Electronic Supplementary Information (ESI)

Fabrication of highly efficient resonant structure assisted ultrathin artificially stacked Ag/ZnS/Ag multilayer films for color filters applications

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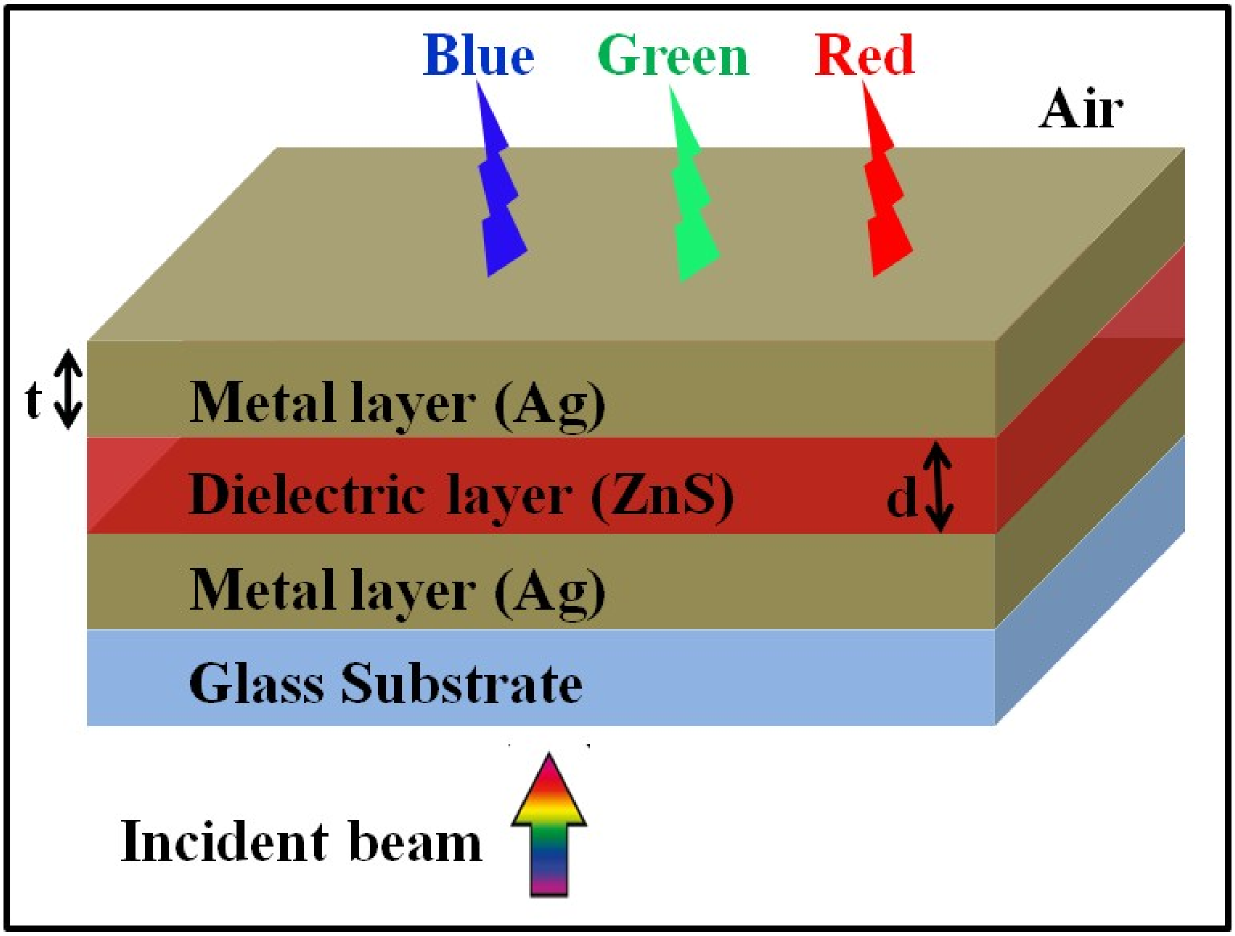

Fig. S1: Proposed metal/dielectric/metal (Ag/ZnS/Ag) multilayer resonant structure based color filter.

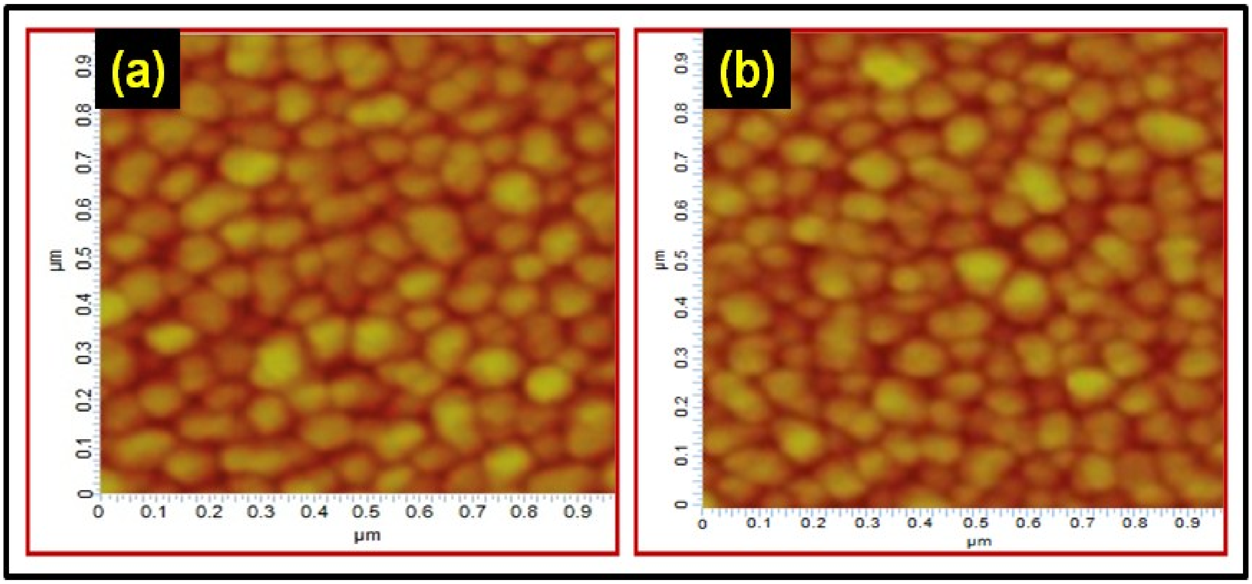

Fig. S2: 2D AFM image of the ultrathin artificially stacked Ag/ZnS/Ag multilayer film (sample 2); it has been taken after (a) 24 hours and (b) 3 months of deposition time.

