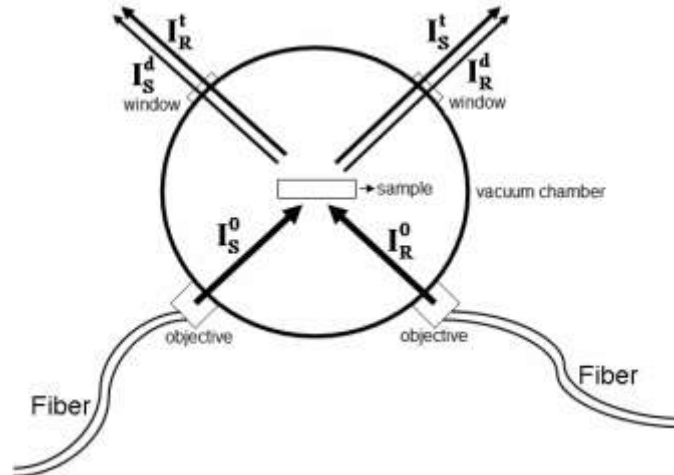


FIGURE 1 -Temperature-controlled vacuum chamber.

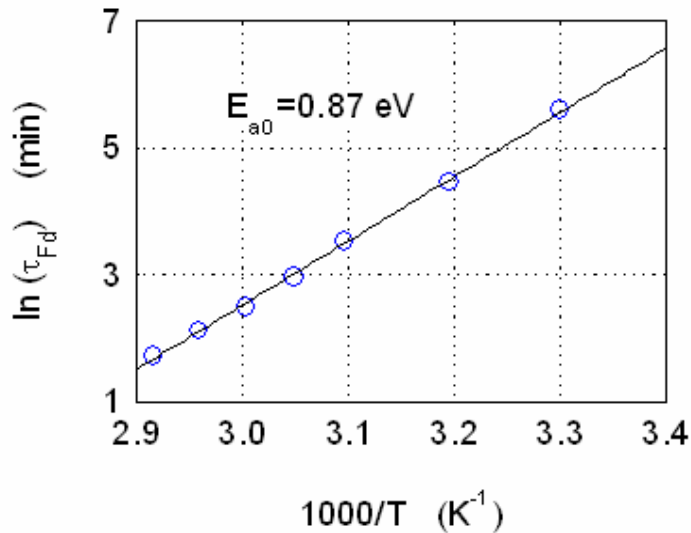


FIGURE 2- Arrhenius curve for the fast grating relaxation in the dark

A similar experiment was carried out in order to characterize the slow non-photosensitive compensating grating, as follows. The fast grating was recorded for about 1 min, as described above. After that, the sample was kept in the dark for 15 min (for the highest temperature range) to 30 min (for the lower temperature range) in order to allow for the compensation of the recorded fast grating by the slower one. After this delay, one of the

recording beams was switched on in order to follow the evolution of the transmitted and diffracted light in order to compute the diffraction efficiency (η) evolution under illumination, as illustrated in **Fig.3**, where the strong photochromic effect is evident and is taken into account for computing η .

