Plasmon Aided Bi_xVO_4-$Ti_{1-x}O_2$ Nanocomposite Series for Efficient Solar Water Splitting

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Abstract

The synthesis of Bi_xVO_4-$Ti_{1-x}O_2$ (x = 0.01, 0.05, 0.10 and 0.20) nanocomposite has been accomplished via two steps solvothermal method. The synthesized TiO_2, $BiVO_4$, and Bi_xVO_4-$Ti_{1-x}O_2$ composites have been characterized well by various techniques. In addition, silver (Ag) NPs deposition over the surface of $Bi_{0.10}VO_4$-$Ti_{0.90}O_2$ nanocomposite has been performed by chemical reduction process. The photoelectrochemical (PEC) measurements of all the synthesized materials were evaluated in terms of current density for water splitting under artificial 1 SUN visible light source using linear sweep voltammetry (LSV) and chronoamperometry. The comparative results indicate that Ag/$Bi_{0.10}VO_4$-$Ti_{0.90}O_2$ has highest water splitting ability due to its narrow bandgap, high current density and long term stability as compared to the other synthesized materials.

Experimental

(a) Synthesis of TiO_2

TBT + Ethanol

↓ HNO_3

Light yellow solution

↓ H_2O Stirred

Teflon Autoclave

↓

TiO_2 NPs

(b) Synthesis of Bi_xVO_4-$Ti_{1-x}O_2$

$Bi(NO_3)$ + V_2O_5 + Ethanol

↓ Ultrasonicated

Yellow ppt.

↓ Washed

Yellowish Product

↓ $(TiO_2)_x$ Ultrasonicated

Teflon Autoclave

↓ Washed Dried

Bi_xVO_4-$Ti_{1-x}O_2$

(c) Ag NPs Deposition

$Bi_{0.10}VO_4$-$Ti_{0.99}O_2$

↓ (i) $AgNO_3$ (ii) $NaBH_4$

Ag/$Bi_{0.10}VO_4$-$Ti_{0.99}O_2$

Product Labeling:

$Bi_{0.01}VO_4$-$Ti_{0.99}O_2$	(B1)
$Bi_{0.05}VO_4$-$Ti_{0.95}O_2$	(B5)
$Bi_{0.10}VO_4$-$Ti_{0.90}O_2$	(B10)
$Bi_{0.20}VO_4$-$Ti_{0.80}O_2$	(B20)
Ag/$Bi_{0.10}VO_4$-$Ti_{0.90}O_2$	(Ag/B10)