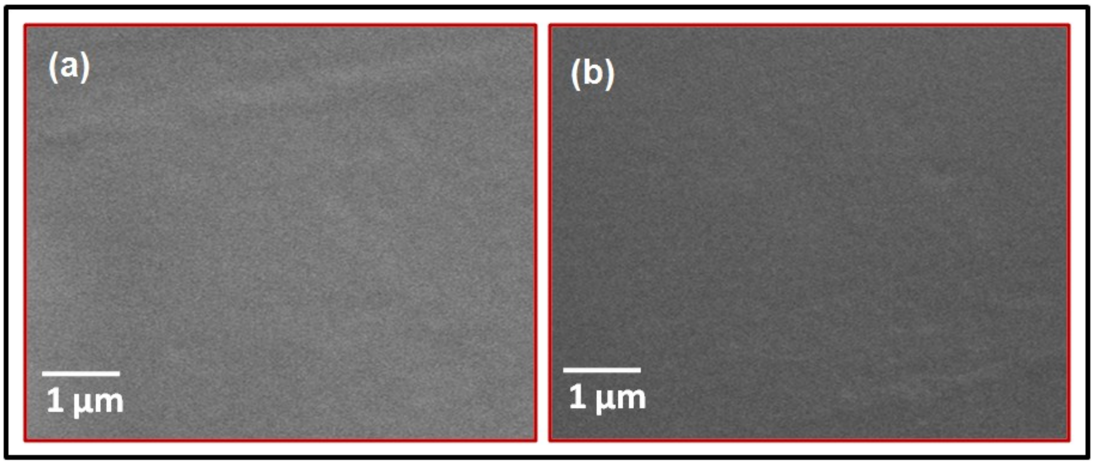

Fig. S3: Top-view of SEM images of (a) Ag/ZnS and (b) Ag/ZnS/Ag films.

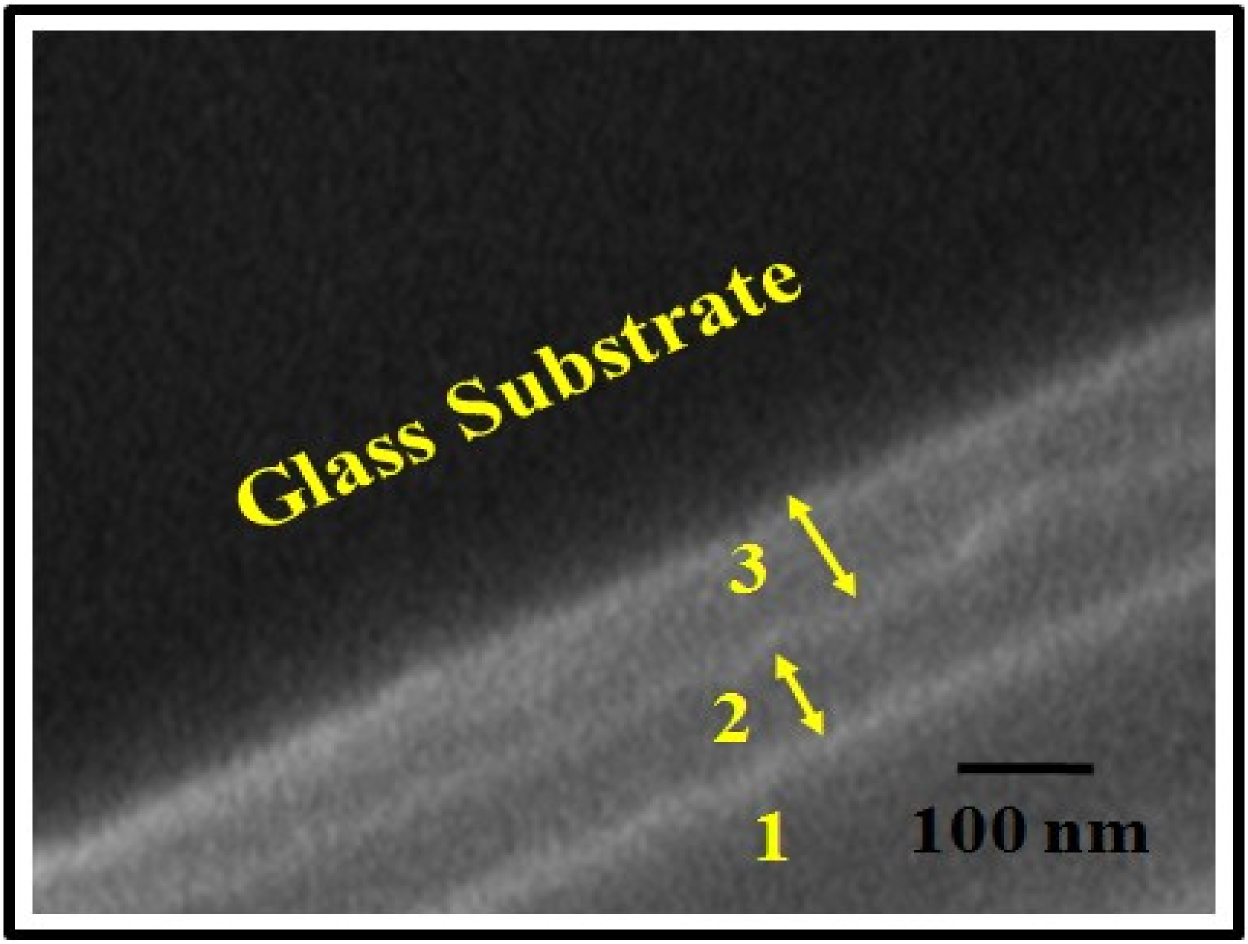

Fig. S4: Cross-sectional SEM image of ultrathin artificially stacked Ag/ZnS/Ag multilayer film in which 1 & 3 represent the Ag layers and 2 indicate the ZnS layer. The light grey parts show the interface between the two deposited layers.