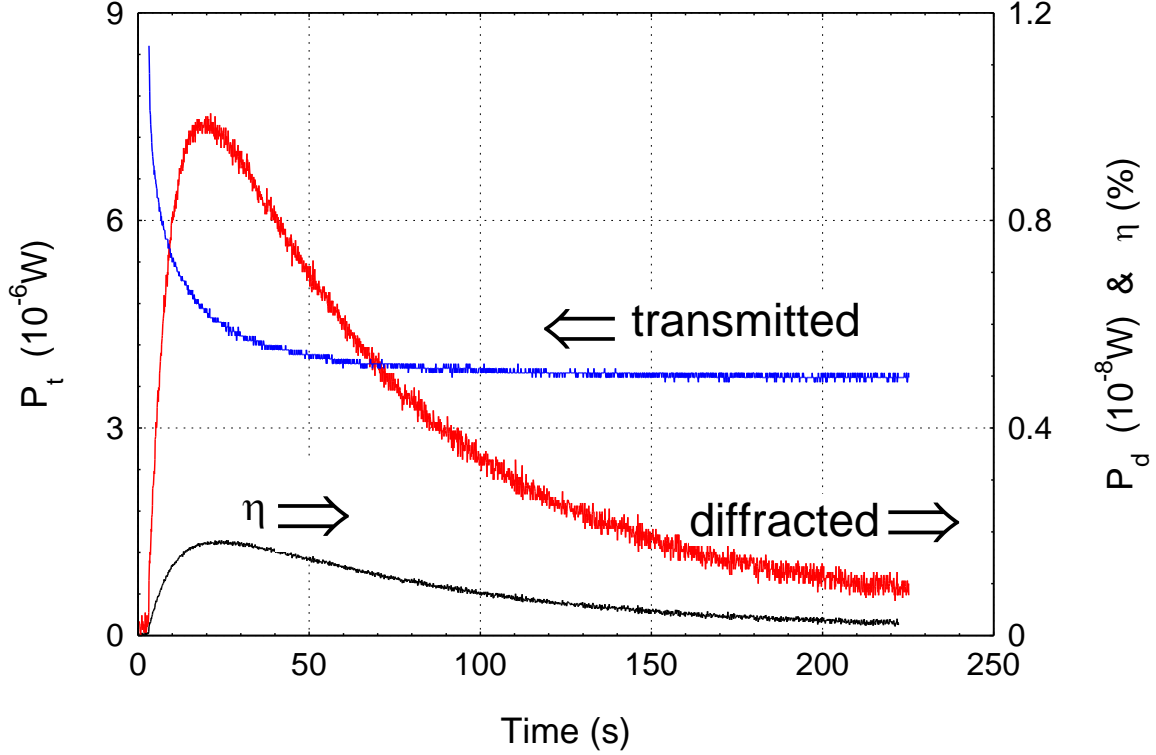


Fig.3- Evolution of the transmitted and diffracted beams during holographic relaxation under 514.5 nm illumination. From these data, diffraction efficiency η is computed and plotted. Remark the strong photochromic effect.

The fast photosensitive electronic-based grating is rapidly erased by the action of the light and, after that, the slow non-photosensitive, grating relaxation is measured. The full relaxation data are fitted with a double exponential curve

$$\eta = \left| ae^{-t/\tau_F} - be^{-t/\tau_S} \right|^2 + d$$

in order to compute the exponential time constant of the fast τ_F and of the slow τ_S gratings under illumination. The procedure was repeated at different temperatures and the resulting τ_S values are plotted in **Fig.4** showing a good Arrhenius curve with an activation energy of 0.85 eV. The fast relaxation time τ_F is not processed because because the fast grating is photosensitive and will therefore not provide an useful Arrhenius curve.

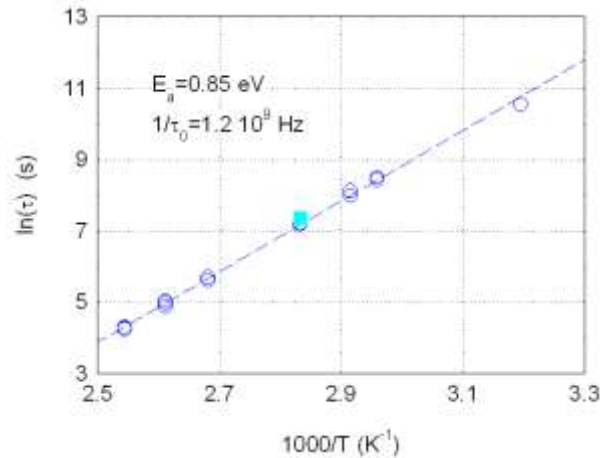


FIGURE 4- Arrhenius curve for the slow grating relaxation under illumination

Discussion.

The present results do confirm that optical recording in undoped BTO is in fact due to photoexcited electrons, as already reported by many researchers before. The novelty in this paper is the finding out of a compensation grating of nonphotosensitive nature that is not due to holes but to positive ions, possibly H^+ . This hypothesis is supported by optical absorption spectroscopy data showing a large peak close to 2900 nm in BTO, that is known [4] to arise from OH^- that is associated to H^+ .

The very similar activation energies for the dark relaxation of the fast grating (0.87 eV) and for the relaxation of the slow nonphotosensitive grating under illumination do strongly support the idea that both phenomena have the same origin. That is to say that the relaxation of the fast electronic grating in the dark is in fact not so, but is just its compensation by the slow ionic grating.

Preliminary results, to be confirmed, have shown that in most doped BTO, particularly in Vanadium doped one, the slow grating is of photosensitive nature, at least at RT, so that in these cases the slow compensation grating is likely to be due to holes and not to ions, although the OH^- -associated absorption peak is also present in most doped (including Vanadium) BTO.

References

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