Surface Plasmon Scattering Probability: A Factor Determining the Surface Plasmon-Enhanced Spectra of Organic Light Emitters

T. Yoneda, Y. Mizoguchi, T. Inui, K. Kasahara
Graduate School of Science and Engineering, Ritsumeikan University,
1-1-1, Noji-higashi, Kusatsu, Shiga 525-8577, Japan
ro0027kr@ed.ritsumei.ac.jp

N. Ikeda, Y. Sugimoto
Nanotechnology Innovation Center, National Institute for MaterialsScience (NIMS),
1-2-1 Sengen, Tsukuba, 305-0047, Japan

Extended Abstract

The improved efficiency of organic light-emitting diodes is crucial for use in display panels and lighting. Although the surface plasmon (SP) losses at the metallic cathode/organic interface limit the efficiency of organic light-emitting diodes, it has been demonstrated that SP energy could be extracted by submicrometre-scale roughness on the surface of a metal film. In one example, the maximum PL enhancement due to energy transfer from nonradiative decay process in an organic layer to SP creation on the surface of a metal and subsequent scattering was about 10 with Alq_3 on Ag, and the wavelength was similar to neither the plasma wavelength of Ag, nor the original PL peak of Alq_3. There, we found that the peak wavelengths in the enhancement spectra shifted towards longer wavelengths while the Alq_3 thickness increased. A comprehensive understanding of the mechanism is still lacking. SP-induced emission enhancements are affected by three processes: 1) SP generation efficiency, 2) the total scattering rate of the SP, and 3) the influence of the Förster energy-transfer mechanism and/or reabsorption after SP scattering, determining the light amplification spectra of the organic light emitters. We have already reported the results of the studies regarding 1) and 3) using low molecular weight organic materials (ex. Alq_3) and polymers (ex. MEH-PPV) (Kawasaki et al., 2013).

The second process, the total SP scattering rate, can be resolved into the SP scattering probability, and the propagation length defined as the distance over which the power of the SP drops to 1/e due to Ohmic loss. The latter propagation length can be easily estimated from an analysis formula. Thus, the aim of the present work is to estimate the SP scattering probability using a rigorous formula for the SP scattering from a one-dimensional surface defect (Sanchez-Gil et al., 1999) in order to investigate whether the experimental results can be interpreted in terms of the computed results. The Finite-Difference Time-Domain (FDTD) method, which turned out to have a limitation in obtaining accurate values, was also used for comparison. We assumed that the average height and pitch of the surface irregularity on Ag were 7 nm and 100 nm from the AFM measurements. It was found that the decreasing enhancement that occurred at the shorter wavelengths could be explained by multiplying the scattering probability and the wavelength-dependent propagation length of SP. When obtaining the scattering probability, the SP created from the energy exchange of the exciton in the organic layer was supposed to propagate as a wave packet extending a few wavelengths along the interface of the organic film and Ag. Thus, the frequency of the scattering grows by the number of defects existing over the extension of the wave packet. The dependence of the penetration depth on the wavelength could account for enhancement peak shifts toward long wavelengths appearing with an increasing thickness of the organic layer.

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