# *Resistive switching memory effect and conduction mechanism in nano-silver incorporated Type-A gelatin films*


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***Abstract*—This paper presents the conduction mechanisms and the observation of bipolar resistive switching in nano silver incorporated gelatin (AgG) composite films. Different concentrations of commercially purchased silver nanoparticles (0.3 w/v%, 0.5 w/v%, 0.7 w/v%) were incorporated in gelatin and AgG films were spin-coated on ITO substrates. We did systematic study of I-V characteristics in these films. The film with 0.5 w/v% exhibits an abrupt increase in current at 6 V with ON/OFF ratio of more than 3 orders of magnitude. Further, the I-V characteristics revealed O-type hysteresis behaviour along with hopping type of conduction for higher nano particle concentrations of 0.5 and 0.7w/v%. However, for much dilute concentration of Ag (0.3 w/v%), the conduction is of ohmic type**



**Keywords—Hopping conductivity, ON/OFF ratio, O-type hysteresis, switching behaviour**


## I INTRODUCTION

Recent research on resistive random access memory (ReRAM) is directed towards polymeric materials with degradability and easy availability for realizing low cost environment friendly memory chips. Biomaterials based memory devices exhibit nonvolatile ReRAM characteristics [1] with advantages of biodegradability and simple fabrication process [2]. There is an ever increasing demand for biomaterial based printable electronic devices because of biocompatability and flexibility[3].However, most biomaterial films react with the atmosphere and are very unstable and there is also a need to look for degree of degradability of the devices [4].Flexible biomaterial devices fabricated with naturally abundant materials have been demonstrated for low cost applications [5]. The practical applications of nanomaterials in polymer films have great potential for realizing two-terminal nonvolatile memory devices [6]. Cost effective biopolymers like chitosan with good transparency have shown memory switching with silver as nano dispersant [7]. Among metal nanomaterials, silver nanoparticles are known to increase memory performance when used as dispersant in biomaterials like chitosan [8]. However, transparency of these films disappears as the nanoparticle concentration is increased leading to opaqueness of the device[9]. Gelatin is another such transparent, low cost and thermally stable biodegradable polymer that has demonstrated resistive switching behaviour and can be stored [8,10]. Gelatin films baked at different temperatures showed good ON/OFF ratio which is an important parameter for memory switching[4]. The conduction mechanism of filament formation of gelatin type B device is similar to switching mechanism in conducting polymers without any nanoparticle dispersion [11]. So far, very little research work has been done on gelatin based memory switching devices. Recently, bistable memory switching has been observed in type A gelatin using CdTe quantum dots as dispersant [12].Gelatin A in the form of crystals is derived from acid cured tissue has higher bloom strength of 300 which is different from Gelatin B in its properties. In this paper, we explore resistive switching behaviour and electrical conduction mechanism(s) in Gelatin A with a homogenous dispersion of silver nanoparticles.


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## II EXPERIMENTAL METHODS

Gelatin of type A with bloom strength of 300 and purity of 99.5% was purchased from Goodrich ingredients and chemicals Pvt Ltd, Chennai, India. Silver nanoparticles with average particle size of 10 nm was purchased from Sigma Aldrich and used as the dispersant. Three batches of mixtures containing 0.3w/v%, 0.5w/v% and 0.7w/v% of Ag nanoparticles in water was dispersed in 5 w/v% aqueous gelatin A solution. To ensure uniform dispersion, composite mixtures were ultrasonicated for 15 min. A few drops of the homogenized solution was dropped on a pre-cleaned indium tin oxide (ITO) coated glass plate and spin coated in two steps, viz., 500 rpm for 15 sec followed by 2500 rpm for 30 sec so that a uniform layer of the gelatin composite was formed over the ITO. The coated glass plate was then dried at room temperature. A home-made thermal evaporator was used to deposit the top aluminium metal electrode of area 0.5 $cm^2$ under a vacuum of $<10^{-5}$ mbar. Electrical measurements were carried out using a semiconductor parameter analyzer (Keithley 4200-SCS). In a typical experiment, the current-voltage (I-V) characteristics of the sandwich structure were recorded by scanning the voltage from -8 V to +8 V (forward sweep) followed by a reverse sweep (+8 V to -8 V). A scanning electron microscope (SEM, Jeol, JSM 6360A) was employed to examine the surface morphology of the thin film layers and to confirm the homogeneity of the films. Thickness of the films was measured using a thin film analyser (Filmetrics F10). Both pure gelatin A and the gelatin + Ag nanocomposite (AgG) active layers were ~600 nm in thickness since the solutions had similar viscosity and the drops were spin coated under similar conditions.

