Abstract

In the present study, a modeled framework through the use of the commercial finite element software COMSOL Multiphysics for electromagnetic analysis. Practical considerations relevant to finite element modelling are highlighted for the simulation of Mach-Zehnder–electro-optic modulator was effectively established. In particular, multi-layered Mach-Zehnder electro-optic modulator was modeled using a number of nanomaterials layers (SiO_2, Si WG, and LN) and gold coplanar electrode, with respect to the Si WG layer width and thickness alteration. In this particular investigation, it was found that high Mach-Zehnder electro-optic modulator performance can be acquired using Si WG width of 2.5 μm and thicknesses of 0.43 and 0.44 μm alongside SiO_2 layer thickness of 0.5 μm. Furthermore, the experimental work was established based on the obtained dimensions; the experimental depositions of the device layers was accomplished using Pulse Laser Deposition technique on Si-substrate and LN-substrate. Additionally, a number of characterization techniques were considered to investigate the micro-structural and optical properties of the deposited (XRD, FESEM, AFM, UV-Vis, and PL).

Specifically, the structural analysis, in particular, the XRD results, revealed that the deposited films delivered higher crystallinity using Si-substrate as compared to that deposited on the LN-substrate. The deposited film on Si-substrate demonstrated a crystallite size of 5.6 nm, while on LN-substrate was 16.6 nm. Furthermore, the morphological analysis showed that a particle size of the deposited nanomaterials could be found in the range of 30-130 nm. In the meanwhile, the thickness of

the deposited SiO_2 layer and Si WG are ~ 400 and $\sim 430\, nm$, respectively. AFM measurements found that the values of roughness average, RMS roughness for Si-Sub. 8.52nm ,9.84nm that is small as compared to LN-Suba. In the optical analysis, it was noticed that the energy band -gap obtained was $3.32\ eV$ for both cases (Si-substrate and LN-substrate); while the refractive index obtained, which was used in the MZM device modeling, were 3.6101 and 3.611 for the deposited films on the Si-substrate and LN-substrate, respectively. Using the refractive index obtained using the UV-Vis technique as well as the deposited layer/s thickness from the FESEM technique, another modeling was performed concerning the fabricated MZM device. This, in turn, was compared with the pre-modeling presented before the experimental work. In detail, the fabricated MZM device delivered a considerable figure of merit ($V\pi.L$) values which dwell within the range of 2.12 to 2.25 and the fabricated MZM $3 - dBe$ electrical bandwidth values around 50GHz at a device length of 2 cm, which can be considered as an acceptable $V\pi.L$ value. Hereinafter, the utilization of Si-substrate indicated a better value of the $V\pi.L$ as compared to the LN substrate, with respect to the Si WG width (2.5 μm).