A novel graded index nanostructured TiO\textsubscript{2} compact layer (arc-TiO\textsubscript{2}) had been successfully deposited on Indium tin oxide (ITO) substrate by long-throw radiofrequency (RF) magnetron sputtering. The main aims of the arc-TiO\textsubscript{2} compact layer were to serve as an antireflective compact layer that could reduce reflection losses, improve the photo-response of dye molecules, and prevent electron recombination in a dye-sensitized solar cell (DSSC) application. The employment of the TiO\textsubscript{2} compact layer in the DSSC was carefully optimised in term of RF power and thickness of the arc-TiO\textsubscript{2} film. Meanwhile, the desired characteristics were systematically investigated by means of UV-absorption spectra, incident photon to current efficiency (IPCE), open-circuit voltage decay (OCVD) and electrochemical impedance spectroscopy (EIS). The average transmittance of the ITO/arc-TiO\textsubscript{2} conducting substrate in the region from 400 nm to 1000 nm was approximately 85%. Corresponding average reflectance difference that was recorded in comparison to the bare ITO was 2.5 \%. The red-shift behaviour of the transmittance peak was actually due to the formation of a new hybrid band energy structure of 3.1 eV resulting from the tin (Sn) diffusion in the ITO film that shifted the absorption edge of the substrate. This had favoured the absorption characteristics and photo-response of N719 dye. Hence, the consistency of peaks between the transmittance spectra of the substrate with the corresponding IPCE spectra of the DSSC cell was improved. Additionally, the arc-TiO\textsubscript{2} compact layer preserved the higher conductivity of the ITO films from oxygen-related defects during the annealing process. The resistivity of the ITO/arc-TiO\textsubscript{2} substrate was conserved at 2.05 \times 10^{-4} \text{ } \Omega \text{ } \text{cm} even at this high temperature. The preserved conductivity had consequently decreased the charge interfacial resistance (R\textsubscript{1}) in the EIS measurement and facilitated the charge transport from the nanocrystalline-TiO\textsubscript{2} to the ITO. In later investigations, it was revealed that the 100 nm thickness of arc-TiO\textsubscript{2} compact layer prepared using 100W RF power become the optimal deposition parameters for preparing the compact layer. At this stage, the reduced interfacial resistance R\textsubscript{1} observed under EIS measurement was 2.36 \text{ } \Omega and the highest IPCE peak of 58\% was achieved at 550 nm wavelengths. The higher IPCE had contributed to 8.93 mA/cm\textsuperscript{2} of the cell’s short-circuit photocurrent, J\textsubscript{sc} and 0.67 V to the associated open circuit voltage, Voc. The photo-generated electron lifetime, \tau of 1.1 orders of magnitude higher than bare ITO was achieved. As a result, the overall conversion efficiency of 3.45\% was recorded for the optimized DSSC device. This record was actually 50\% improved compared to that of bare ITO cell. Therefore, the combined effects (i.e., reduced reflection losses and interfacial resistance with better photo-response) owed to the arc-TiO\textsubscript{2} compact layer prepared at their optimal condition was found to be important as it had originated the remarkable improvement in this arc-TiO\textsubscript{2} based DSSC.