Bi_xVO_4-$Ti_{1-x}O_2$ Characterization

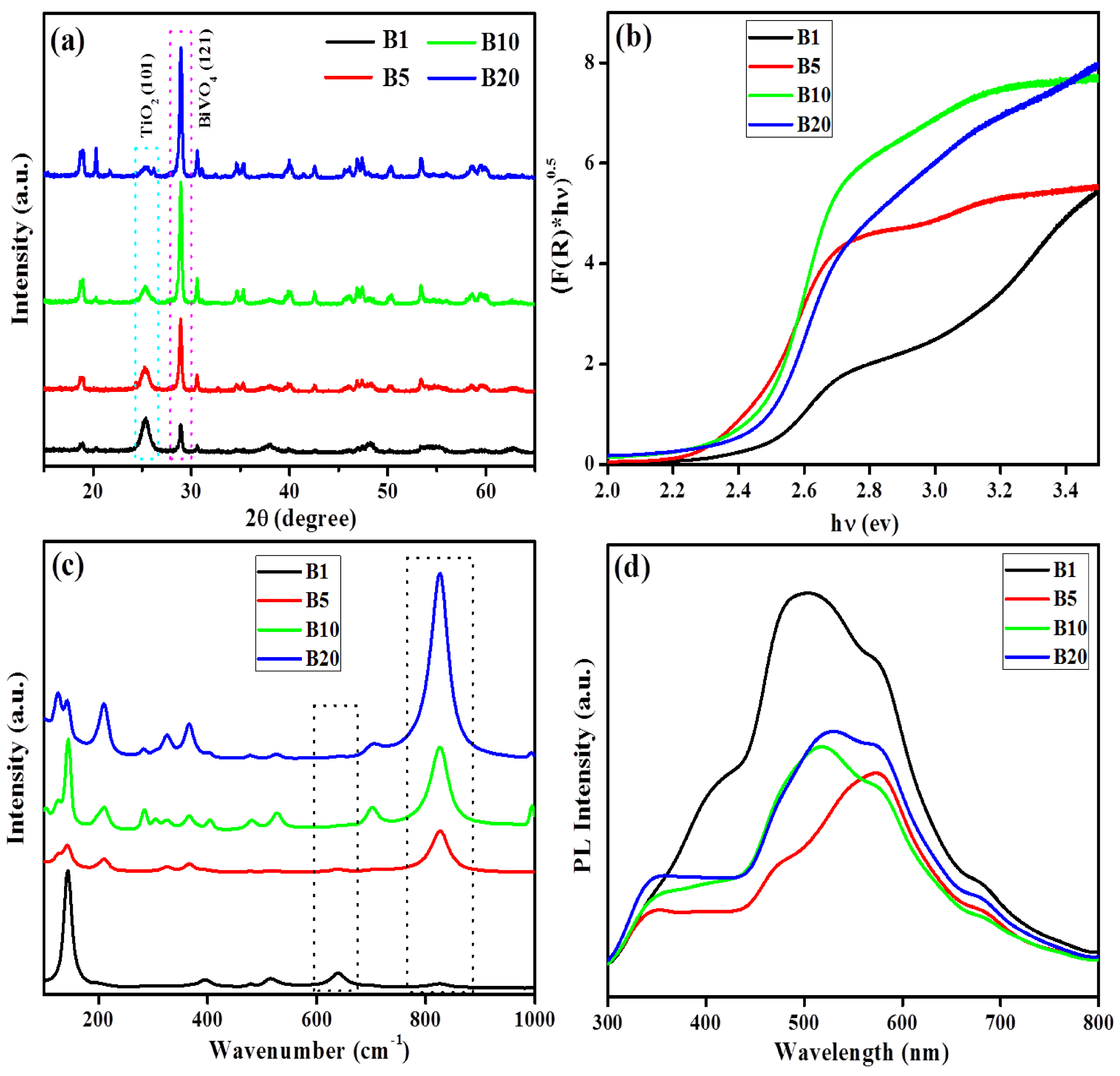

Figure 1: (a) XRD patterns, (b) bandgap calculation from Kubelka−Munk plots, (c) Raman and (d) PL spectra for B1, B5, B10 and B20 composites.

Material Characterization

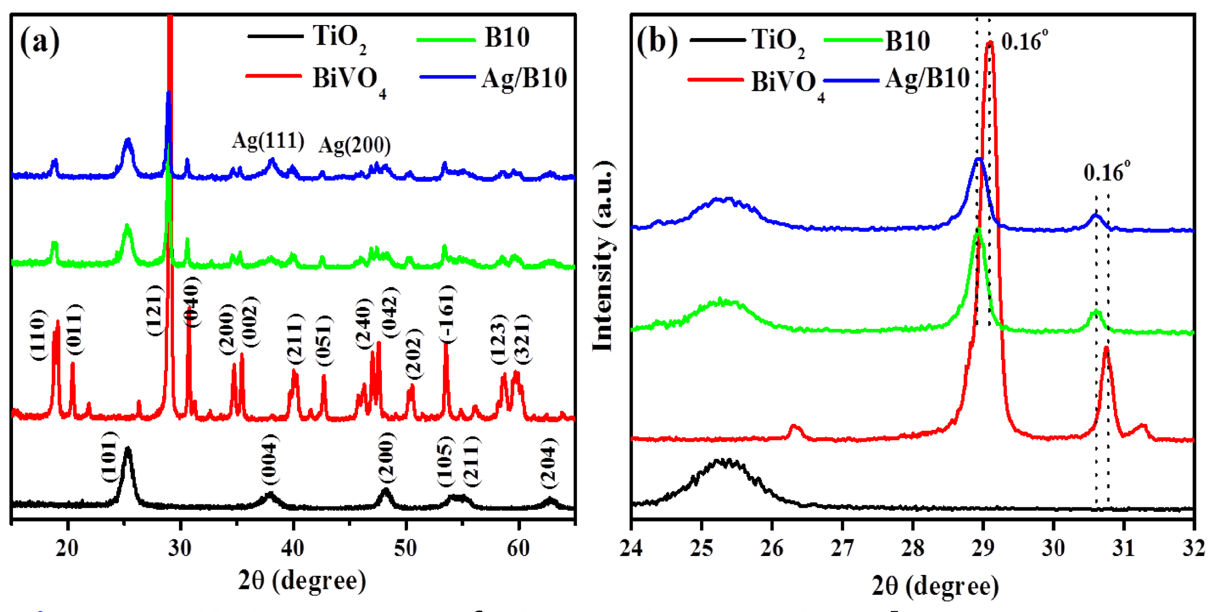

Figure 2: XRD patterns of TiO_2, $BiVO_4$, B10, and Ag/B10.

