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EFFECT OF CONCENTRATION ON THE MORPHOLOGICAL AND OPTICAL PROPERTIES OF DYE-SENSITIZED ANTIMONY SULPHIDE (SB_2S_3) THIN FILM

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Abstract

In the present study, the effects of concentration on the morphological and optical properties of dye-sensitized antimony sulfide (Sb_2S_3) thin films deposited on glass substrate using chemical bath deposition technique were investigated. The concentration of dyes was varied and other deposition variables were kept constant. The surface morphology of the films showed flake-like surface which became more pronounced with increase in concentration. Using UNICO-UV-2012PC spectrophotometer, the optical properties of the films were investigated to determine the transmittance, band-gap and extinction coefficient. Analysis from the optical characterization revealed that the sensitization of antimony sulfide thin film with Naulcea latilotifia, improved the optical properties of films by increasing the transmittance and band-gap.

Keywords: *band gap, concentration, chemical bath, optical, dye, antimony sulphide.*

I. INTRODUCTION

In recent years, dye-sensitized thin films fabrication has continued to generate more and more interest among researchers in thin film technology across the world [1]. The development runs parallel withadvances in the field of semiconductor physics and have manifested in practical applications especially in optoelectronic and photovoltaic devices. It is known that silicon is the principal material used in photovoltaic cell but despite being abundant in nature, the high cost of producing silicon based solar cell has limited its wide usage for electricity generation. It is therefore imperative to explore other materials that are abundant in nature, posses low cost fabrication technique and environment friendly. Antimony and sulfides are the basic constituent of antimony sulphide (Sb_2S_3). These materials are abundant in nature. They are more environmentally friendly compared to the cadmium related materials used in the fabrication of some advanced thin film solar cells. One important advantage of antimony sulphide thin films is the possibility of using low-cost and effective deposition technique to grow the films. Thin films of antimony sulphide have been widely used in various device applications including solar cells [2-9]. Antimony sulphide thin film can be deposited by variety of low-cost deposition techniques such as chemical bath [10-12].It is well known and accepted that chemical bath deposition technique is a more universallyused method due to the fact that the method offers high quality thin films at low temperature, suitable for depositing large area semiconductor thin films, and has proved to be the simplest and the most economical since the equipment used for deposition are very common and easily affordable. The objective of this work is to deposit dye sensitized antimony sulphide using low cost chemical bath deposition method, with emphasis on the effect of concentration of dye extracts on the morphological and optical properties of the films.

II. MATERIALS AND METHODS

Chemical bath deposition technique was used for the deposition of the films. First, antimony sulphide was deposited from antimony chloride, sodium thiosulphate, methanol and aluminium chloride precursor solutions in a chemical bath containing given volume of the prepared solutions for 30 minutes deposition time. To prepare the dye extracts,20gm of fresh leaves of *Naulcea latilotifia* (uvuruilu) were boiled in 200ml distilled water at 358k for 60 minutes. The deodorized leaves were carefully taken out from the extraction solvent. The dye-extracts were filtered onto an already clean and dry container and sealed with the cap and stored at room temperature. The glass substrates containing antimony sulphide deposits were dipped into a chemical bath containing given volume of 0.1-0.25M of dye extracts for the formation of dye-sensitized antimony sulphide.The transmittance data of the films were obtained using UNICO-UV-2012PC spectrophotometer on 200 – 1100nm range of light at normal incidence to the sample. Scanning electron microscope was used for morphological investigation.

III. RESULTS AND DISCUSSION

Figures 1 and 2 are micrographs of dye-sensitized antimony sulphide thin films at 0.1M and 0.25M respectively. The SEM images showed an increase in grain size with concentration. Critical observation showed flake-like structure which became pronounced as the concentration increased. Engagement of small grains of the films in flower–like structure is clearly observed in SEM image of the films, suggesting nanostructured films. The observed long network of structure ordering makes the films good material for design of light-trapping configuration for solar cells [13]. The absence of cracks in the SEM images of the film samples accounts for the high mechanical stability of the films.

