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Nanometal plasmon polaritons

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Abstract

A nanometal is a nanometric metallic structure. A plasmon is a collective excitation of an electron gas. A plasmon polariton is a plasmon coupled to an electromagnetic wave. Whereas plasmons in bulk metal do not couple to light fields, a thin metal film can sustain surface polaritons when excited by light. This can be achieved via an evanescent prism coupling, the help of surface corrugations to ensure momentum matching, etc. Such surface polaritons propagate as coherent electron oscillations parallel to the metal surface and decay exponentially perpendicular to it. Thus, the electromagnetic energy is confined to dimensions below the diffraction limit perpendicular to the metal surface. Corrugations can further act as light scattering centers for surface plasmons, allowing for the fabrication of interesting optical devices such as an all-optical transistor. This surface science report reviews the present literature on surface polaritons in nanostructures and waveguides. Models, computer simulations and experiments are reviewed and illustrated by simple comprehensive examples. Experimental and theoretical studies of short and long range sensing using plasmonic nanostructures are in particular considered. Some applications for nanometals are outlined. The interactions between metallic particles and films due to the interactions between several localized and delocalized surface plasmons are among the examples. Applications to fluorescence extraction in the interaction between near-field and matter are also included here. Nevertheless this report cannot be an exhaustive one. This would be an endless task. It leaves space for future Surface Science Reports issues by colleagues whose achievements do not appear here.

Keywords: Polariton; Plasmon; Nanometal; Transmission; Filter; Multiplexer; Fano resonance; Biosensor; Near-field; Fluorescence

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1. General introduction

Plasmons are collective excitations of an electron gas. Zenneck–Sommerfeld polaritons are electromagnetic waves coupled to plasmons [1,2].

Early publications on surface polaritons associated with a planar interface between two media were reviewed by Maradudin, Wallis and Dobrzyński [3,4]. Another recent review by Kushwaha [5] on plasmons and magnetoplasmons in semiconductor heterostructures may be of interest to some readers. The cases of cylindrical and spherical interfaces have been studied by Ruppin and Englman [6,7].

Whereas plasmons in bulk metal do not couple to light fields, a two-dimensional metal surface can sustain plasmons if excited by light either via evanescent prism coupling or the help of surface corrugations to ensure momentum matching (see Raether's monograph for more details [8]). Such surface plasmons propagate as coherent electron oscillations parallel to the metal surface and decay exponentially perpendicular to it. Thus, the electromagnetic energy is confined to dimensions below the diffraction limit perpendicular to the metal surface [9]. Corrugations can further act as light scattering centers for surface plasmons, allowing for the fabrication of interesting optical devices such as an all-optical Tominaga et al. transistor [10].

A further confinement of energy-guiding surface plasmon modes can be achieved using metal nano-wires instead of extended surfaces. In nano-wires, the confinement of the electrons in two dimensions leads to well-defined dipole surface plasmon resonances, if the lateral dimensions of the wire are much smaller than the wavelength of the light [11–13]. Plasmon circuits are plasmon conducting networks. Bozhevolnyi and Pudonin circuits made out of nanometric metallic clusters and wires [14–17] can also be tuned to work at visible light wavelength. Thus, the optical properties of metal nano-wires can be optimized for particular wavelengths of interest, and non-regular cross sections and coupling between closely spaced nano-wires allow a further tuning of the Kottmann and Martin optical response [18,19]. Indeed, the