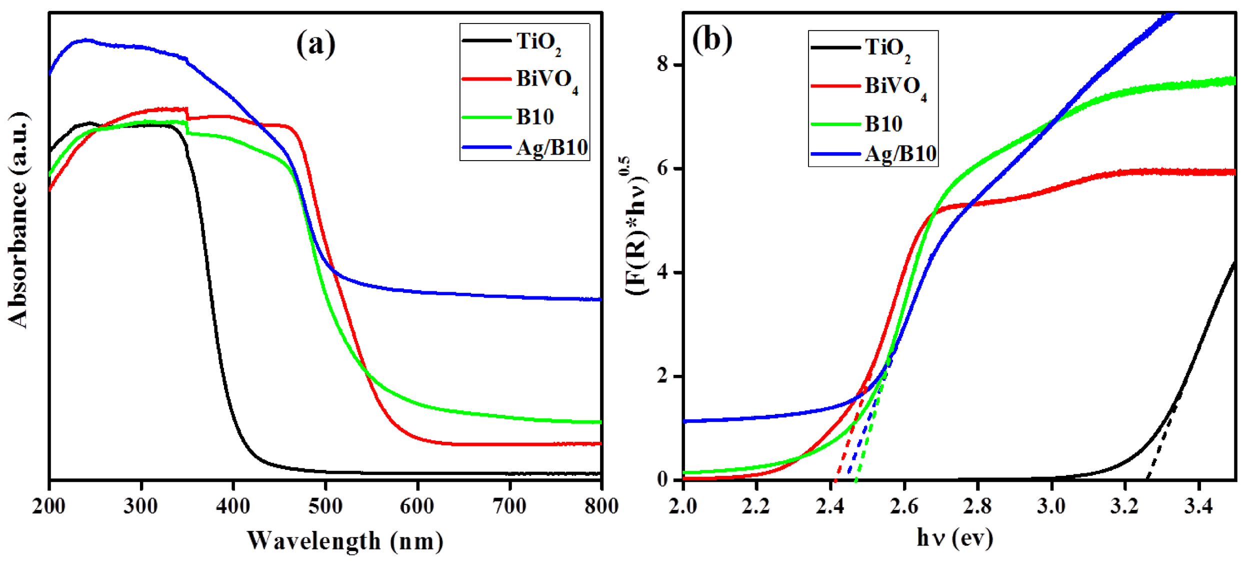

Figure 3: Bandgap calculation from (a) DRS absorption spectra and (b) Kubelka−Munk plots for semiconductor materials.

