

S1 EDS of the Bi_2Te_3 quantum dots

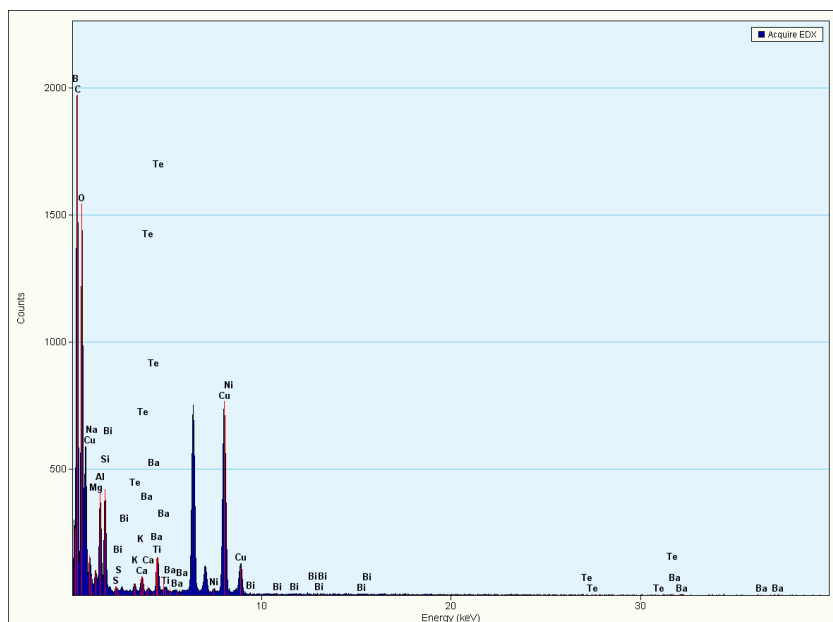


Figure S2: EDS of the Bi_2Te_3 quantum dots

EDS shows the component of total glass system along with Bismuth and Tellurium.

S2 Magnetic properties of Bi_2Te_3 nanocomposite

Figure 5 shows the hysteresis loop of the Bi_2Te_3 quantum dots. We found that the coercive field (H_C) of the glass nanocomposite treated at 580°C for 5 hr (i.e. bigger particle size) is 204 G. With decreasing particle size (decreasing the heat treatment time), the H_C value increases to a maximum of 864 G and then decreases to nearly zero.

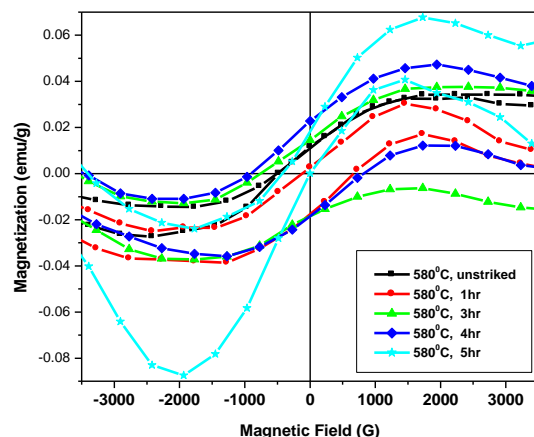


Figure 5: Room-temperature hysteresis loops corresponding to Bi_2Te_3 samples heat treated at temperatures 580°C for 1, 3, 4, 5 hrs.

This observation is consistent with the reported result that the coercivity will reach a maximum value near the size of a single domain in nanoscale magnets. [30] The coercivity is an extrinsic property of a magnet, which depends not only on the spin carriers but also on the shape or size of the magnets. The increase of the coercivity of a magnetic material has been considered to be the increase of the magnetic anisotropy, since an applied field at a given temperature should be able to change the orientation of magnetization. The variation in the magnetization with quantum dot size is also observed in the hysteresis loop of synthesized glass nanocomposite samples. The saturation magnetization is decreases with decreasing the dot size (decreasing the treatment time). It was that the saturation magnetization (M_S) of the glass nanocomposite treated at 580°C for 5 hr is 77.8 memu/g G. With decreasing particle size (decreasing the heat treatment time), the M_S value decrease to a minimum of 24.1 memu/g. The variation of saturation is as the reported results. [31]

S 3 Theoretical Explanation

Faraday rotation (RF) is the rotation of the plane polarization of a linearly polarized electromagnetic wave in a longitudinal magnetic field. The field induces a different dispersion of the right and left circularly polarized component (with refractive index n^+ and n^- , respectively). The phase difference between the two component results, after distance d , in a Faraday rotation of the plane of polarization over an angle θ_F :

$$\theta_F = \frac{\omega d}{2c} (n^+ - n^-), \quad (1)$$

Where ω is the radiation angular frequency and c is the velocity of light in vacuum. In macroscopic theoretical explanation the absorption and diffraction are related to each other through the Kramers-Kronig relation. In a diamagnetic material, such as glasses under investigation here, the Becquerel relation holds [24]

$$\theta_F = \frac{\omega d}{2c} \frac{dn}{d\omega} \omega_L \quad (2)$$

This relation follows from equation (1), expanding the $n^\pm(\omega) = n(\omega \pm \omega_L)$, where ω_L is Larmor frequency.

It shows that the general expression for absorption (direct and indirect transitions) are related to the refractive index and FR (KLN) formulas through Kramers-kronig and Becquerel relations; these are support to hold for diamagnetic materials.

