Preparation of gold nanoparticles embedded in lead zirconate titanate films

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Nanocomposite films consisting of nanoscale metal particles such as gold, silver, and copper embedded in a dielectric matrix have been studied for many applications [1]. Nanocomposite films could be fabricated by sputtering, sol-gel, ion implantation, chemical vapor deposition, and aerosol deposition methods [2]. However, these methods are complex, including instrument requirements, complicated processes, and small doped amount into the matrix. In the study, we demonstrate a simple method that prepare the gold/ lead zirconate titanate (PZT) nanocomposite films by organic chemical addition method.

In our study, when $AuCl_4^-$ ions were complexed with dodecylamine, the $AuCl_4^-$ dodecylamine complexes remained stable during the period of gel drying and organic solvent prevented PZT precursor from water to form precipitation. A solution of Au^{3+} ions are added into the metalorganic decomposition (MOD) precursor of PZT, and small Au particles could form due to the decomposition of $AuCl_4^-$ dodecylamine complexes in the high temperature heating process (as shown in Figure 1). Because the PZT precursor is easily hydrolysis, the $[AuCl]^-$ need to hydrophobize in toluene were separated from the aqueous phase. The 1g PZT solution is mixed with 0.1, 0.5, and 1 ml of 25 mM $HAuCl_4$, and uniformly stirring. Each film is dried at 120℃ and heated to 200-450℃ in air. Figure 2 shows X-ray diffraction (XRD) spectra of Au/PZT composite film with contain $HAuCl_4$, as-deposited, and post-annealed film at 450℃ and found the composite film has been fully crystallized. Moreover, we observe the compressive residual stress and small crystalline size in the as-deposited film. No peak of gold is found since the amount in the film is too small to detect. Figure 3 shows the transmission electron microscope (TEM) images and electron energy-loss spectrometers (EDS) of Au/PZT composite films with containing $HAuCl_4$ of as-deposited and post-annealed samples. As shown in Figure 3(a), there aren't any Au nanoparticles in the PZT matrix and Au composition can be observed from TEM images and EDS analysis. As post-annealed at 450℃, the Au nanoparticles are precipitated in the PZT matrix and can be detected by EDS analysis (Figure 3(b)). The size of gold nanoparticles is about 5-10 nm in the PZT matrix. Polycrystalline structures of Au nanoparticles can be identified from weak rings and some scattered spot clearly. As shown in Figure 4 (a), there are not obviously absorption peak in the absorption spectra with increasing $HAuCl_4$ contents. The extinction coefficient is not any tendency with increasing $HAuCl_4$ contents. Figure 4(b) shows absorption properties of the postannealed composite Au/PZT thin films at 450℃. The stronger absorption with increasing $HAuCl_4$ contents and the SPR absorption peak is found at about 620 nm. The extinction coefficient is increasing with increasing $HAuCl_4$ contents. These phenomena appear to be consistent with the TEM images and EDS analysis. In this study, we present the results of convenient chemical synthesis to fabricate nanocomposite Au/PZT films with obvious SPR phenomena.

[1] H. B. Liao, W. Weng, and G. K. L. Wong, J. Appl. Phys. 93, 4485 (2003).
[2] J. M. Lamarre, Thin Solid Films 479, 232 (2005).

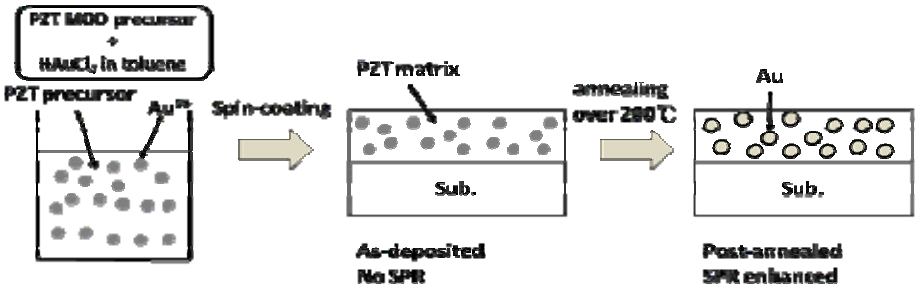


Fig. 1 Schematic of organic chemical addition method of nanocomposite films.