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## III RESULTS AND DISCUSSION

Fig. 1 shows I-V characteristics for AgG film with 0.3 w/v% silver. The I-V data shows negligible hysteresis and mostly simple ohmic behavior as shown by the linear fit of the data in Fig. 2 (a) & (b) for both forward and reverse sweeps. It is also to be noted that the slope of the linear fit for both forward and reverse sweeps is almost same, indicating that the resistance is same along with negligible hysteresis. It has to be pointed her that we did not observe any appreciable electrical response or switching behaviour in pure type A gelatin film unlike in type B gelatin as observed by Chang et al [4]. As the silver concentration is increased to 0.5 w/v%, a O-type hysteresis emerges in I-V characteristics with resistive switching around 6 V embedded in it, as shown in Fig. 3.. In order to understand the electrical conduction mechanism in this film, the I-V data was analysed with different relations corresponding to, (a) ohmic, (b) space charge limited current (SCLC) and (c) hopping conduction mechanisms. The data fits very well with an exponential function characteristic of hopping conduction behavior [13] for both forward and reverse sweeps in the entire voltage range as shown in Fig 4 (a) & (b). This clearly indicates a hopping type of conduction mechanism prevalent in the film. The resistive switching that occurs at 6 V is well defined with an ON/OFF ratio of 3 orders of magnitude followed by multiple switching. As the concentration is further increased to 7 w/v%, the I-V characteristics show much smaller hysteresis as shown in Fig. 5. However, the conduction is still dominated by hopping type of behaviour, as shown in Fig. 6. Thus, the conduction mechanism in type A gelatin film embedded with silver nanoparticles exhibit a completely different behavior with respect to the report by Chang et al[14]. In their work and report, they have incorporated silver by dissolving metal salts in gelatin, and their films show essentially a space charge limited conduction (SCLC) mechanism. Thus the particle size of the dispersant is different in both cases apart from the type of gelatin used. This establishes that the conduction mechanism in AgG composites depends on the type of gelatin and also the nature of the dispersant that has been embedded into gelatin. Our results indicate that a simple addition and direct incorporation of silver nanoparticles in type A gelatin can bring in the resistive switching with dispersant concentration dependent conduction mechanism.

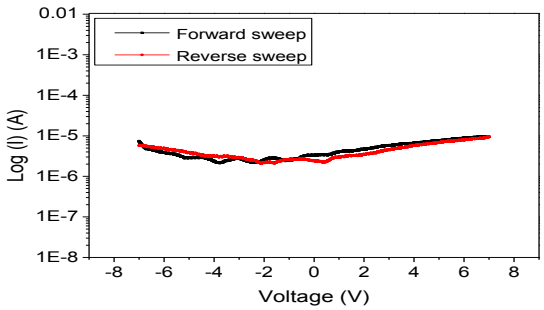


Fig.1 I-V characteristics for AgG film with 0.3wt/v% silver

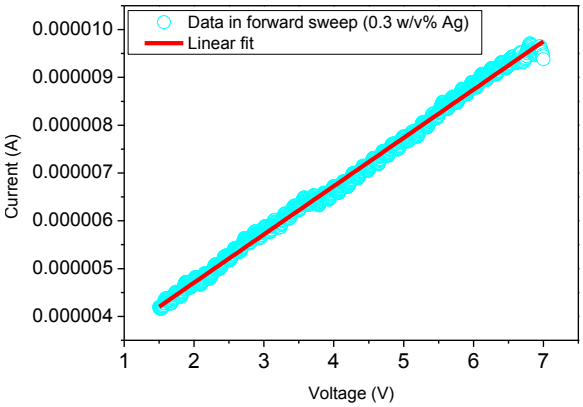


Fig.2(a) Linear fit for I-V data of AgG film with 0.3w/v% Ag recorded in the forward sweep

