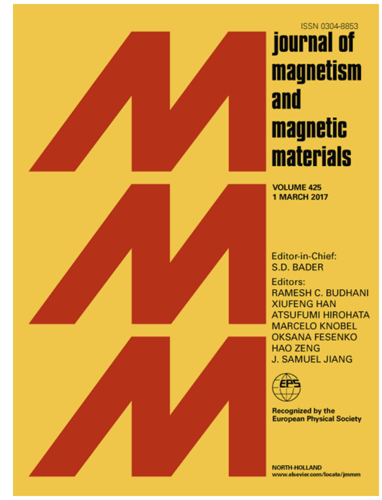

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Artificial Crystals with 3d Metal and Palladium Particles Subjected to High-Temperature Heat Treatment

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Abstract

High-temperature heat treatment has valuable impact on the structure and physical properties of artificial crystals with 3d metal and palladium particles. Artificial crystals are obtained by means of introduction of particles into the interspherical voids of opal matrices. The magnetic properties are studied at the temperatures ranging from 2 to 300 K and in fields up to 350 kOe. Microwave properties are investigated in the millimeter frequency range. The complex dielectric permittivity of several nanocomposites is measured. The influence of heat treatment up to 960 °C on the structure of artificial crystals is clarified.

Keywords: opal matrix, nanostructured materials, microwave properties, hysteresis loops, temperature dependencies of magnetization.

1. Introduction

In recent years the magnetic, magneto-optical, and microwave properties of nanocomposites and nano- and mesoporous media are the subject of intensive study [1]. Artificial crystals, nanocomposites based on the opal matrixes and inverse opal matrices are a class of complex and interesting objects.Three dimensional magneto-photonic crystals based on inverse opals impregnated by $CoFe_2O_4$ nanoparticles have been realized [2]. Transmittance optical measurements show a combination of photonic band gaps with the absorption of nanoparticles. Nonreciprocal magneto-optical effect has been demonstrated in the inverse opals through a Faraday effect hysteresis loop. Nanocomposites based on opal matrices with the particles of transition metals have peculiar magnetic and microwave properties. The magnetic and structural properties of a cobalt inverse opal-like crystal have been studied by a combination of complementary techniques ranging from polarized neutron scattering and superconducting quantum interference device magnetometry to X-ray diffraction [3]. The SQUID measurements demonstrate that the inverse opal-like structure film possesses easy-plane magnetization geometry. In the demagnetized state the magnetic system consists of randomly oriented magnetic domains. A complex magnetic structure appears upon application of the magnetic field. Investigations of microwave properties of Ni-based inverse ferromagnetic opal-like film with the [111] axis of the fcc structure along the normal direction to the film have been carried out in the 2–18 GHz frequency band [4]. Multiple spin wave resonances have been observed for the magnetic field applied along to the [111] axis of this artificial crystal. For the field applied in the film plane, a broad band of microwave absorption is observed. The evolution of the magnetic structure for an inverse opal-like structure with Co under an applied magnetic field has been studied by small-angle neutron scattering [5]. Applying the "ice-rule" concept to the structure, the local magnetization of this ferromagnetic three-dimensional lattice has been described. Both experimental and numerical studies of the magneto-optical properties of nickel infiltrated opals have been performed in paper [6]. The coupling of light to surface plasmon modes of Ni, and a clear dependence of the magneto-optical response as a function of the structural parameters of the template has been observed. A new class of bifunctional catalysts with a metal and silica yolk–shell nanostructure has been discussed in the review [7].

The magnetic properties of nanocomposites based on opals with the particles of ferrite spinels have been considered in [8]. It is shown that at low temperatures the coercivity and the saturation magnetization considerably increase. Magnetic antiresonance in the nanocomposite based on opal matrix with the particles of a nickel-zinc ferrite has been discovered in [9]. Moreover, in this work the magnetic resonance in such nanocomposite has been studied by using the transmission wave technique. The properties of opals with the cobalt metallic particles have been studied in [10]. It is shown that in a weak magnetic field the refractive index introduced on micro-scale is positive but less than 1. The comparison of magnetic and microwave properties of opal nanocomposites with the particles of ferromagnetic Co and antiferromagnetic CoO has been carried out in [11].

Nanoheterostructures and nanocomposites containing metallic palladium attract essential interest due to the presence of spin-dependent phenomena because of the long spin diffusion length in palladium. Creation of submicron grain structure can influence the electronic structure of palladium in such a manner that it increases its magnetic susceptibility. A model in which a local spin on the iron atom magnetizes the surrounding matrix is applied to explanation of the