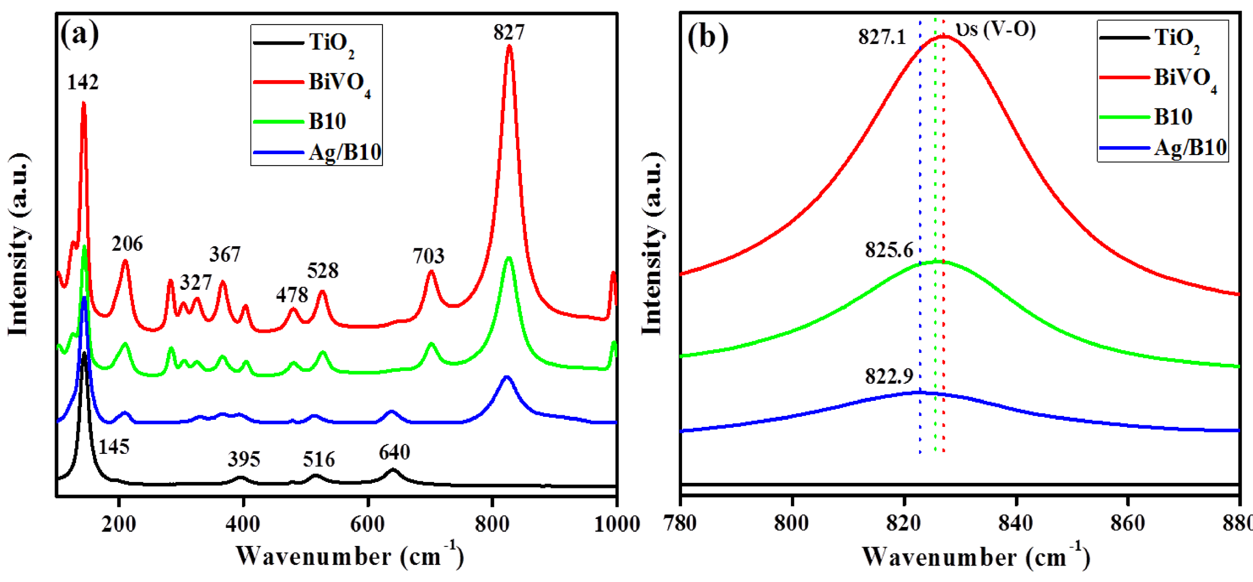

Figure 4: Raman spectra of TiO_2, $BiVO_4$, B10, and Ag/B10.

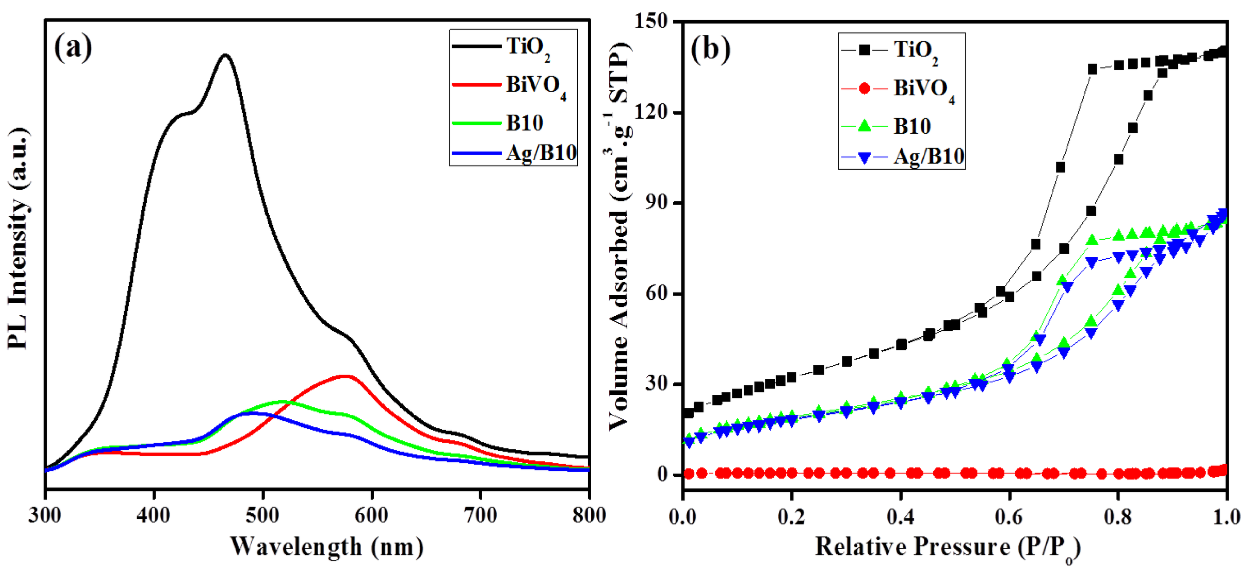

Figure 5: (a) PL spectra and (b) N_2 adsorption-desorption isotherms for TiO_2, $BiVO_4$, B10, and Ag/B10.

