Electromagnetic metamaterials – availability and spectral coverage of a new class of micro/nanofabricated composite materials

H.O. Moser, B.D.F. Casse, M. Bahou, P.D. Gu, L.K. Jian, J.W. Lee

Singapore Synchrotron Light Source (SSLS), National University of Singapore (NUS), Singapore

Introduction

Exhibiting simultaneously negative dielectric permittivity and magnetic permeability, electromagnetic metamaterials (EM^3) were first discussed theoretically by Veselago [1]. Not occurring in nature, such EM^3 possess a wealth of unusual features that may lead to radically new applications. Pendry et al. [2] proposed a geometric structure of a composite material that would exhibit EM^3 features. Based on nested split metal rings, his proposal was immediately used to demonstrate the transmission and negative refractive index properties in the GHz range [3]. Alternative structures were proposed [4, 5]. More recently, micro/nanofabrication has been exploited to push the useful resonance frequency by more than 4 orders of magnitude into the THz range, thus reaching already near infrared telecommunications frequencies around 193 THz [6-9].

Methods and Materials

SSLS is using its LiMiNT facility (Lithography for Micro/Nanotechnology) to produce the EM^3. LiMiNT is a one-stop shop comprising the full LIGA process cycle for micro/ nanomanufacturing in a clean room class 1000. The larger structures were patterned by means of a Heidelberg DWL66 laser writer, the smaller ones by means of an FEI Sirion SEM equipped with the Nabity Nanopattern Generator. X-ray lithography can be employed for batch processing of larger quantities of EM^3 on 4’’ wafer format. The resonance frequency at which the composite materials show EM^3 behaviour is determined by means of IR Fourier transform spectroscopy using the Bruker IFS 66v/S at SSLS’ ISMI beamline.

Results

SSLS has produced and characterised micro/nanofabricated EM^3 with resonance frequencies from about 1 to 187.5 THz. Present development at SSLS aims to reach even higher resonance frequencies by reducing the geometric dimensions of the structures further, to improve isotropy of the materials by means of tilted X-ray exposure, and to produce copious amounts of high-quality samples by X-ray lithography and, later on, hot

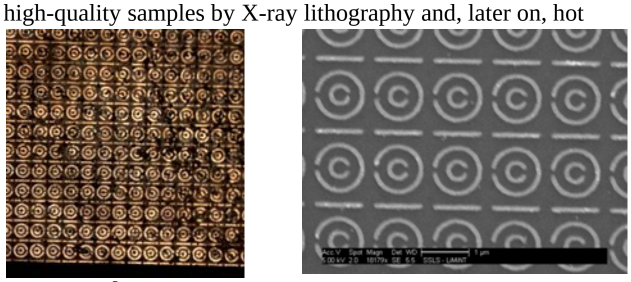

Fig. 1: EM^3 samples made of Ni in AZP 4620 matrix at 1.5 THz with an outer ring diameter of about 80 μm (left) and Au on glass/ITO with less than 1 μm outer diameter at 187.5 THz (scale bar 1 μm, right).

embossing. Fig. 1 shows 1.5 THz and 187.5 THz structures. Fig. 2 shows the excellent agreement of measured resonance frequencies with the ones predicted from Pendry’s formula [2].

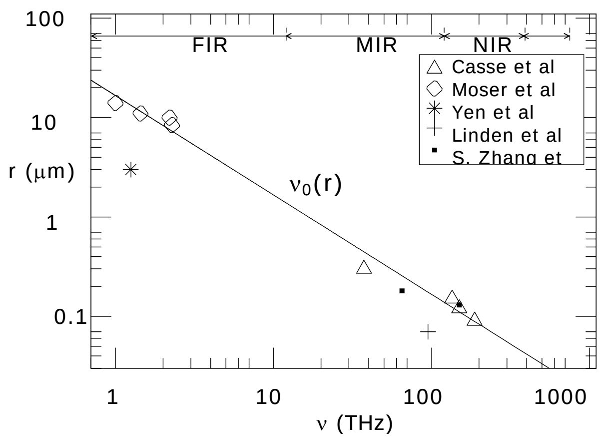

Fig. 2: Inner radius of the inner split ring versus resonance frequency. SSLS’ results given as ◊ and △.

Discussion

Split ring based EM^3 samples can be fabricated for any frequency in the range up to about 190 THz. Ongoing work is expected to extend this range even further.

Acknowledgments

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