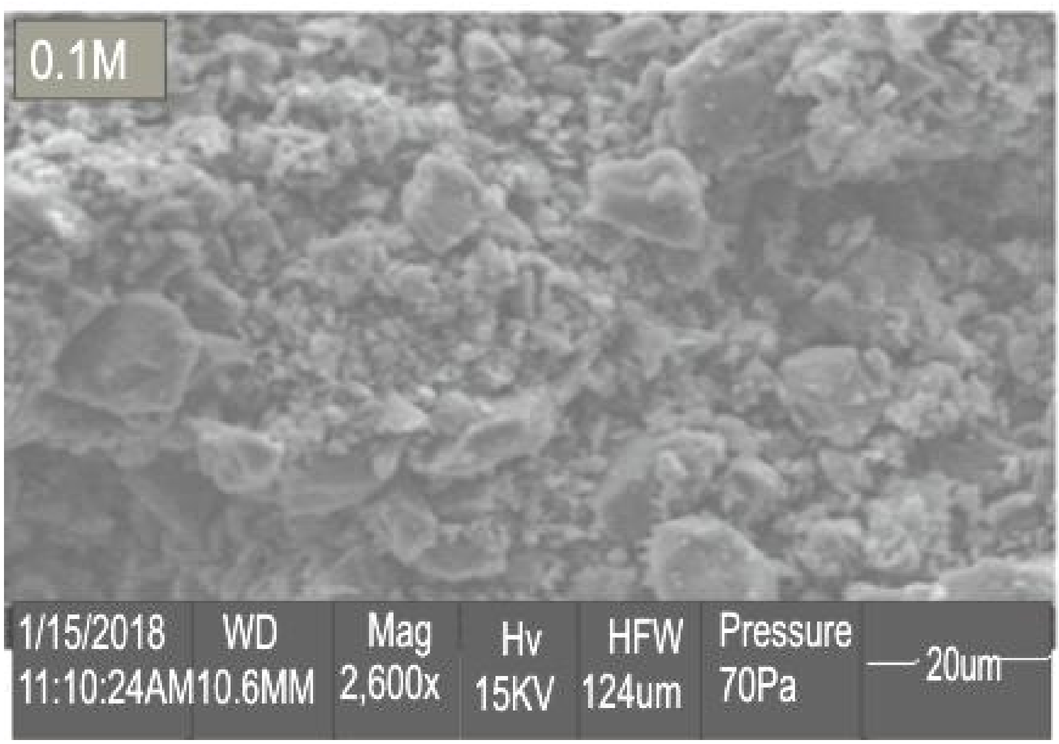

Figure 1: SEM of Dye-Sensitized Sb_2S_3 for concentration of 0.10M

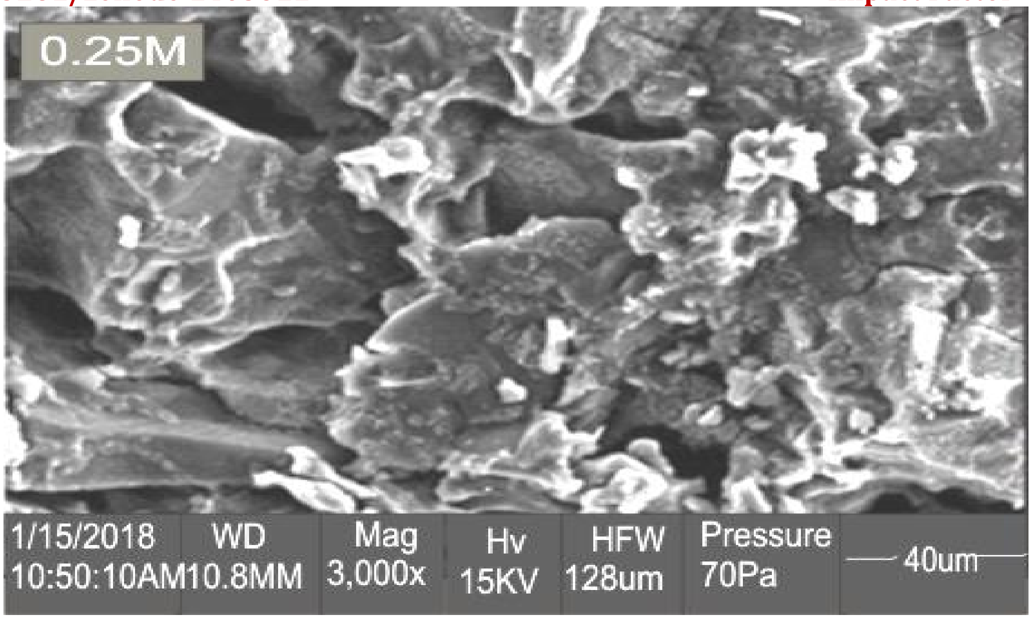

Figure 2: SEM of Dye-Sensitized Sb_2S_3 for concentration of 0.25M

Figure 3 is the transmittance spectra of the as-grown Sb_2S_3 thin films.The transmittance exhibited a concentration dependent behavior. It indicates that the film with concentration of 0.10M has the highest transmittance of about 70% while others have transmittance less than 30%. This behavior may be due to increase in thickness as the concentration increased. Such increase can cause an increase in the crystallite size as they tend to approach the bulk crystalline Sb_2S_3 leadingto larger unfilled inter-granular volume so that absorption per unit thickness is reduced hence, the behavior [12, 14, 15]. Figure 4 is the transmittance spectra of dye-sensitized Sb_2S_3. The dye improved the transmittance appreciably, indicating the incorporation of the dye into antimony sulphide matrix. The transmittance of thin films can be greatly modified by varying deposition parameters. In the literature, it has been reported that transmittance of thin films can be altered by growth parameters such as concentration [16-20], annealing temperature [21-25], deposition time [26-30] and p^H [30-34].

