Ultra-thin, Smooth and Low loss Al-doped Ag Film and its Application in Plasmonic Interconnects

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Thin Ag films are widely used in plasmonic devices and meta-materials due to the low loss in the visible and NIR regions. However, it is very difficult to obtain a very thin and smooth Ag film due to its tendency to form 3D islands during the film growth. We have developed an effective approach to achieve ultra-thin and smooth Ag films by co-depositing a small amount of Al during the film deposition [1]. Al could suppress the Ag 3D growth mode and promote thin/smooth film formation [2]. Figure 1 shows the scanning electron microscope (SEM) images of a 9 nm Al-doped Ag film and 9 nm pure Ag film with dramatically different morphologies. The Al-doped Ag film optical properties are close to that of thick Ag, but with the advantage of being ultra-thin and smooth. Besides, the Al-doped Ag has significantly improved stability as compared with pure Ag [2].

As demonstration of the material, thin Al-doped Ag films are used to fabricate long range surface plasmon polariton (LRSPP) waveguides, whose device layout is plotted in figure 2a. The Al-doped Ag strip waveguide is patterned on a fused silica substrate and index matching oil is used to clad the sample for operation at 1.55 μm. The Al-doped Ag film is prepared by magnetron co-sputtering of Al and Ag. Then an annealing treatment is applied to further reduce the film loss. Photolithography is used to define the waveguides in the resist first and the pattern is transferred into the metal by Argon (Ar) ion etching (figure 2b). The device performance is characterized by a fiber end-coupling approach. Figure 2c shows a measured profile of an output plasmon mode from a 10 nm thick, 8.6 μm wide metal strip, which shows the excellent mode confinement at the metal/dielectric interface. The mode size along the vertical direction is fitted to be around 7 μm (figure 2d), with an estimated propagation length greater than 1 cm. The low loss characteristics make this an attractive solution for short distance plasmonic interconnects.

1. C. Zhang, D. Zhao, D. Gu, H. Kim, T. Ling, Y. K. Wu and L. Jay Guo, Adv. Mater. 26, 5696-5701 (2014)
2. D. Gu, C. Zhang, Y. K. Wu and L. Jay Guo, ACS Nano 8, 10343–10351(2014)

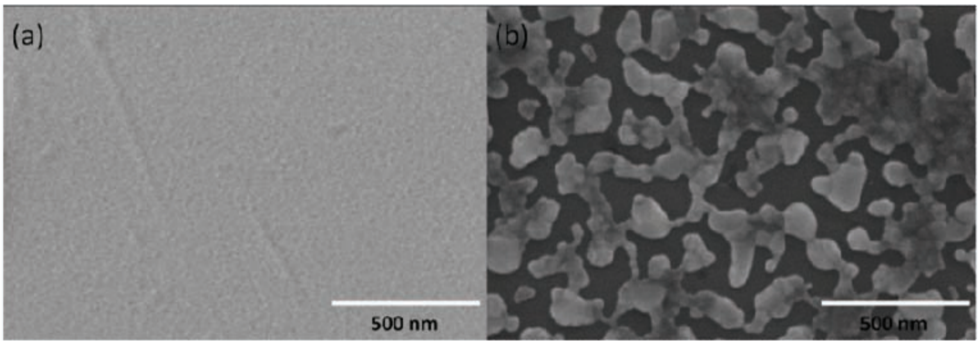

Figure 1: SEM images of (a) 9 nm Al-doped Ag and (b) pure Ag. 9 nm pure Ag film is discontinuous with large roughness of 10.8 nm as measured by AFM. In sharp contrast, the Al-doped Ag film shows smooth surface morphology with a 0.86 nm roughness.

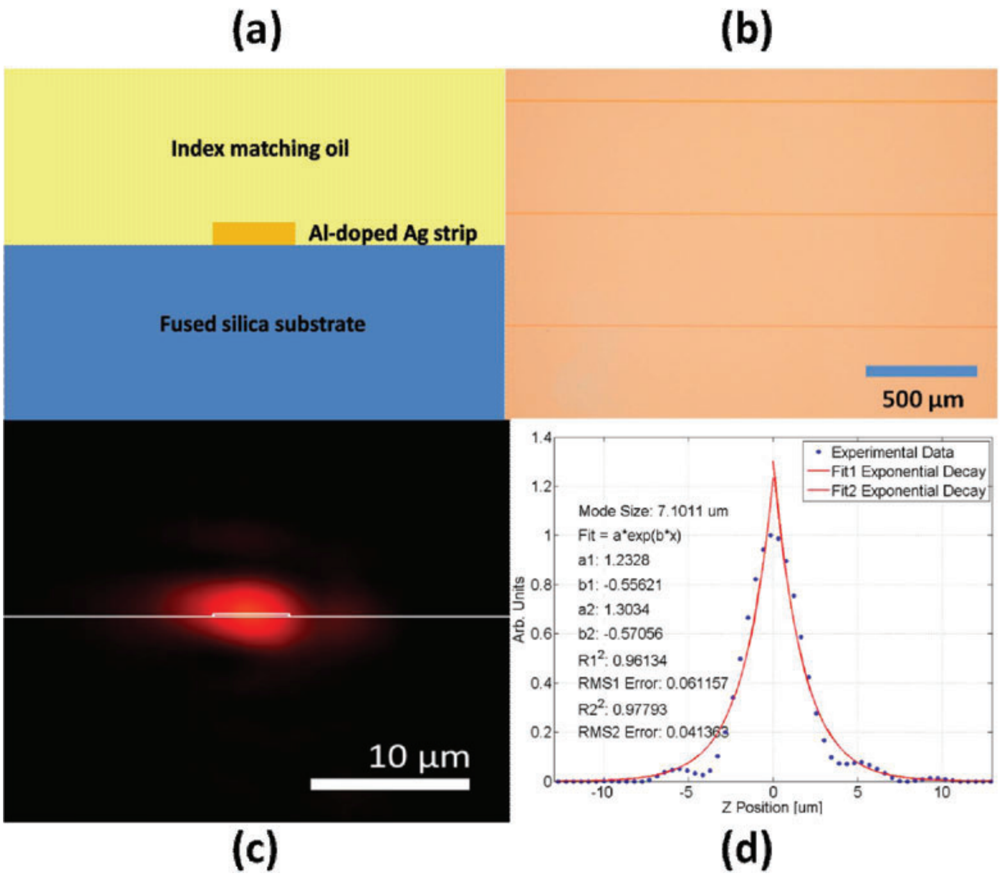

Figure 2: (a) Al-doped Ag LRSPP waveguide layout; (b) Optical microscope of fabricated waveguide; (c) Measured plasmon mode from the waveguide; (d) Fitting mode profile along the vertical direction.