Photoelectrochemical Studies

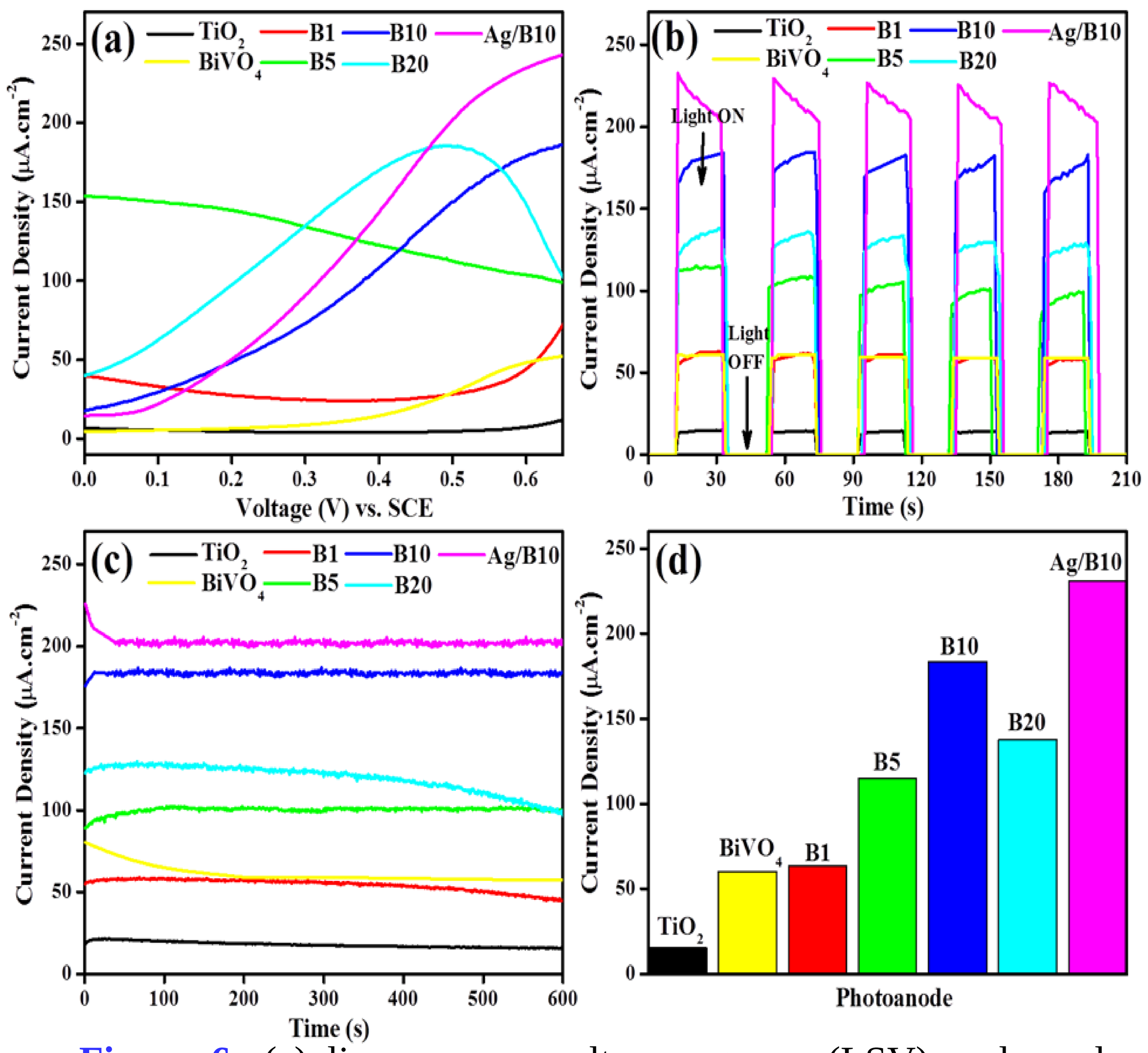

Figure 6: (a) linear-sweep voltammograms (LSV) under solar irradiations, (b) amperometric *I*−*t* curves with 20 s ON/OFF cycle (c) *I*−*t* stability curves at an applied potential of 0.6 V, (d) column chart representing comparison of current densities.

