Vapor-phase deposition of ultrathin polymer gate dielectrics for high-performance flexible field-effect transistors

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Insulators are an essential component enabling reliable operation of FETs, flash memories, and capacitors in modern electronic systems.[1] In this work, initiated chemical vapor deposition (iCVD), a dry process with mild process temperature, is applied as an alternative tool to develop ultrathin polymer gate insulators with excellent insulating property.[2] Ultrathin (< 50 nm) polymer insulators, poly(1,3,5-trimethyl-1,3,5-trivinyl cyclotrisiloxane) (pV3D3), poly(ethylene glycol dimethacrylate) (pEGDMA), poly(isobornyl acrylate) (pIBA), and poly(1*H*, 1*H*, 2*H*, 2*H*-perfluorodecyl acrylate) (pPFDA), were synthesized via iCVD process and exhibited low leakage current densities (J_i) of lower than 10^{-8} A/cm^2 and high breakdown field (E_{break}) over 4 MV/cm. Especially, pV3D3 exhibited excellent insulating properties and high resistance to a tensile strain of up to 4% with the thickness as low as 6 nm. Moreover, on the 15nm-thick pV3D3 dielectric layer, a simple oxygen plasma treatment could be applied to form a molecular thin SiO_x capping layer on the pV3D3 insulator. Ultrathin pV3D3 with SiO_x capping layer maintained its insulating property even after the thermal exposure in ambient air, confirming the improved thermal and environmental stability of ultrathin pV3D3. Thanks to the improved stability of pV3D3, additional silane-based self-assembled monolayer (SAM) treatment could also be utilized for the purpose of surface modification of the ultrathin pV3D3 dielectric layer. With the surface-modified pV3D3, low-voltage operating (< 5 V) pentacene OTFTs with improved device performance could be achieved. TFTs on flexible substrates were also demonstrated, which indicates the approach is suitable for developing flexible/soft electronic devices.

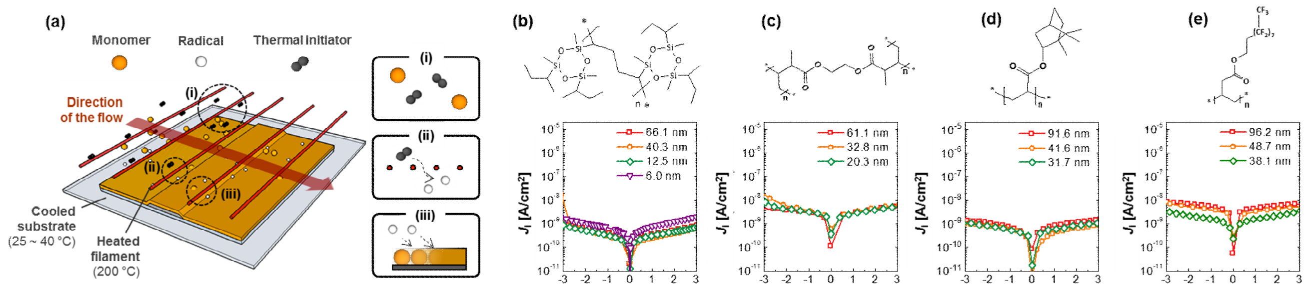

Fig. 1. **(a)** Schematic of the iCVD process mechanism: (i) vaporized monomers and initiators are introduced, (ii) initiators are thermally dissociated into radicals by contact with the heated filaments (~200 °C), and (iii) radicals are contact with adsorbed monomers on the surface, and they undergo free-radical polymerization. **(b-e)** Chemical structures and J_i-E_i characteristics of 4 iCVD polymers: pV3D3, pEGDMA, pIBA, and pPFDA, respectively.

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References

1. A. Facchetti, M.H. Yoon, and T.J. Marks, *Adv. Mater.* 17(14), 1705-1725 (2005).
2. H. Moon, H. Seong, W.C. Shin, W.-T. Park, M. Kim, S. Lee, J.H. Bong, Y.-Y. Noh, B.J. Cho, S. Yoo, and S.G. Im, *Nat. Mater.* Advance online publication (DOI:10.1038/nmat4237) (2015).