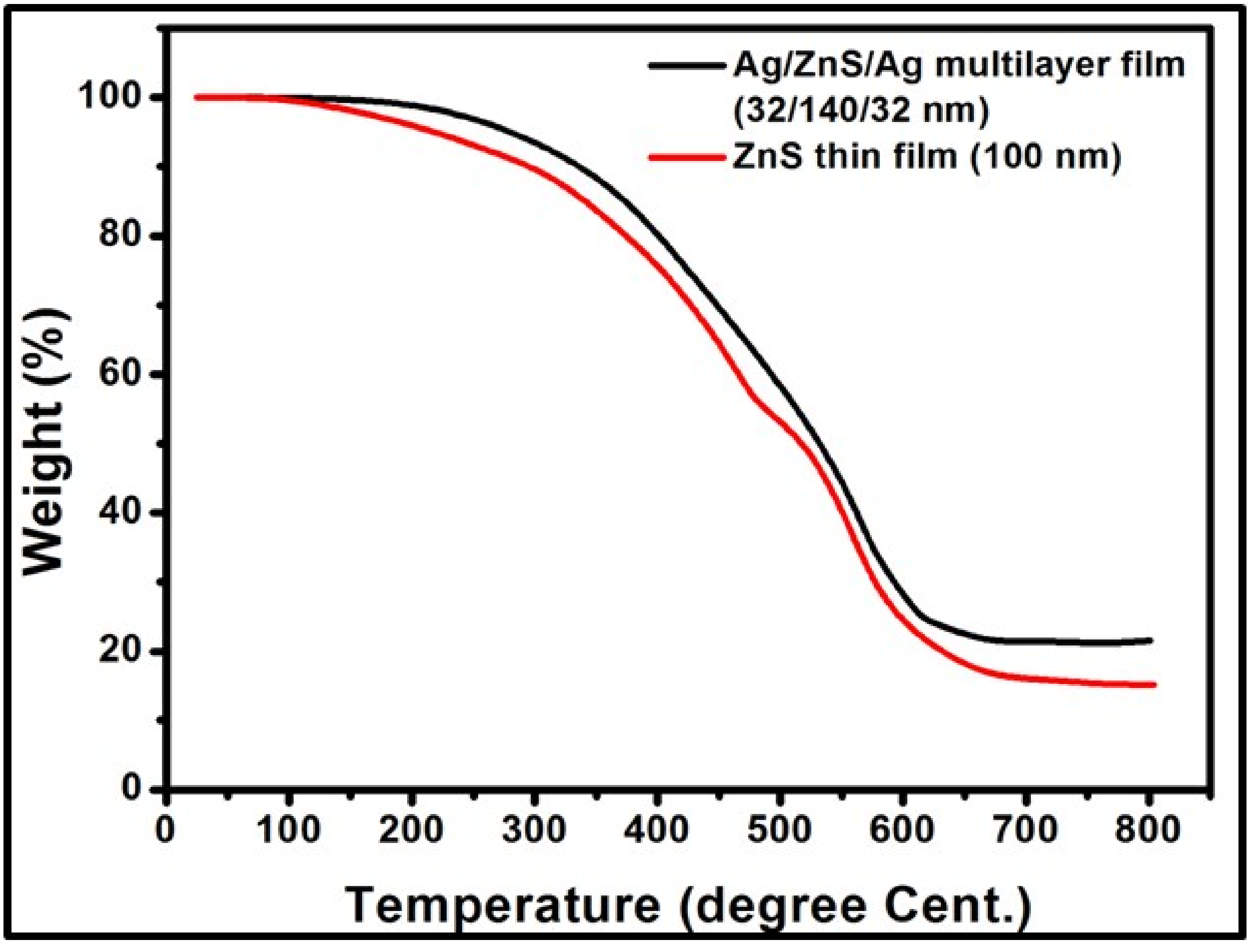

Fig. S5: TGA analysis curve of the ultrathin artificially stacked Ag/ZnS/Ag multilayer film and ZnS thin film.

Thermal stability of ultrathin multilayer films has been analyzed by Thermo-Gravimetric Analysis (TGA). Fig. S5 presents the TGA results for ZnS thin film (100 nm thickness) and artificially stacked Ag/ZnS/Ag multilayer film (32/140/32 nm thickness). The weight loss of almost 20-30% is observed from the TGA spectra up to 400 °C, due to the evaporation of residual moisture or solvent adsorbed to the surface or inner of the samples. The weight loss decreases as we increase the temperature from 400 °C to 600 °C and after 600 °C, the weight of samples is basically unchanged. The residue amounts are more decreases in case of ZnS thin film sample as compared to the Ag/ZnS/Ag multilayer film. The results reveal that the multilayer films are highly stable at 400 ºC.

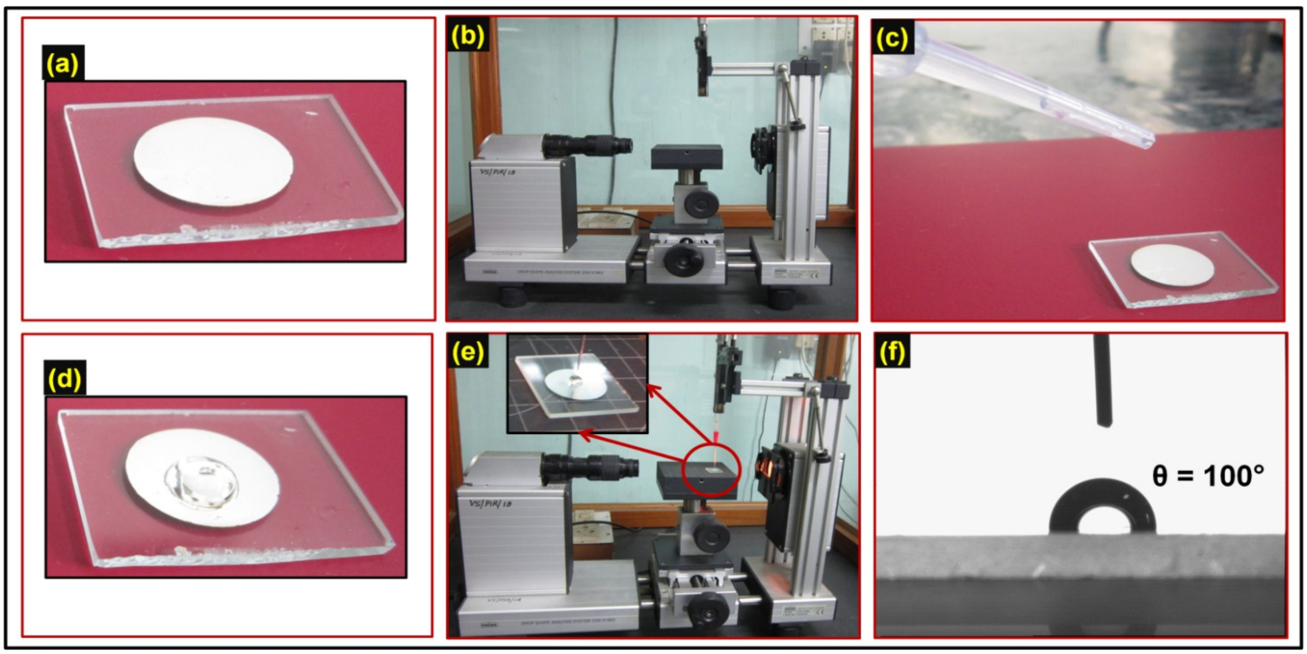

Fig. S6: The hydrophobic nature of artificially stacked Ag/ZnS/Ag multilayer film; optical image of (a) Ag/ZnS/Ag multilayer film, (b) contact angle measurement setup, (c-d) casted a water droplet on the multilayer film using dropper, (e) measurement setup to measure contact angle; inset shows the large view of drop casted multilayer film sample and (e) drop interact with the upper surface layer of the Ag/ZnS/Ag multilayer film and measured contact angle between the layer and a water droplet is about 100°.