FESEM Images

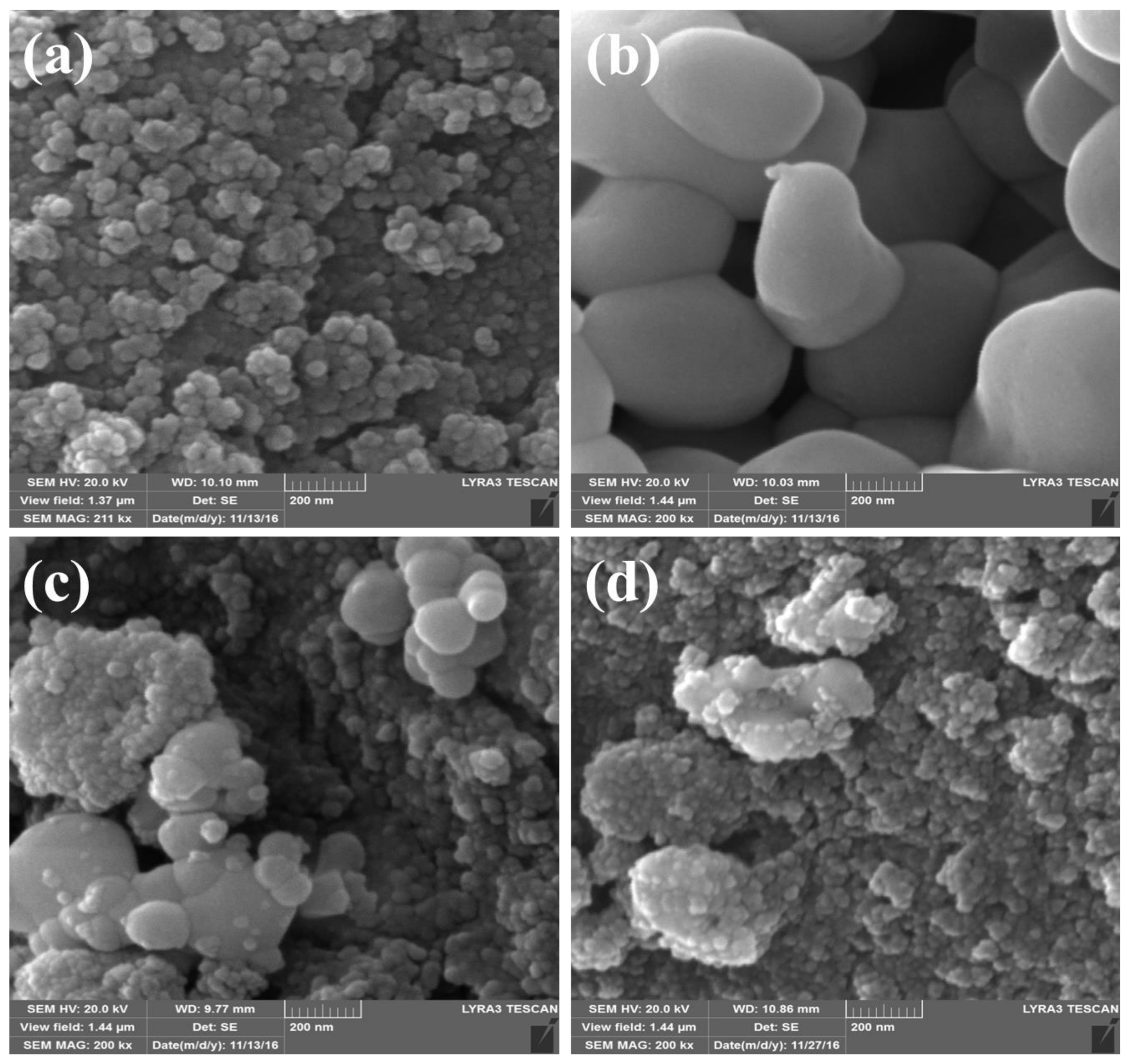

Figure 7: FESEM images of (a) TiO_2, (b) $BiVO_4$, (c) B10, and (d) Ag/B10.

