

Operational degradation of organic light-emitting diodes: Mechanism and identification of chemical products

Despite the importance of the operational lifetime of organic light-emitting diodes (OLEDs) in practical applications, little is known about the nature of chemical reactions associated with efficiency losses during operation. To gain an insight into a chemical mechanism of operational degradation, we studied operation-induced changes in chemical compositions of fluorescent and phosphorescent OLEDs utilizing carbazole derivatives in emissive layers. We detected substantial losses of the emissive components, including the carbazole-derived host 4,4'(-bis(N-carbazolyl)biphenyl (CBP) and, if present, phosphorescent dopant. Several different materials were found only in the degraded OLEDs, and some of them were isolated and identified by nuclear magnetic resonance and mass spectrometry. A similar set of products was found upon UV irradiation of CBP films. Structures of degradation products suggest that the key step in operational degradation of OLEDs is homolytic cleavage of weaker bonds, e.g., an exocyclic C-N bond in CBP, in the excited state, followed by radical addition reactions to yield stabilized pi radicals. Overall, OLED operation leads to the accumulation of the neutral radical species and their reduced or oxidized forms, acting as nonradiative recombination centers and luminescence quenchers.