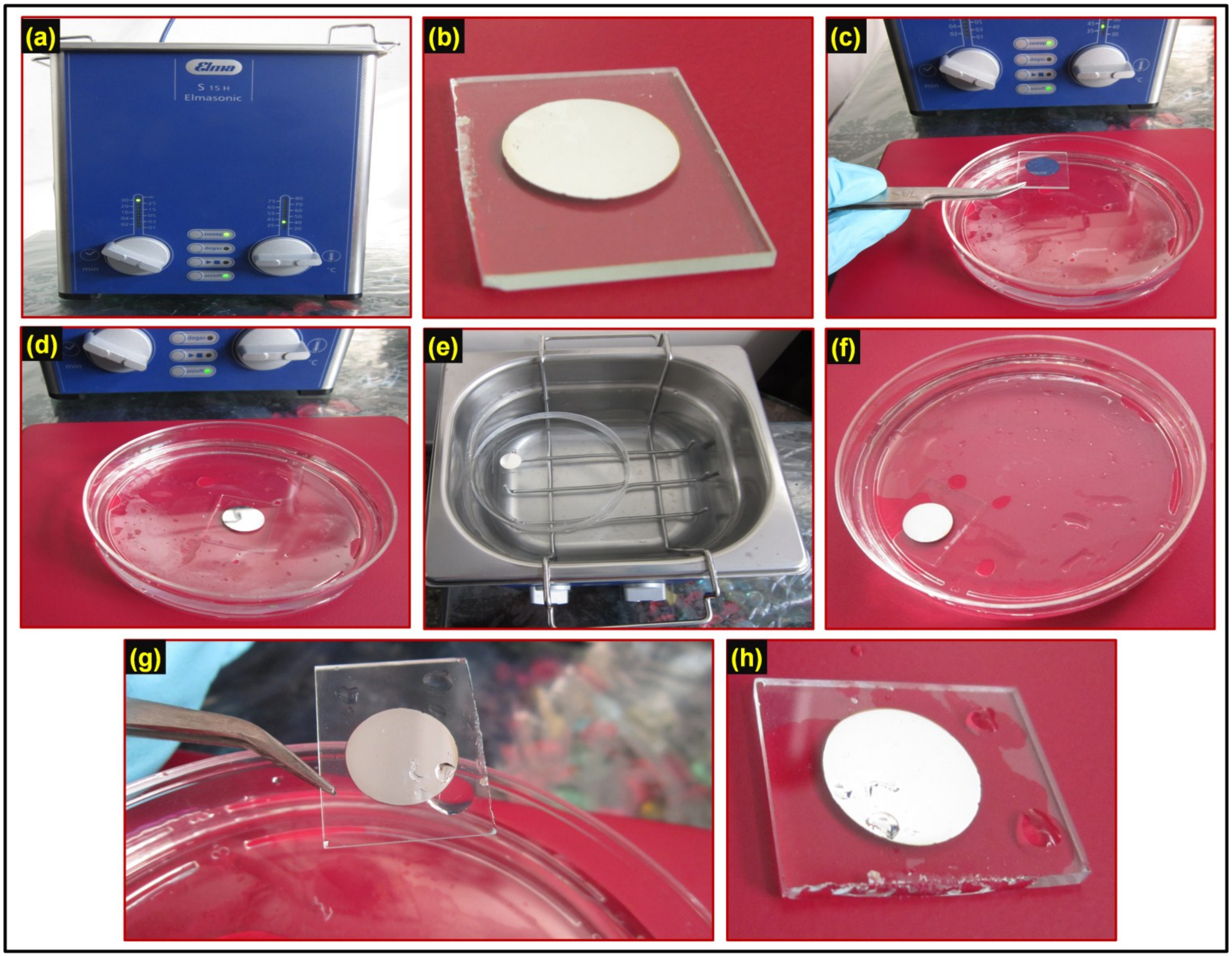

Fig. S7: Application of the ultrasonication bath treatment to the artificially stacked Ag/ZnS/Ag multilayer film for measuring the mechanical stability; optical image of (a) ultrasonication bath, (b) Ag/ZnS/Ag multilayer film, (c-d) placed multilayer film sample into a perti-dish, which is filled with water, (e) processed petri-dish under ultrasonication bath treatment (at 40°C for 30 min),(f) extracted a petri-dish from the ultrasonication bath and (g-h) separate out a multilayer film sample from perti-dish, demonstrating that the layers are not affected after the ultrasonication treatment. The strong stability adhesion of the ultrathin film with the glass substrate and between the Ag and ZnS layers are observed.

Moreover, the interaction of water with surfaces is frequently used to define the surface properties. The hydrophobic nature of the multilayer film (Fig. S6a) was examined using contact angle measurement setup (Fig. S6b). The water droplet is drop casted on the multilayer film using dropper (Fig. S6c and S6d). Then, using measurement setup (Fig. S6e), the contact angle between the layer and a water droplet is measured and it is about 100° (Fig. S6f). Thus, water droplets form on hydrophobic surfaces, implying that cohesive forces associated with bulk water are greater than the forces associated with the interaction of water with the surface layer. After measure the contact angle, the mechanical stability of multilayer film is also examined by ultrasonication bath (Fig. S7a). We have carried out ultrasonication bath treatment at 37 kHz frequency upon 40°C temperature for 30 min. The multilayer film is placed using forceps into a perti-dish which is filled with water (Fig. S7b-d). This petri dish, which has contained multilayer film sample, is processed under ultrasonication bath treatment (Fig. S7e). This treatment is carried out at 40°C for 30 min. The petri-dish is extracted from the ultrasonication bath (Fig. S7f) and after this; the multilayer film sample is separate out from the perti-dish (Fig. S7g-h). It can be noticed that the strong stability adhesion of the ultrathin film with the glass substrate and between the Ag and ZnS layers are observed. Hence, the multilayer film is not affected after the ultrasonication treatment.

Fig. S8. Optical micrograph image of Ag/ZnS/Ag multilayer thin film; it was taken using confocal PL mapping instrument.

