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Thermal Hysteresis of Photoinduced Magnetic Effect in Yttrium Iron Garnet

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Abstract. In single crystals of yttrium iron garnet irradiated with laser (the most effective wavelength is 700 nm) or white light at 77 K, a remarkable change of the temperature dependence of complex permeabilities μ' and μ'' is observed, which is peculiar to photoinduced magnetic effect. Simultaneously, conspicuous double peaks of DA around 125 K and 200 K below room temperature were found to be induced by light-irradiation, with correlative onset of the irreversible decrease of permeability insensitive to demagnetization at low temperature. In order to explain these observations, we propose a new model.

1. INTRODUCTION

Photoinduced magnetic effects in Si-doped yttrium iron garnet (YIG:Si) has attracted the attention of researchers since Teal *et al.* [1] found for the first time one of these effects, so called the I-effect. These effects can be divided into the I-effect (vectorial) and the II-effect (scalar) in dependence on whether is dominant or not the polarization state of light for the observation. The origin of I-effect was explained as a redistribution of uniaxial anisotropy of Fe^{2+} along one of the four cubic directions of octahedral sites, while the II-effect (Enz-type) was attributed to the different behaviors of Fe^{2+} close to and far from Si^{4+} ions, in the demagnetized state [2]. Disaccommodation (DA) in the dark which is often observed is, phenomenologically, similar to the II-effect[3]. DA is, however, so far considered as essentially different from the II-effect, since the former is sensitive but the latter is insensitive to demagnetization. In this report, we observed a thermal hysteresis and the phenomenon of DA can be produced by white light irradiation in the high purity crystals of YIG [4] indicating of photoinduced formation and relaxation of a potential barrier for photoexcited electron to return to an original state.

2. EXPERIMENTAL

These samples of YIG are very pure, with neither Si nor Ca incorporated except for intentional dopants (Ga 0.0625 mol or Ca 0.001mol). In all samples, however, a considerable oxygen vacancy is incorporated of the order of 0.1 mol % estimated from spectroscopic method. Source of irradiating the samples was a xenon lamp, since no conspicuous differences among the many kinds of light sources such as laser light(650nm-laser is the most effective in the range among 1520 nm~500nm), mercury light, X-ray and or gamma-ray[4] employed in this experiment.

3. RESULTS AND DISCUSSION

The permeability of YIG which is decreased by irradiation at low temperature returns to the state prior to irradiation, when the sample is once brought back to room temperature[2]. In order to examine the more detail of the behavior, the warming process was stopped at several temperatures termed as turning temperature T_r below room temperature and then the sample was returned to 77 K. Without irradiation, the sample was again warmed to room temperature. The temperature dependence of complex permeabilities μ' and μ'' of the samples after white light irradiation was found to show a thermal hysteresis or

the different permeabilities at the 1st run and the 2nd run as shown in fig.1. Both of μ' and μ'' at the 2nd run appear featureless curve as a function of temperature. The concaves of permeabilities versus temperature curves (125 K and 200 K) were ascribed to photoinduced DA which was confirmed by using the automatic DA tester. In several samples, an additional DA peak independent of irradiation is observed around room temperature, the reason of which may be ascribed to oxygen vacancy with double electrons trapped [5]. These results are interpreted within the context of configuration coordinate(CC) diagrams with large lattice relaxations[6]. In this case the photoexcitation energy is larger than 1eV while the thermal energy for recovery process is less than 0.1 eV. The basic concept of our explanation is as follows. Cooled in the dark, oxygen vacancies or deep donors capture the double electrons and so called F-centers are formed. Pinning centers for domain walls are created due to lattice distortion, when the trapped electrons are photoexcited from the deep levels to the conduction band.

Fig.1 Temperature dependence of complex permeabilities μ' and μ'' of the samples after white light irradiation (measuring frequency and field, 1 kHz and 1 mOe, raising temperature rate; 0.5K/min).

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