プラズマメタマテリアルとマイクロ波との様々な相互作用

Various types of interaction between plasma metamaterials and microwaves

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1. Introduction

A plasma metamaterial is a composite of plasma and solid metamaterials, exhibiting various extraordinary features in contrast to normal microwave media. It is also feasible to possess different properties from typical solid-state metamaterials like roles of a high-energy carrier [1] and an intensified nonlinear medium [1, 2]; recently, we reported details of plasma generation in a negative-permeability metamaterial space, in which we expect unlimited high-density values in plasma generation [3]. In this report, with a brief overview of plasma metamaterials, we demonstrate their structural flexibility that opens various types of interaction between plasma metamaterials and microwaves.

2. Methods

In a definition of metamaterials, the size of a meta-atom, the individual unit of a metamaterial, is less than about 1/5 of the wavelength of a given wave. There is a certain limitation in the upper side of this ratio arising from the first Brillouin zone, but no limit has been reported about its lower limit and its size balance between two paired elements (like for permittivity and permeability). We surveyed a number of reports about various metamaterials verified in experiments so far, and also investigated its lower limit experimentally and numerically [4].

3. Results

From the survey, we recognized the ratio ranging from 0.03-0.2, within one order. However, when we used bulk plasma in a plasma metamaterial, the unit size of the meta-atom (assuming that sheath thickness plays this role) was at least less than 0.1 mm for microwaves, the ratio was less than 10^{-3}. This value is in the range of the size of lump circuit elements, suggesting that this lower ratio will be unlimited [4]. Plasma metamaterials can perform such contribution for general metamaterial science.

References [1] O. Sakai *et al.*, Plasma Sources Sci. Technol. **25**, 055019 (2016). [2] A. Iwai *et al.*, Phys. Rev. E **92**, 033105 (2015). [3] A. Iwai *et al.*, Plasma Sources Sci. Technol. (in press). [4] O. Sakai *et al.*, Advances in Phys.: X **3**, 1433551 (2018).

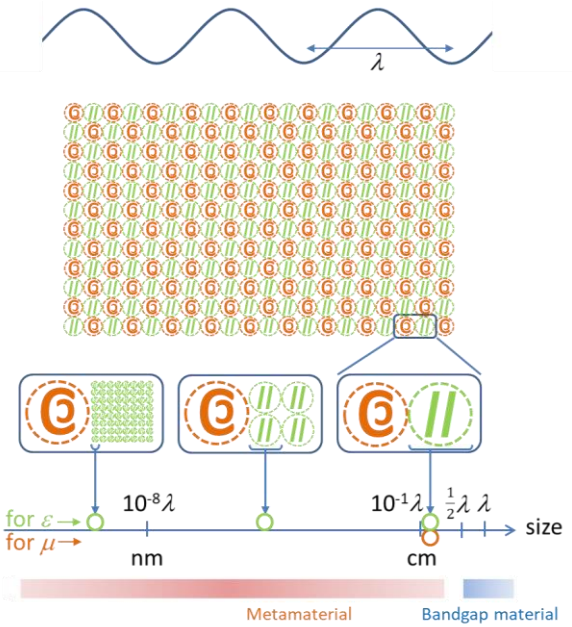

Fig. 1. Schematic view of metamaterials and waves with various ratios of meta-atom and wavelength, Ref. [4].