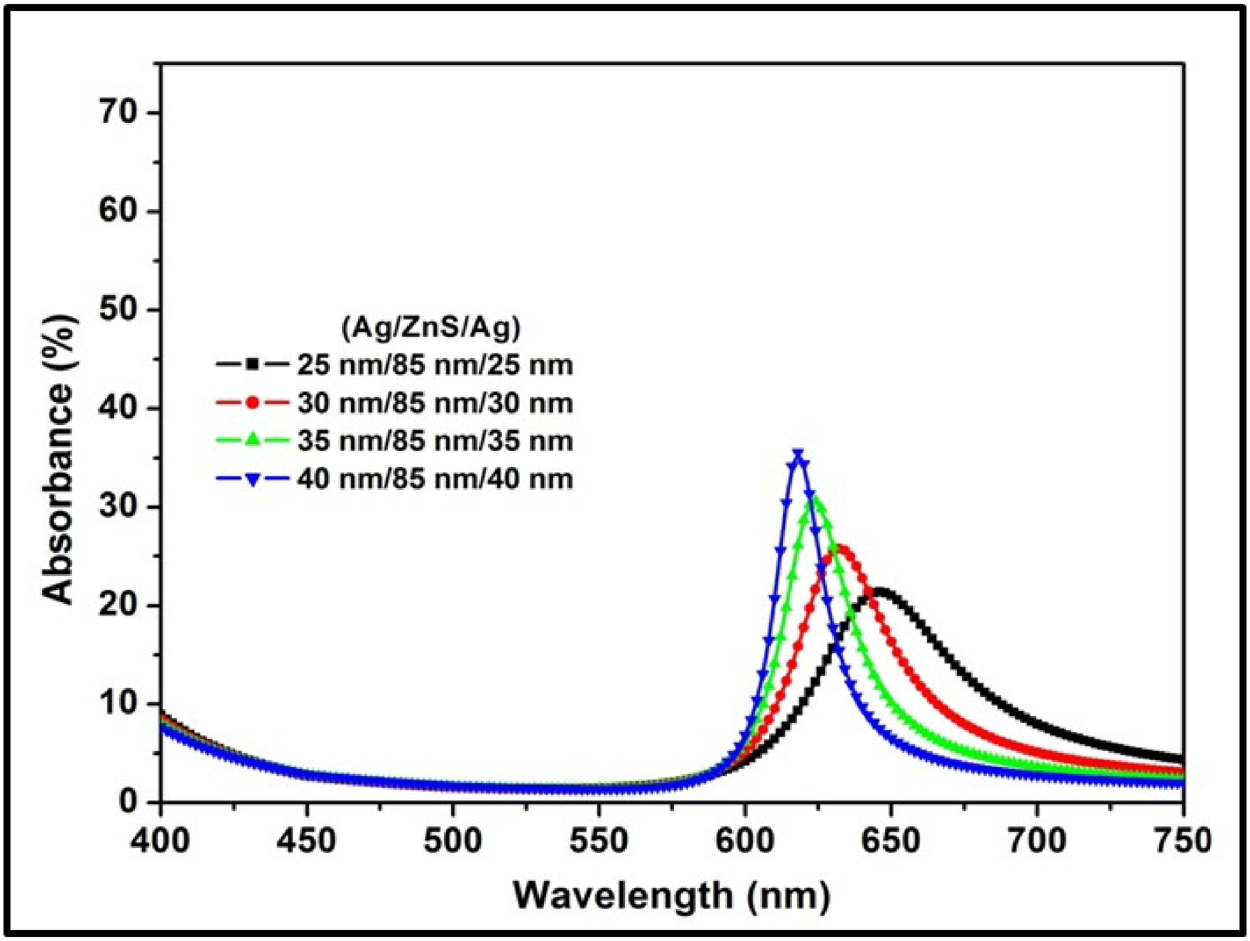

Fig. S9: Absorbance spectra of Ag/ZnS/Ag multilayer thin film structures for varying the thickness of Ag (sample 1-4; details are given in Table 1) at normal angle of incidence.

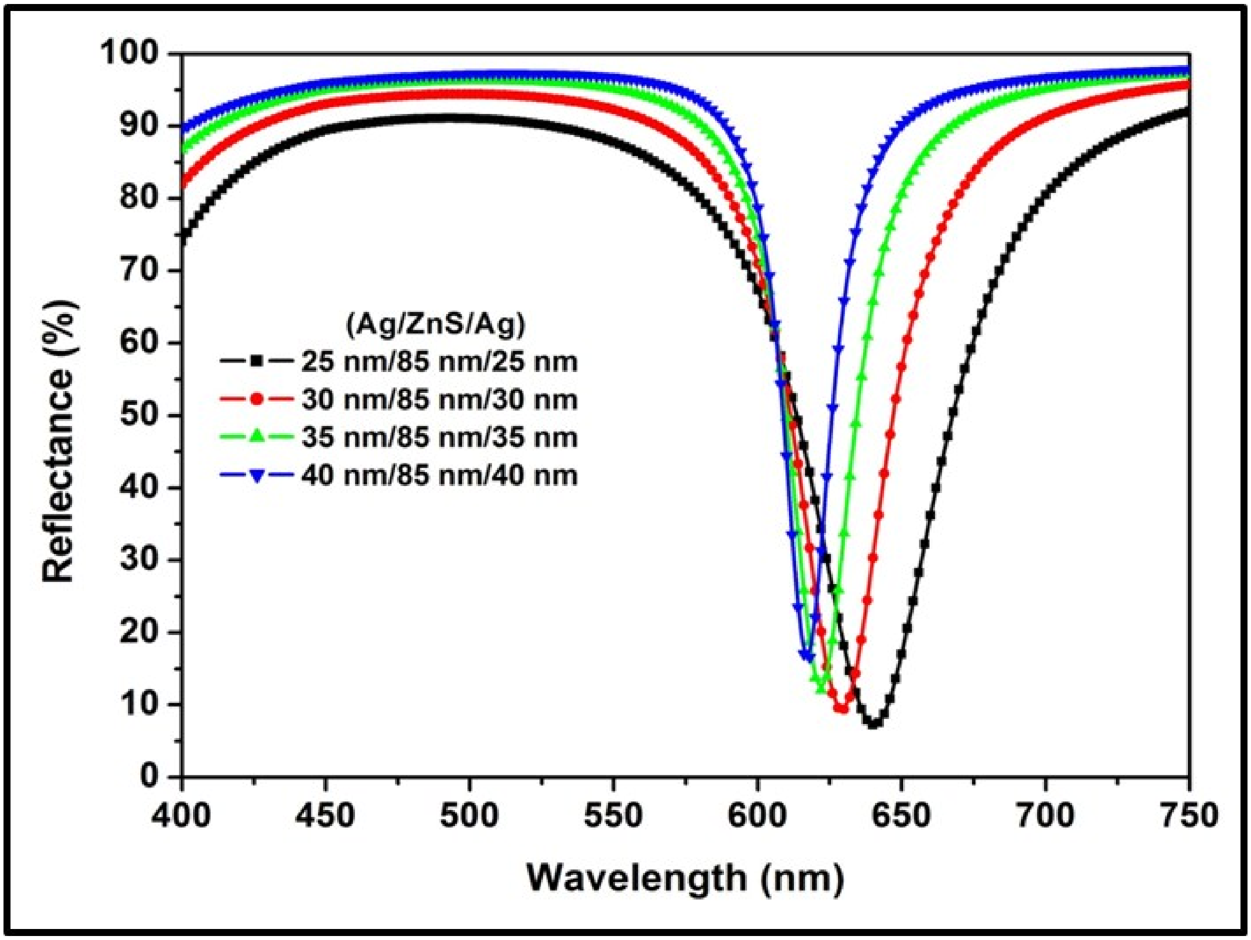

Fig. S10: Reflectance spectra of Ag/ZnS/Ag multilayer thin film structures for varying the thickness of Ag (sample 1-4; details are given in Table 1) at normal angle of incidence.