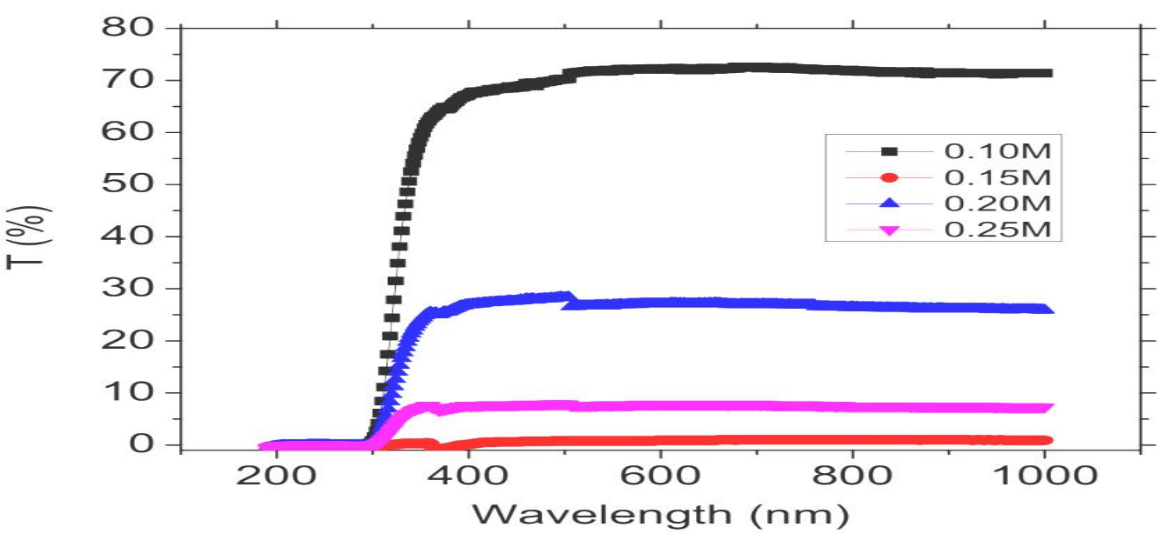

Figure 3: Plots of Transmittance against wavelength for as-grown films

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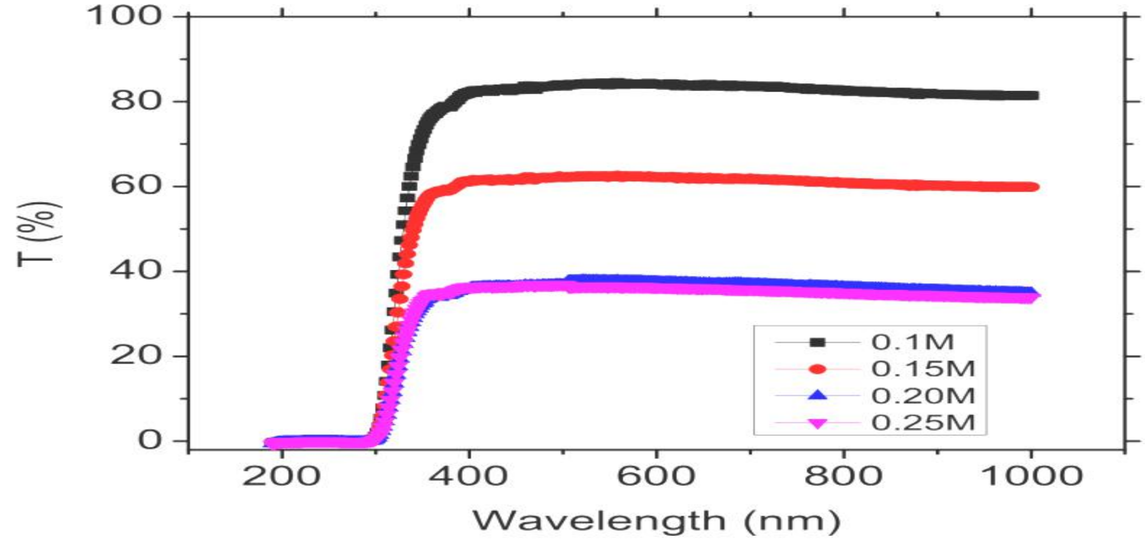

Figure 4: Plots of Transmittance against wavelength for dye-sensitized films.

The plots of $(\alpha h\upsilon)^2$ against photon energy (hυ) is shown in Fig. 5 for as-grown Sb_2S_3 while that of the dye-sensitized films is shown in Fig.6. The optical absorption coefficient α, was calculated using the formula contained in the literature [35] as;

$$\alpha = \frac{1}{d} \quad In\left[\frac{100}{T\%}\right] \tag{1}$$

In equation (1),α retains its meaning, d is the film thickness (in nm for this study), and T is the transmittance in percentage. The optical absorption coefficients data were used to estimate the energy band gap according to the relation contained in the literature[36].

$$\left(\alpha h\nu\right) = \mathrm{B}\left(h\nu - \mathrm{E}_g\right)^n \tag{2}$$

As shown in equation (2), α retains its meaning, h is the Planck's constant, ν is the frequency of the electromagnetic radiation, B is an energy independent constant, but generally depend on the refractive index and the effective masses of the hole and electron respectively [37], E_g is the energy band gap, which is obtained from the direct band gap extracts from Tauc's relation from which the plots of $\left(\alpha h\nu\right)^2$ *vs* $h\nu$ down the photon energy axis give the energy band gap and n is an index that determines the nature of the transition exhibited by the materials under investigation. In direct transition, n = 0.5. E_g values for as-grown Sb_2S_3 thin films are 1.15eV, 1.35eV and 1.70eV at 0.10M, 0.20M and 0.25M respectively. E_g values for dye-sensitized Sb_2S_3 thin filmsare 1.25eV, 1.40eV, 1.50eV and 1.70eV at 0.10M, 0.15M, 0.20M and 0.25M respectively. Clearly, band gap widening can be observed by the dyed samples thus tailoring the band gap for special applications. It has been reported that ideal band gap for solar photovoltaic applications is about 1.50eV [38]. Therefore, some of the film samples are suitable materials for solar cell fabrications.