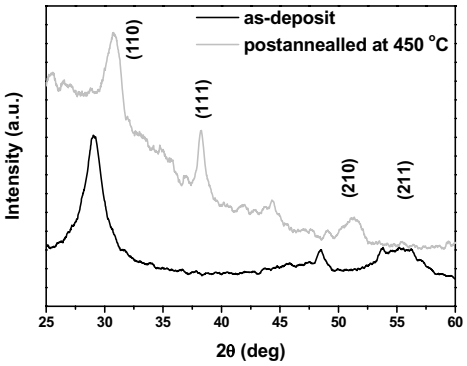
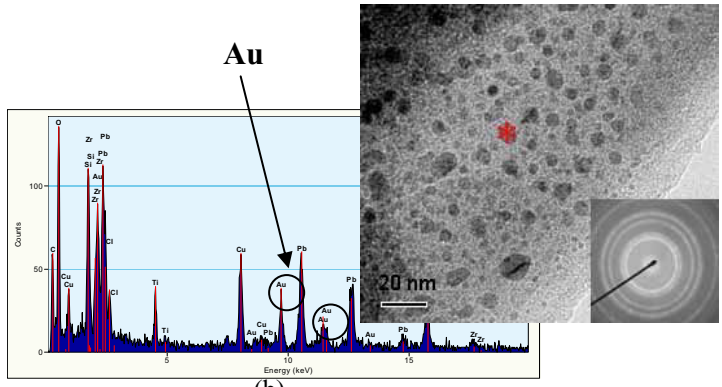


Fig.2 XRD spectra of composite film with containing 1 ml $HAuCl_4$, as-deposite, and post-annealed film at 450 ℃ for 30 min.



(b)

Fig.3 TEM images and EDS analysis of Au/PZT composite films. (a) as-deposited (b) post-annealed film at 450 ℃ for 30 min.

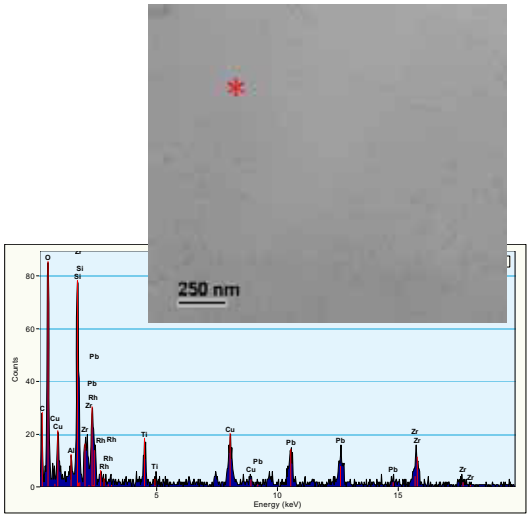
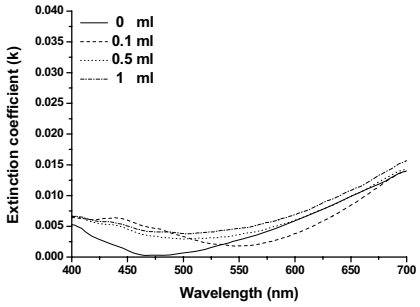
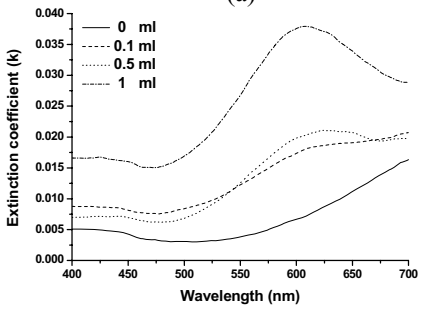


Fig. 3(a)



(a)



(b)

Fig.4 The extinction coefficient of composite films with various $HAuCl_4$ contents (a) as-deposited and (b) 450 ℃.