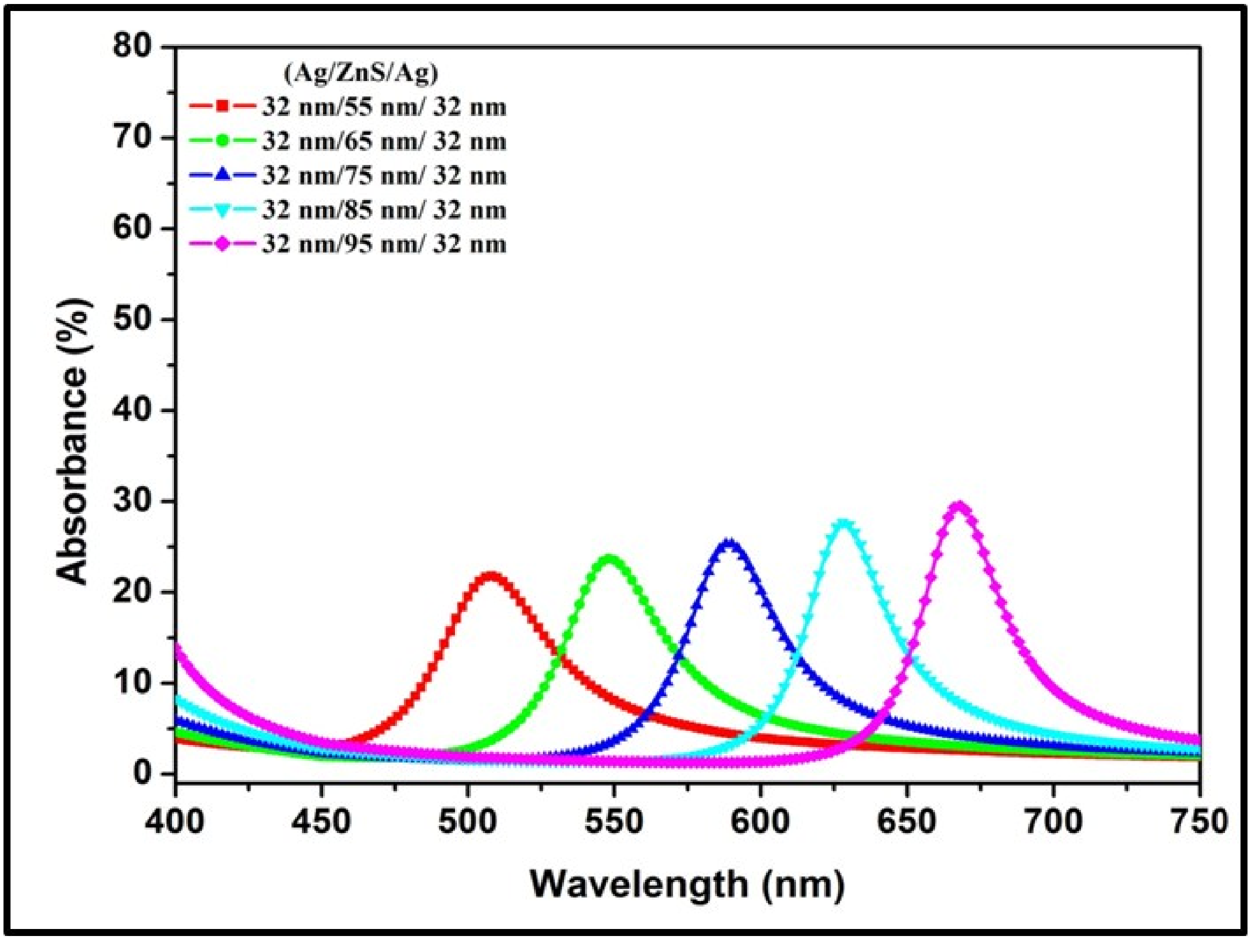

Fig. S11: Absorbance spectra of Ag/ZnS/Ag multilayer thin film structures for different values of ZnS thickness (sample 5-9; details are given in Table 1) at normal angle of incidence.

