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"ALD and related ultra-thin film processes foradvanced devices"

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Nickel-Copper Multilayer Metamaterials

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Plasmonic metamaterials are able to shape optical space in ways rarely or never found in nature. As such plasmonic metamaterials are used as superlenses, superabsorbers, refractometric sensors, invisibility shields, etc. [1]. Responsible for these unique properties are Surface Plasmon Polaritons (SPP), surface waves propagating along interfaces between materials with different signs of relative dielectric permittivity [2]. Most metals are good conductors and posses intrinsic free electron plasma which allows for negative relative permittivity. However, despite wide variety of such materials in nature desired plasmonic response is limited to very narrow spectral band in optical frequency range due to set plasma frequencies and high absorptive losses of metals. One of the means to overcome innate limitations imposed by material properties is to combine two or more materials into metamaterial composites [3].

Copper possesses plasmonic properties similar to that of most commonly used plasmonic materials such as gold and silver but has much lower cost. Unfortunately it prone to corrosion when exposed to environment and losses its plasmonic properties. By adding nickel we form a metamaterial composite with increased functionality due to interfaces between the two materials as well as prevent copper oxidation. Simplest way to achieve this is to form stratified metamaterial of alternating copper and nickel layers. To this purpose we used electrochemical process to deposit highly uniform nanocrystalline Ni and Cu layers on a cold-rolled copper substrate [4].

Electromagnetic properties of Ni-Cu metamaterials are obtained by the finite element method using realistic material parameters and rich modal behavior is observed. Furthermore because of the difference between Cu and Ni plasma frequencies metamaterial can switch between metal-dielectric and metal-metal character i.e. at higher frequencies nickel behaves as dielectric material while copper exhibits metallic properties. Additional functionality can be achieved by selectively etching one of the constituent materials forming a diffractive grating enabling coupling of propagating waves to SPPs when metamaterial is laterally illuminated. High material losses ensure almost complete absorption of incident light when coupling conditions are met enabling use of Ni-Cu metamaterials as low cost basis for highly specific applications such as refractometric biochemical sensors.

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