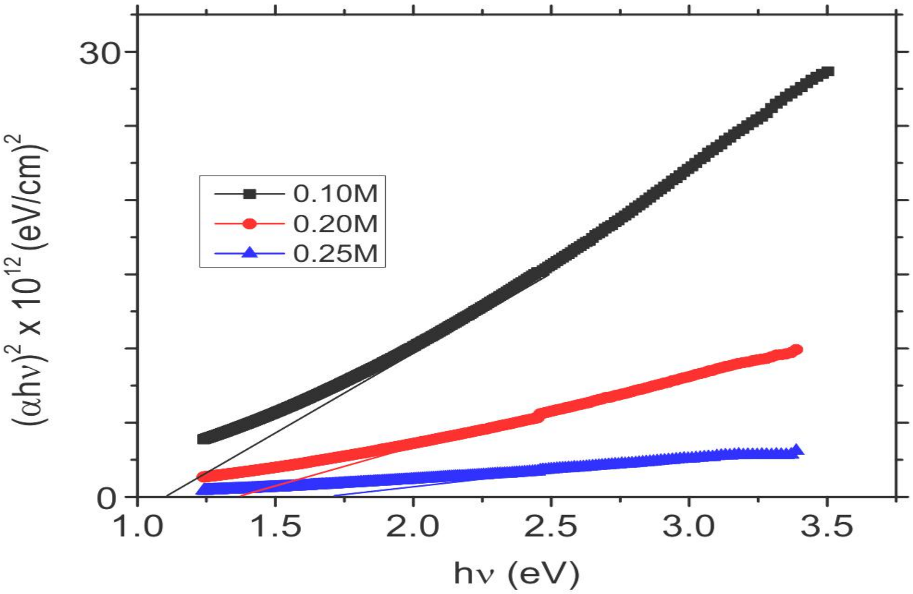

Figure 5: Plots of $(\alpha h\nu)^2$ vs $h\nu$ for as-grown films.

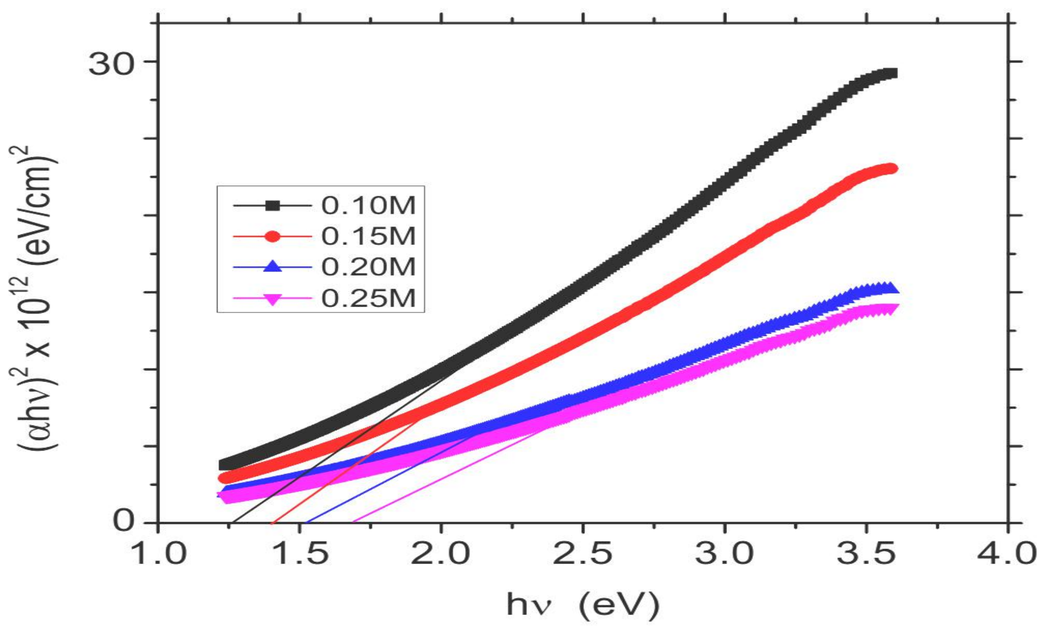

Figure 6: Plots of $(\alpha h\nu)^2$ vs $h\nu$ for dye-sensitized films.

Figures 7 and 8 show the variation of extinction coefficient with photon energy for as-grown and dyed samples of antimony sulphide respectively. The extinction coefficient was calculated using the relation

$$K = \frac{\alpha\lambda}{4\pi} \quad (3)$$

The extinction coefficient is in the range 0.05 and 0.40 which decreased with increase in photon energy.The extinction coefficient of the dye-sensitized Sb_2S_3 ranged between 0.08 – 0.40 which shows improvement as the dye is introduced.