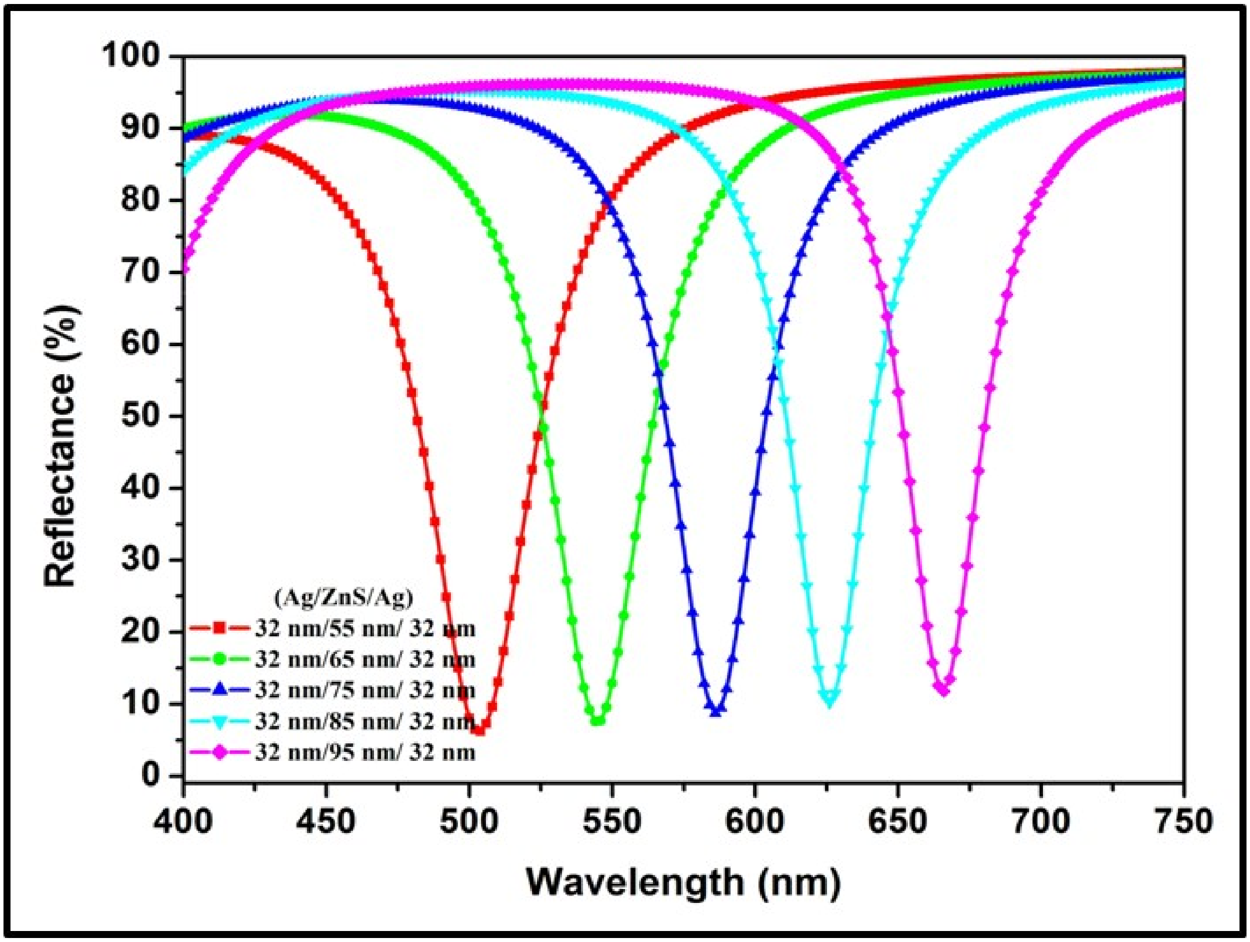

Fig. S12: Reflectance spectra of Ag/ZnS/Ag multilayer thin film structures for different values of ZnS thickness (sample 5-9; details are given in Table 1) at normal angle of incidence.

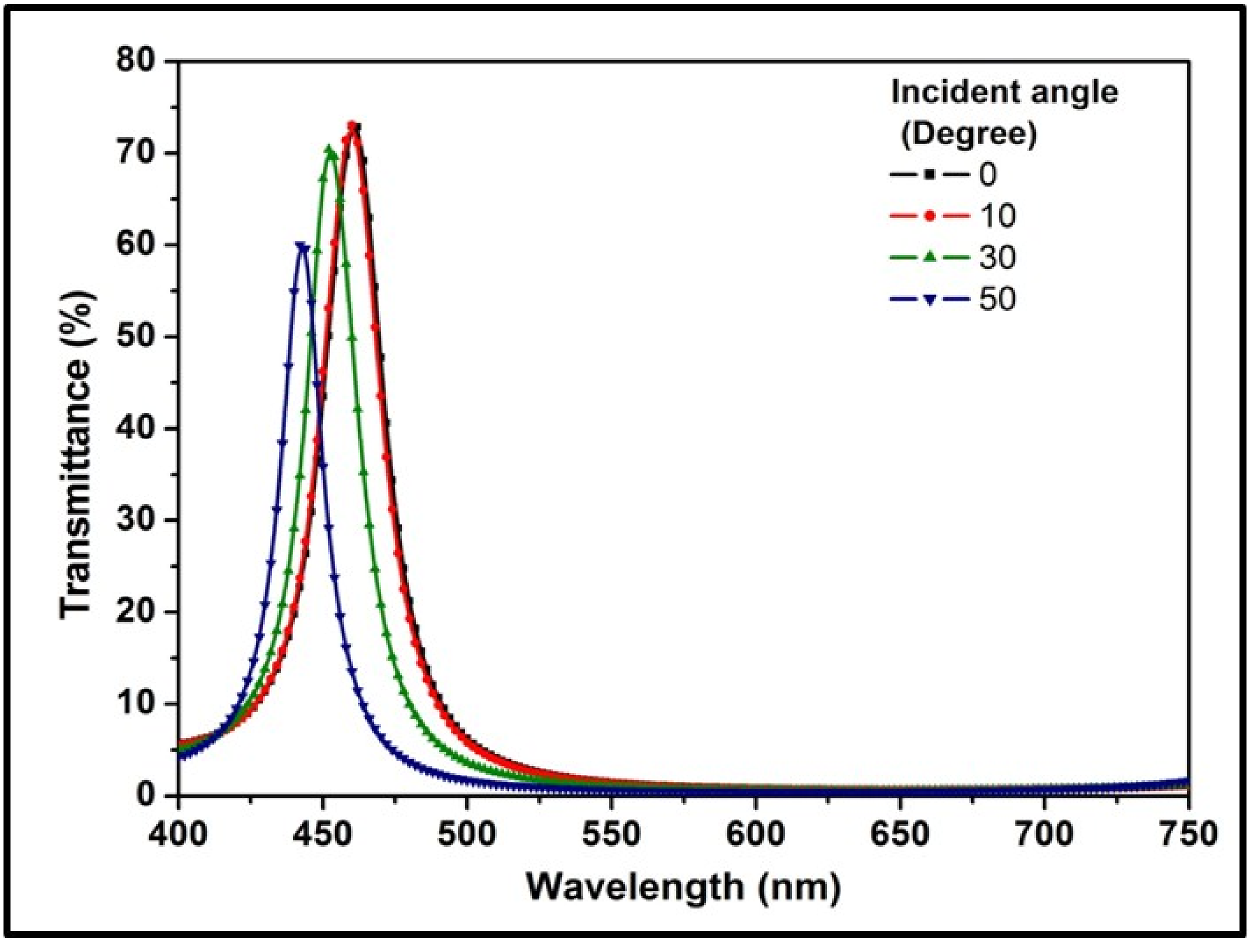

Fig. S13: Transmittance spectra for blue color filter at different angle of incidence.

