WS_2 quantum dot/Si heterojunction based self-biased photodetector with plasmon mediated suppressed dark current and fast photoresponse

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Van der Waals heterostructure based photodetectors built from transitional metal dichalcogenides on a conventional semiconductor are drawing much attention due to their superior spectral responsivity, high photocurrent to dark current ratio and ultrafast response time. Herein, we fabricate a heterojunction photodetector by combining a p-type Si substrate with n-type WS_2 quantum dots synthesized by liquid phase exfoliation. The WS_2 QD/Si heterojunction photodetector has a response time of ~55 µs and an I_{on}/I_{off} ratio of ~200. The fabricated photodetector can also operate at zero bias owing to the separation of photogenerated charge carriers by the built-in electric field. Next, we integrate plasmonic Au nanoparticles into the WS_2 QD/Si heterojunction, which greatly elevates the photodetector capabilities. The WS_2/Au/Si heterojunction device exhibits a very high I_{on}/I_{off} ratio ~10^5, which is 3 order of magnitude higher than that of bare WS_2 QD/Si photodetector. Additionally, the WS_2/Au/Si detector shows a faster response speed of ~4.4 µs (Figure 2). The peak responsivity and detectivity of the fabricated WS_2/Au/Si detector are estimated to be ~1.23 A/W and ~ 2.9×10^{11} Jones, respectively at an applied bias of −5 V. These results indicate that integrating plasmonic nanoparticles with the WS_2 QD/Si photodetector holds great potential for application in future high performance photodetectors.

Figures

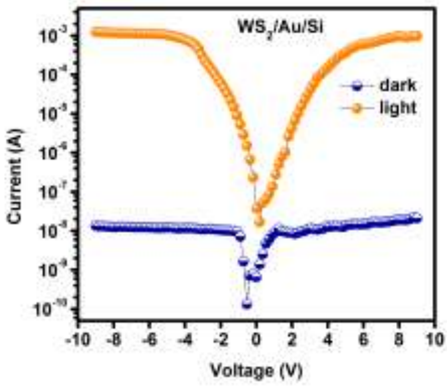

Figure 1: I–V characteristics of the photodetector in the dark and at illumination wavelength 405 nm (20 mW/cm^2) at room temperature under a wide range of bias voltages.

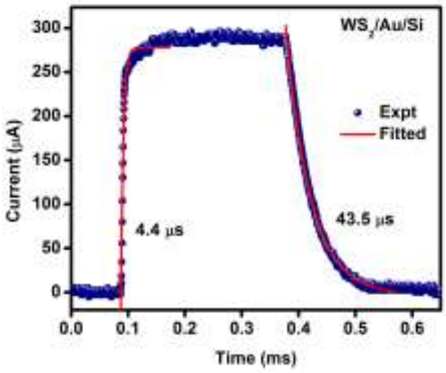

Figure 2: Rising and falling edges for the estimation of rise and fall times at 20 kHz.