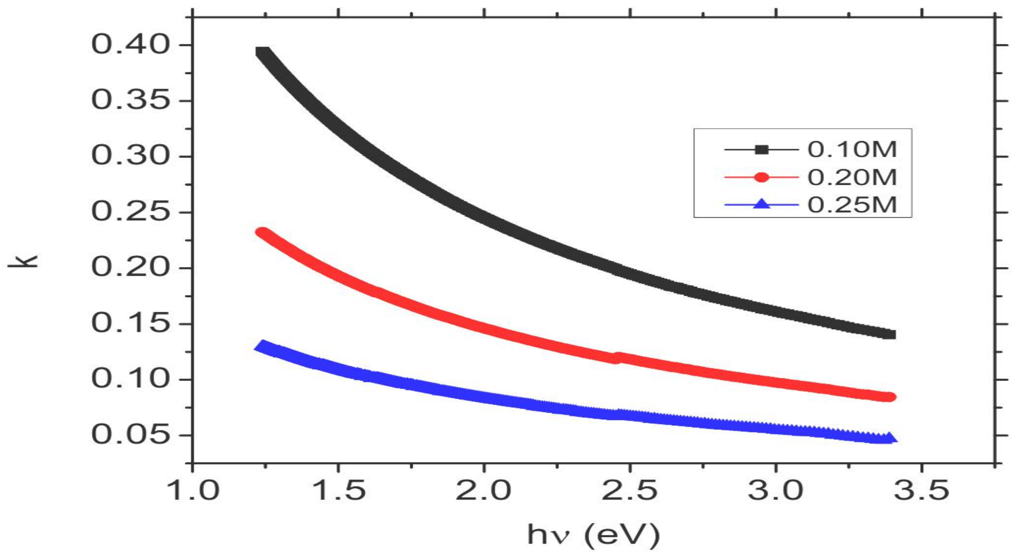

Figure 7: Plots of Extinction Coefficient vs $h\nu$ for as-grown samples

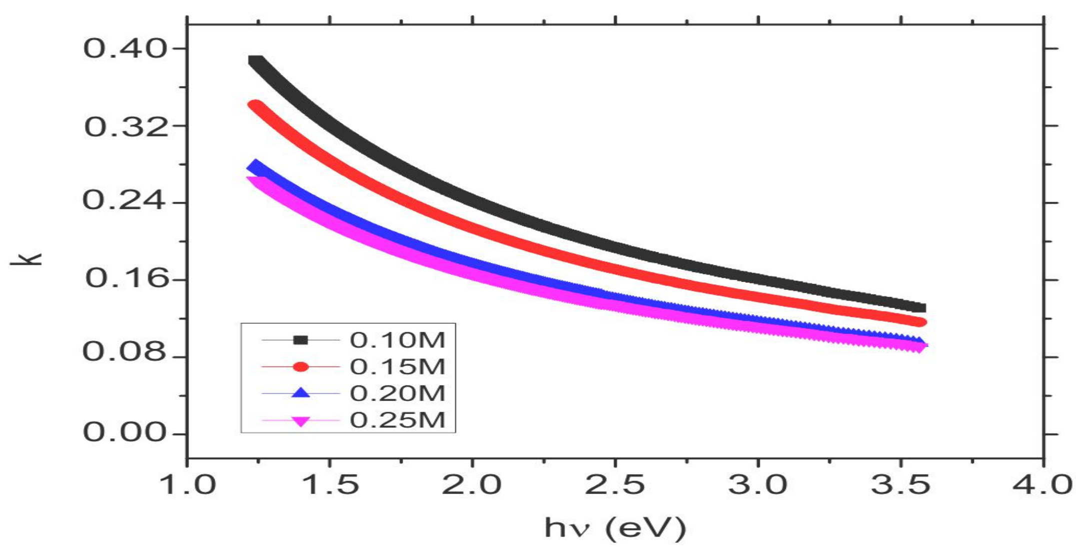

Figure 8: Plots of Extinction Coefficient vs $h\nu$ for dyed samples

IV. CONCLUSION

Dye-sensitized Sb_2S_3 thin films were successfully grown using chemical bath deposition technique and UNICO-UV-2012PC spectrophometer was used for the optical characterization while scanning electron microscope was used for morphological characterization. The results of optical characterization showed that the dye samples have higher transmittances, wider band gaps and increased extinction coefficient values. The results of morphological studies showed that the dyed samples exhibited higher grain sizes with well-defined grain boundaries. Based on the properties of the films, it can be concluded that they are suitable materials for solar cell fabrications, construction of poultry houses as well optoelectronic applications.

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