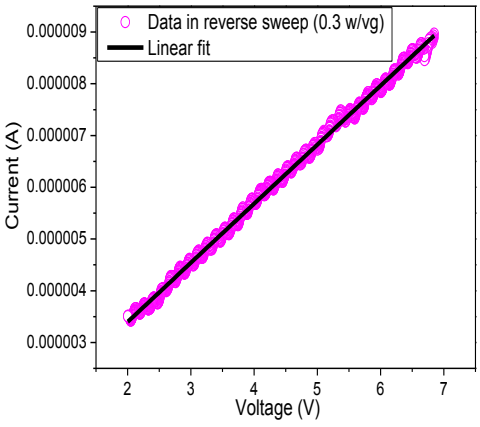


Fig.2(b) Linear fit of the I-V data for 0.3wt% AgG film in the reverse sweep

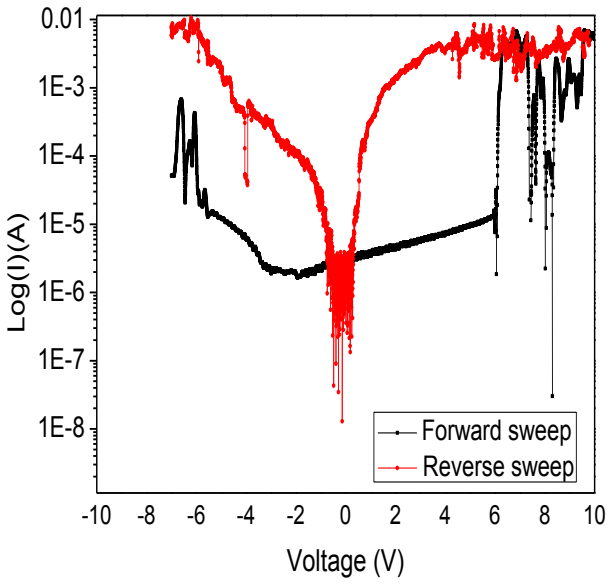


Fig.3 I-V characteristics for AgG film with 0.5wt/v% silver.

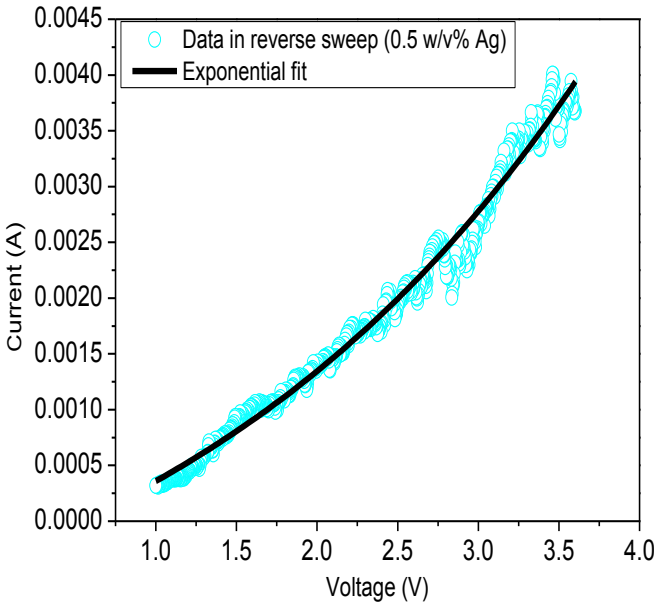


Fig.4(b) Exponential fit of the I-V data for AgG film with 0.5w/v% Ag in the reverse sweep