Starting from Maxwell's equations the quantity $n^+ - n^-$ may, away from the resonance energy, is expressed as a function of the complex dye electric tensor. For a weak magnetic field in the z direction, Eq.(1) reduces (in SI units) to,

$$\theta = \frac{\omega d}{2\epsilon_0} \epsilon_{xy}^I(\omega), (3)$$

where $\epsilon_{xy}^I(\omega)$ is the frequency – dependant imaginary part of the off diagonal element of ϵ ; ϵ_0 is the permittivity of vacuum and $n = \frac{1}{2}(n^+ - n^-)$ is the refractive index in the absence of magnetic field. Calculation of the permittivity tensor ϵ , or the associated conductivity tensor σ , as function of the frequency and macroscopic parameter are reported by several authors [25-27] In most cases where σ is used, the transition frequencies are given as $\omega_{kk'}$ and momentum matrix is written as $P_{kk'}$ because these are for crystalline material and work with k space. The wave number k is not good quantum number for amorphous material and general energy notification is more suitable. The expression derived by Bennett and Stern [4] using Kramers-Kronig relation and Fermi golden rule for the absorption of two right and left circularly polarized components is given as

$$\epsilon_{xy}^I = \frac{e^2 \hbar}{2\omega m^2} \frac{1}{vol} \sum_{state} \left[\frac{|M_{cv}^+|^2}{|E_{cv}^+|^2 - \hbar^2 \omega^2} - \frac{|M_{cv}^-|^2}{|E_{cv}^-|^2 - \hbar^2 \omega^2} \right] \quad (4)$$

where m is mass of the electron and M_{cv} represent the matrix element. The signs – and + indicates the left circularly polarized and right circularly polarized waves in which linearly polarized light may be decomposed. Faraday rotation is due to the different dispersion of these components. According to Zeeman splitting, the energy difference between the energy E_v in the initial state of valance band and the energy E_c in the conduction band may be written as

$$E_{cv}^{\pm} = E_c^{\pm} - E_v^{\pm} = E_c - E_v \pm \gamma \hbar B \quad (5)$$

For the zero Faraday rotation at the lower frequencies, we can write for matrix elements [5] as follows,

$$\frac{|M_{cv}^+|^2}{|E_{cv}^+|^2} = \frac{|M_{cv}^-|^2}{|E_{cv}^-|^2} = \frac{|M_{cv}|^2}{|E_{cv}|^2} \quad (6)$$

where M_{cv} is the matrix element for transition between two states c and v in the absence of magnetic field. E_{cv} is the energy difference between these two states. From equation (4), (5) and (6) and after first order Zeeman splitting equation (3) becomes

$$\theta_F = \text{const} \frac{\omega^2}{n} \sum_{state} \frac{|M_{cv}|^2 \gamma \hbar B}{E_{cv} (E_{cv}^2 - \hbar^2 \omega^2)^2} \quad (7)$$

For the crystalline materials, calculations for Faraday rotation is done in the momentum space are not appropriate to describe different energy levels in amorphous materials. Hence, we introduce the parameter named as density of states $N(E)$. When the magnetic field is applied then not only energy levels splits but also redistribution of energy levels. The effect of energy level splitting and its recombination is known as Landau effect. From the resonance caused by Landau effect and weak magnetic field approximation [2], we can write

$$N(E) = \text{constant} \sqrt{E} \quad (8)$$

The energy between the band edges is denoted as E . For crystalline semiconductors, it is generally accepted that indirect transitions play only minor role and Faraday rotation effect is mainly due to the direct transitions. Same as indirect transitions in crystals one could try to calculate equation (8) for glasses as same as indirect transition in crystals. One could try to calculate equation 8 for glasses as a gyros over all states in the valance and conduction band. It one assume a correlation between states in both bands, so that transition take place between a state in the valance band and the associate state in conduction band, and if the density of correlated states has the same energy dependence as the states in one band, equation (8) may be written as

$$\theta_F(\omega) = \text{const} \frac{\omega |M_{cv}|^2}{n} \gamma \hbar B \int_0^\infty \frac{E^{1/2}}{(E_g - E)[(E_g - E)^2 - \hbar^2 \omega^2]^2} dE \quad (9)$$

E_g is the energy difference between the band edges of valance band and conduction bands. Γ is phenomenological factor which involves parameter of the conduction band and valance band and may be given by $\gamma = \frac{1}{2} \mu_B (g_v + g_c)$, where μ_B is the Bohr magnetron and g_v and g_c are the effective g factors of conduction and valance bands suitable for the splitting of the magnetic levels. As in most theoretical cases the matrix elements M_{cv} for transitions discussed as above is constant. With $E_g = \hbar \omega_g$ equation (9) may be written as

$$\theta_F = \frac{\text{const}}{n\omega} \left\{ \frac{1}{\sqrt{(\omega_g + \omega)}} - \frac{1}{\sqrt{(\omega_g - \omega)}} + \frac{4}{\omega} [2\sqrt{\omega_g} - \sqrt{(\omega_g - \omega)} - \sqrt{(\omega_g + \omega)}] \right\} \quad (10)$$

As mentioned above, the equation (10) obeys the Kramers-Kronig dispersion relation and Becquerel relation. This means that same expression for the Faraday rotation is obtained when starting from the absorption equation developed under same condition.