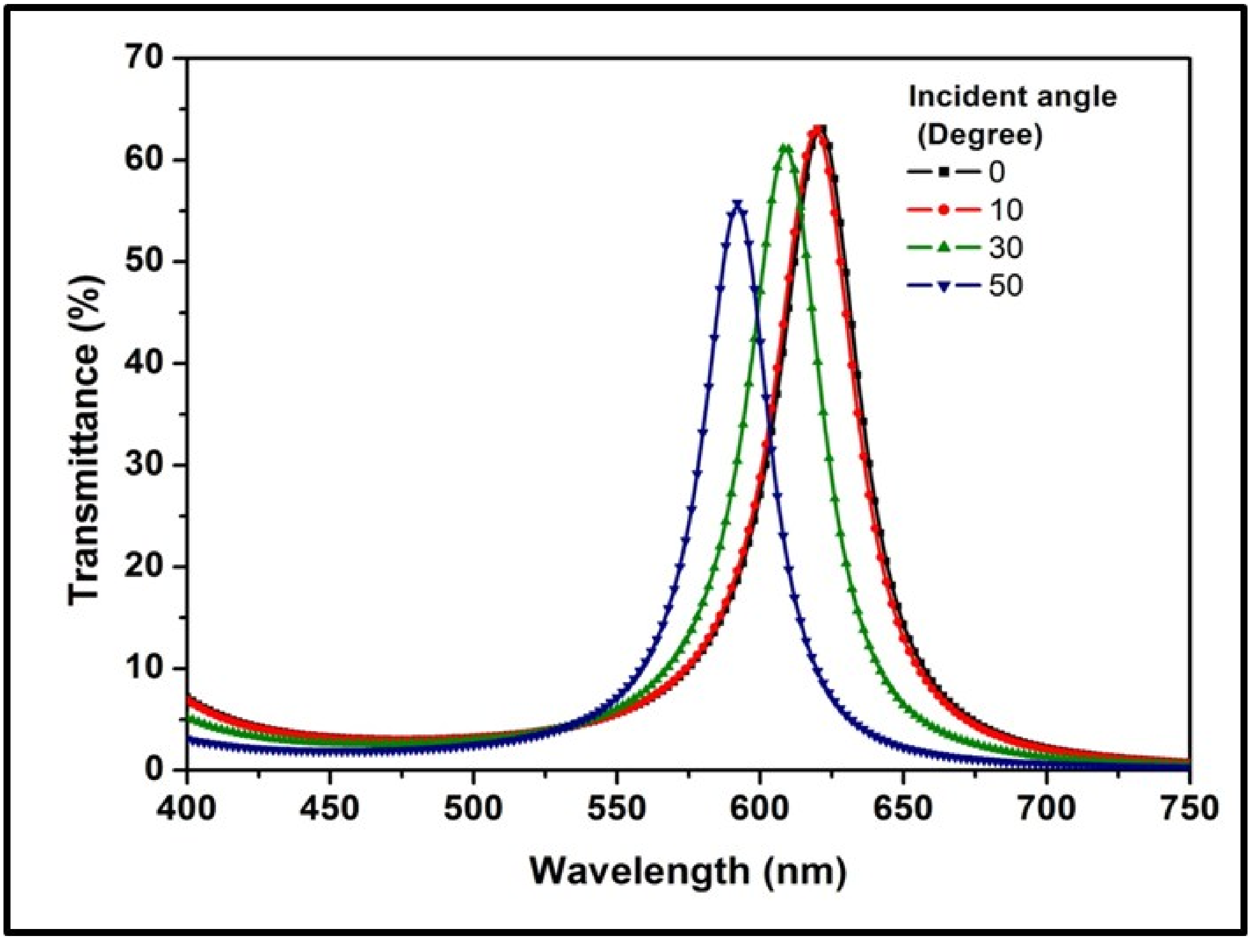

Fig. S14: Transmittance spectra for red color filter at different angle of incidence.

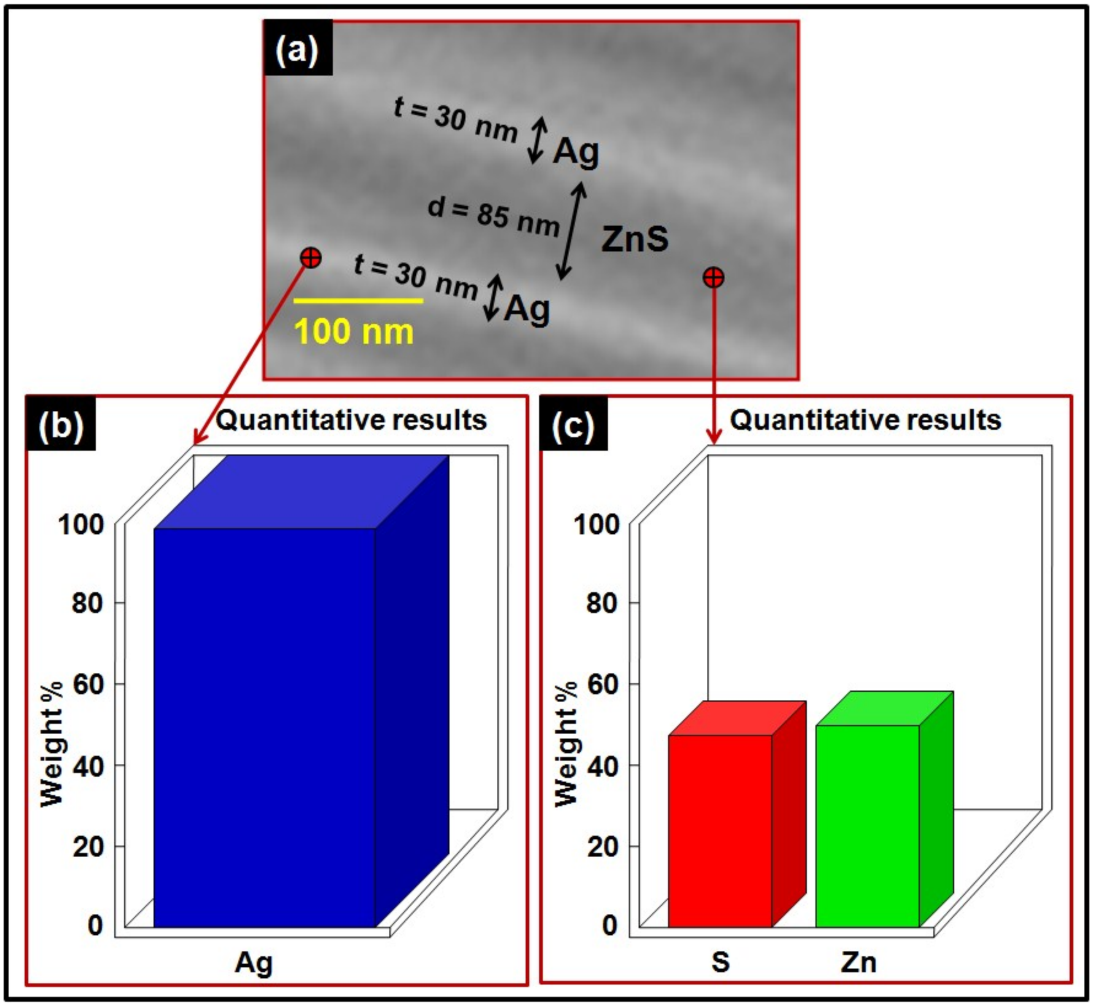

Fig. S15: (a) cross sectional SEM image of red color filter which indicates the thickness of each layer and clear interface between the Ag and ZnS layer, (b) and (c) quantitative analysis of selectively spot area on individual layers, representing the presence of weight % of Ag, Zn and S elements, respectively, which has been taken from the Fig. S15 a, marked by the red cross colored circle.