Mid-infrared narrowband polarization management with Al doped ZnO-$ZnWO_4$ eutectic composites.

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Abstract. We report a narrowband polarization-dependent reflectivity from Al-doped ZnO/ZnWO4 self-assembled eutectic composites in the mid-infrared range. Our results show a reflectivity modulation from 0.05 to 0.75 for two orthogonal polarizations of the incident field with a 10% Al concentration. Acting as natural polarizing filters these eutectic composites could open the way to the future development of low-cost photonics components in the IR.

1 Introduction

Control and manipulation of mid-infrared (mid-IR) radiation by low cost and compact devices is a crucial task towards the development of a photonic platform for sensing of biomolecules and harmful/explosive substances as well as for thermal imaging and diagnostics. Recently proposed polarization sensitive applications in mid-IR relies on artificial metamaterial design and fabrication[1] or in the peculiar properties of van der Waals (vdW) materials exhibiting natural hyperbolicity[2]. Another interesting strategy might be provided by the exploitation of self-assembled ZnO/ZnWO4 eutectic composites [3].

We have recently shown that the optical linear properties of these kind of structures exhibits a natural narrowband strong polarization dependence of transmitted signal at λ=(397±3) nm [4]. The effect is due to the refractive index matching of the two constituents so that the composite medium appears homogenous to light propagating at a specific wavelength and polarization while it produces strong scattering losses in every other conditions. Here we show that a similar polarization sensitive behaviour can be obtained in reflection in the IR range (around 11.6 μm).

2 Discussion

We characterized the polarization dependent reflectance in the 2-16 micron range from Al doped eutectic ZnO/ZnWO4 with different concentration of Al. Reflection spectra have been performed with a FTIR microscope (Bruker Hyperion). Our results show that it is possible to obtain a polarization sensitive reflection band by taking advantage of the optical phonon properties of ZnWO4 and excitation of surface phonon polaritons at Al-ZnO/ZnWO4 interfaces. Indeed, the composites under investigation have a lamellar geometry as shown in the inset of Fig.1 (image taken with an optical microscope). The dark regions are composed of Al-ZnO while the brighter regions correspond to ZnWO4. We show polarization dependent reflection spectra for two samples having different concentration of Al. The high reflectivity band around 850 cm^{-1} (11.6 μm) clearly visible in Fig 1a-b is due to a phonon Reststrahlen band of the $ZnWO_4$ and it reaches its maximum value when the incident field is polarized along the direction of the lamellas. On the other hand, when the input field is polarized along the orthogonal direction with respect to the lamellas a strong reduction of the reflected signal is observed. This effect is related to the excitation of surface phonon polaritons at the Al-ZnO/ZnWO4 interfaces. We note that the polarization sensitivity of the reflected signal in higher for Al concentration of 10% (Fig. 1a) and it is very weak for Al concentration of 1% (Fig. 1b). Higher concentration of Al seems to enhance surface waves coupling at the interfaces, however from the preliminary optical images we also note that higher Al concentration leads to thicker and more defined lamellas. This behaviour is under further investigation. Another interesting effect related to the presence of Al is evidenced at shorter wavelengths. We also report a modulation of the reflection spectra in the 3-5 micron wavelength ranges as a function of Al concentration when the input field is polarized in the orthogonal direction with respect to the lamellas. Our results suggest that this effect could be interpreted with the plasma frequency shift of the Al-ZnO [5] for different concentrations of Al and/or with the optical thickness of the lamellas.

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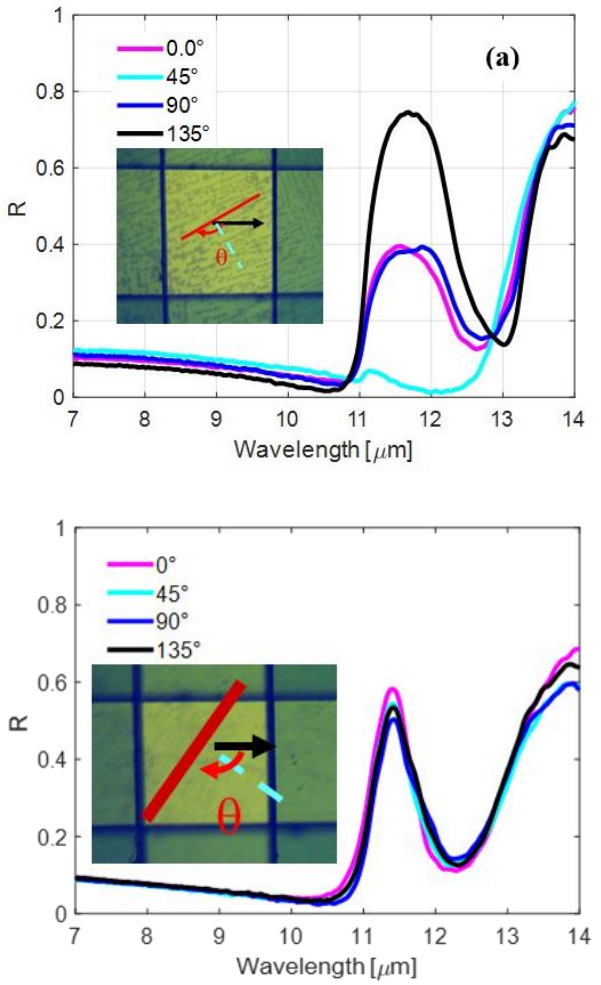

Fig. 1. (A) FTIR reflection spectra for the Al(0.1)-ZnO/ZnWO4 eutectic composite as a function of the input field polarization angle (45° corresponds to perpendicular to the lamellas, 135° is along the lamellas). **(B)** FTIR reflection spectra for the Al(0.01)-ZnO/ZnWO4 eutectic composite as a function of the input field polarization angle (30° corresponds to perpendicular to the lamellas, 120° is along the lamellas).

3 Conclusions

In conclusion the complex geometry of the eutectic composite reveals peculiar properties both in the visible and in the IR ranges, The investigated structures act as natural narrowband polarizing filters. The Al doping adds versatility opening the way to new interesting photonics applications in the IR. However the role of Al doping in these eutectic composites as well as its distribution is not clear and it will be the subject for future studies.

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