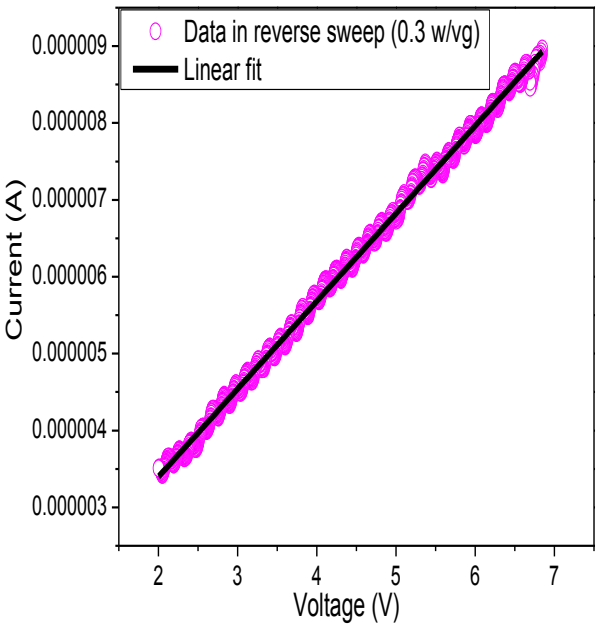


Fig. 4(a) Exponential fit to I-V data of AgG film with 0.5 w/v% Ag in the forward sweep

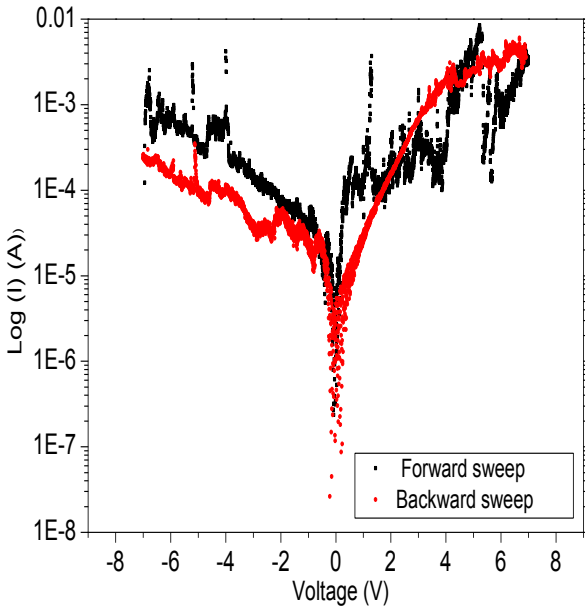


Fig.5 I-V characteristics of AgG film with 0.7 w/v% silver nanoparticles

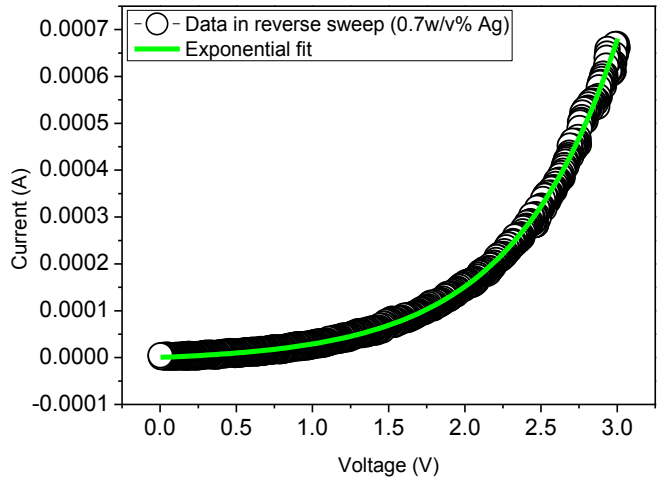


Fig.6. Exponential fit for I-V data of AgG film with 0.7 w/v% Ag in the reverse voltage sweep.

## IV CONCLUSION

Resistive switching has been observed in silver nanoparticle embedded type A gelatin with bloom strength of 300. Gelatin films with 0.3w/v% Ag showed ohmic conduction. As the Ag nanoparticle concentration increased further, the conduction is dominated by hopping type conduction. Also resistive switching occurred around 6 V with an ON/OFF ratio more than 3 orders of magnitude for the AgG film with 0.5w/v% Ag. The hysteresis is of O-type which signifies bistability. As the concentration of Ag particles is increased beyond 0.5w/v%, the conduction remained the same but resistive switching was not observed, indicating an optimum concentration for achieving resistive switching in these composite films.

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