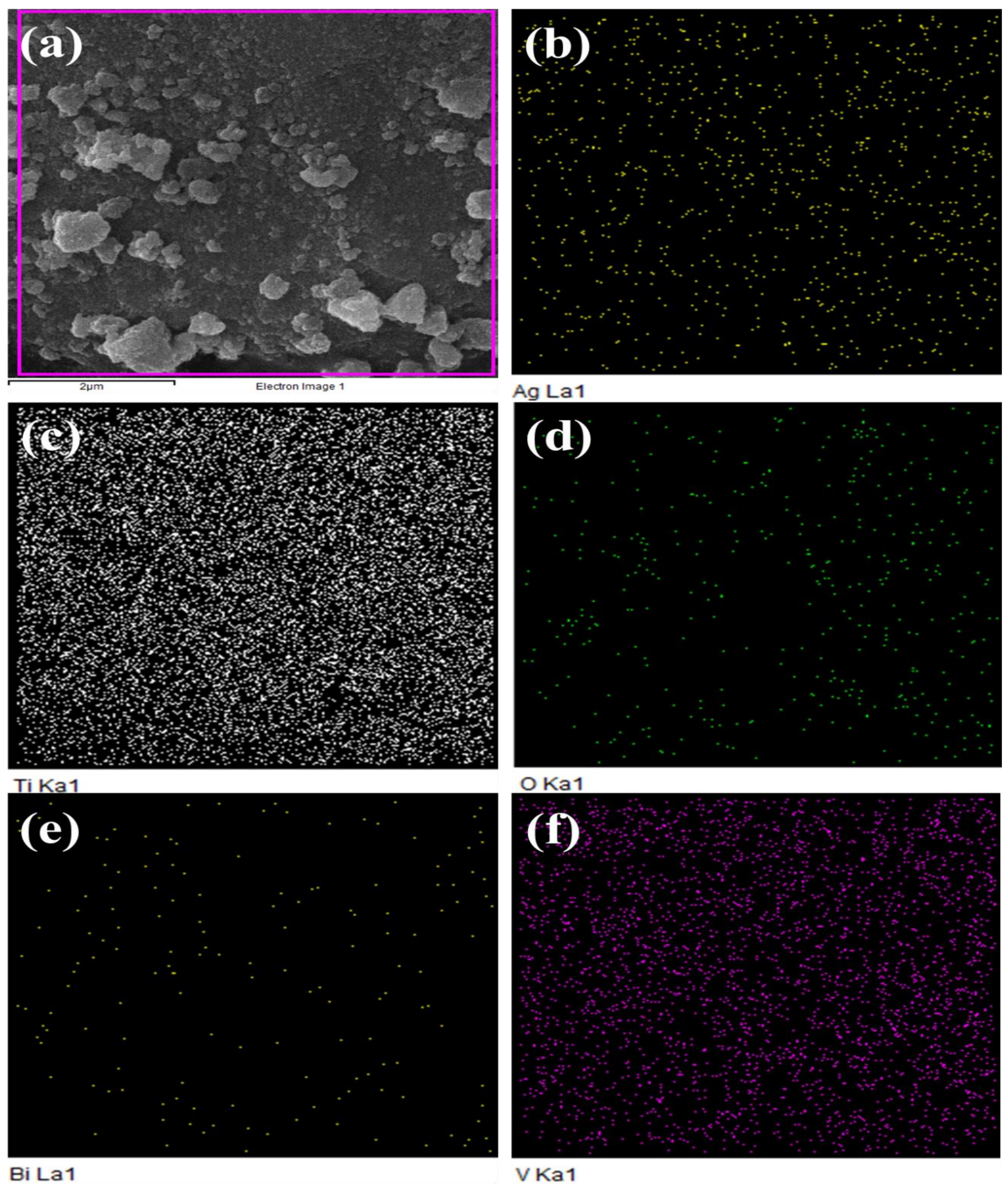

Figure 8: Elemental mapping of selected area for Ag/B10 composite.

Table 1: Parameters obtained from adsorption-desorption isotherms.

(BET Analysis) Catalyst	Surface Area, S_{BET} / (m^2g^{-1})	Pore Size, d_{BJH} / (nm)	Pore Volume, V_{Total} / (cm^3g^{-1})
TiO_2	115.83	7.47	0.226
$BiVO_4$	2.25	3.01	0.002
B10	69.02	7.44	0.128
Ag/B10	66.67	7.61	0.127

Conclusions

- Bi_xVO_4-$Ti_{1-x}O_2$ (x = 0.01, 0.05, 0.10 and 0.20) nanocomposite series has been successfully prepared via two steps solvothermal method.
- Composites showed improve water splitting ability and stability as compared to pure $BiVO_4$ and TiO_2 alone.
- The enhanced PEC water splitting ability is attributed to low band gap and high charge separation efficiency.
- High surface area of TiO_2 NPs also contributed to improve catalytic activity.
- The comparison indicates that $Bi_{0.10}VO_4$-$Ti_{0.90}O_2$ exhibits narrow bandgap, high current density and long term stability among the composite series.
- Ag NPs deposition on the surface of $Bi_{0.10}VO_4$-$Ti_{0.90}O_2$ nanocomposite further enhance water splitting ability via localized surface plasmon resonance (LSPR) effect.

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References

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2. Miller, E., *Photoelectrochemical water splitting.* Energy & Environmental Science, 2015. **8**(10): p. 2809-2810.

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