# 電荷二重層と酸化物中間層の複合効果による有機ショットキーダイオードの性能改善

# Improvement in the Performance of Organic Schottky Diodes through Combined Effect of Charge Double Layer and Oxide Interlayer

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**Introduction:** Solution processable organic semiconductors with good solution rheology led to their vast implementation as active components in organic electronic devices. Advent of organic CPs have made it possible to fabricate devices under ambient laboratory environment at low cost but due to undesired doping and trap sites should controlled amicably to have reproducible device performance. Although huge scientific efforts has been continued by numerous research groups to interpret and tackle these issues, still a significant advancement is needed. In this work, organic Schottky diodes (OSDs), which is an essential part of high frequency organic electronics, were fabricated with different interfacial structures and film morphology. Their electrical characteristics with emphasis on rectification ratio ($\eta$) were analyzed to investigate the combined effect of interfacial layer and charge double layer at the Schottky contact.

**Experimental:** The OSDs were fabricated in different device architectures as shown in the Figure 1(b,c). As active semiconducting element, regioregular poly (3-hexylthiophene) (P3HT) was spin coated (1.5% w/w in dehydrated chloroform) on glass substrate pre-patterned with bottom electrodes followed by annealing at 150°C for 20 min in Argon atmosphere. Finally, the top electrode was thermally evaporated. The bottom and top electrode were selected based on the required OSD architecture, where aluminum (Al) and gold (Au) make Schottky contact and Ohmic contacts, respectively, with P3HT. In the case of Al as top contact, thin aluminum oxide ($AlO_x$) interlayer was grown by depositing thin layer of Al (10 - 20 nm) on P3HT thin film followed by keeping the sample under ambient conditions. Finally, thick Al top electrode was deposited above it to complete the OSDs.

**Results and Discussion:** Performance of OSD depends on the interfacial band structure at the Schottky contact, therefore, low work function electrode material is recommended for high rectification ratio in the case of p-type CPs. However, the low work function of material leads to deterioration in device performance due to their relatively lower stability under ambient conditions. In this work, $AlO_x$ interlayer was grown to form large Schottky barrier since upon oxidation the work function of Al decreases. In the case of Al as bottom contact, the oxide layer is formed at the Schottky interface but the $\eta$ was found to be hampered. The reason might be the charge double layer, which is developed due to transfer of electron to the adsorbed oxygen at surface from the underlying Al. The effective field due to this layer led to enhancement in rectification ratio when, Al electrode was at top and vice versa is true for other case as schematically shown in the Figure 1(b). The average resultant $\eta$ obtained for the device with Al at top with 10 nm $AlO_x$ interlayer was $1.44 \times 10^6$ with 16.8% slandered deviation, which is 10 - 100 times large then other configurations. The effect of film crystallinity and morphology on $\eta$ was also studied by fabricating thin films of P3HT using drop casting also. For proper justification of obtained electrical result of the OSDs, the samples were subjected to other characterizations also, such as AFM, XPS, UPS and XRD measurements. Apart from this the current-voltage response of the OSDs were also fitted with the modeling equation, which was constructed based on the possible physical phenomena occurring in the device like thermionic emission, charge tunneling, space charge limit current, presence of trap states and Ohmic loss. Details about characterizations and analytical modeling will be discussed.

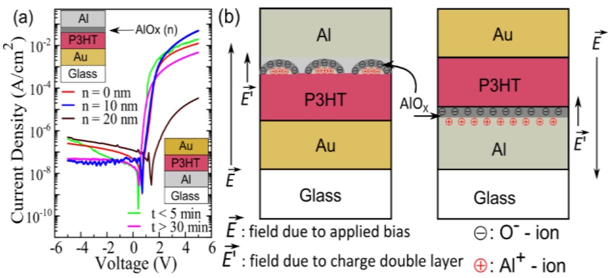


**Figure 1.** Electrical characteristics of the OSDs in the structure as shown in inset, (b) the schematic illustration regarding the effect of field due to charge double layer.