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EXPERIMENTAL AND NUMERICAL INVESTIGATION OF MICROSTRIP AND DIELECTRIC RESONATOR ANTENNAS (DRA)

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14. ABSTRACT

n this work the magnetic and dielectric properties of ceramic-ceramic and ceramic-polymer composites with BiNbO4, SrBi2Nb2O9 (SBN), BaBi4Ti4O15 (BBT), Na2Nb4O11(NNO), Sr2CoNbO6 (SCN) and ferrites BaFe12O19 and Y3Fe5O12 (YIG) was studied for RF and dielectric resonator antenna applications. New configurations of magneto-dielectric composites and blends structures for high frequency applications was done. This group of dielectric and magnetic phases was studied in the RF and microwave region. New configurations of microstrip antennas based on those new materials were fabricated and tested

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Experimental and Numerical Investigation of Microstrip and Dielectric Resonator Antennas (DRA)",

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The main characteristics of ceramic materials are good mechanical resistance, thermal resistance and chemical stability. Because of these characteristics, they are attractive in a wide range of industries that can apply them in the manufacture of new products and/or insert them in industrial processes. The development of new materials that can be applied in the telecommunications, aerospace, military and medical industries has grown greatly in recent years. This growth has happened due to the study of advanced ceramic materials in conjunction with the study of families of structures, such as perovskite, rutile, spinels and others, that have important electrical and dielectric properties in the radio-frequency and microwave ranges.

In this work the magnetic and dielectric properties of ceramic-ceramic and ceramic-polymer composites with $BiNbO_4$, $SrBi_2Nb_2O_9$ (SBN), $BaBi_4Ti_4O_{15}$ (BBT), $Na_2Nb_4O_{11}$(NNO), Sr_2CoNbO_6 (SCN) and ferrites $BaFe_{12}O_{19}$ and $Y_3Fe_5O_{12}$ (YIG) was studied for RF and dielectric resonator antenna applications. New configurations of magneto-dielectric composites and blends structures for high frequency applications was done. Magnetic Yttrium Iron Garnet (YIG) and (SBN) powders were used to enhance the permittivity and permeability of the composites. This group of dielectric and magnetic phases was studied in the RF and microwave region. New configurations of microstrip antennas based on those new materials were fabricated and tested.

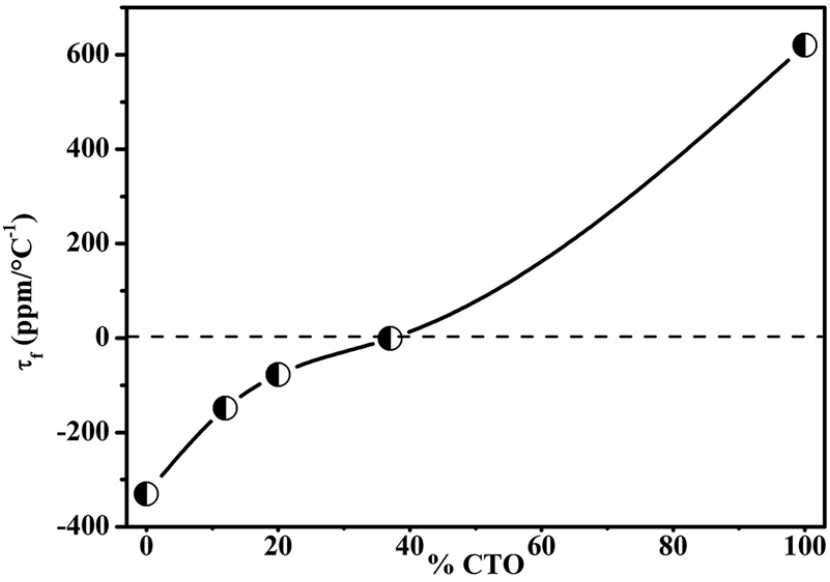
The microstructure, high frequency dielectric and magnetic properties of individual layers and 2-2 composites was investigated.

In this work, the properties of BCNO (Ba_2CoNbO_6) and CTO ($CaTiO_3$) were combined. The combination of BCNO and CTO can exhibit thermal stability (τf) close to zero since the materials have opposite signs for τf. For this reason, cylindrical resonators were prepared to study the properties of the composites in the radio and microwave frequency ranges at room temperature.

X-ray diffraction (XRD) was used to analyse the crystallographic phases, while dielectric and electric properties and thermal stability of the mixture of BCNO and CTO were analysed by complex impedance spectroscopy (CIS), the Hakki-Coleman method and the Silva-Fernandes-Sombra method (SFS). The composites were constructed for evaluation as Dielectric Resonator Antena (DRA) and simulated using HFSS® software (high-frequency structural simulator) and the parameters analysed were the coefficient of reflection (S11), gain, Smith chart and radiation pattern.

The dielectric properties of ceramic cylinders in the microwave range were measured by the Hakki-Coleman technique. All samples presented radius/height ratios close to one, which is required by the technique. The compounds did not show the expected increase in the dielectric permittivity and dielectric loss with the increase of the CTO concentration. This can be explained by the sintering temperature, which in the literature can be higher than 1200 °C , chosen for the material. The temperature coefficient of the resonant frequency was measured in all samples by the SFS method.

The measurements of τf for BCNO showed that the negative values become positive with the addition of CTO, thus improving the thermal stability of the dielectric properties of the studied ceramic, as seen in Figure below. The improvement in the thermal stability with CTO addition occurred because CTO (τf=625 ppm.°C−1) presents opposite τf values compared to BCNO and, in the sample with 37%wt of CTO, it presented better thermo-stability, from this CTO concentration the τf values increases for τf positive values due to the CTO properties (figure below)..



BCNO was tested as a DRA. Figure below , shows the experimental setup for the antenna tests, where A is the radius and L is the height of the DRA.
The antenna feed is lateral, considering that the dominant mode is the HE11δ. Eq. (2) shows the frequency of the fundamental mode.
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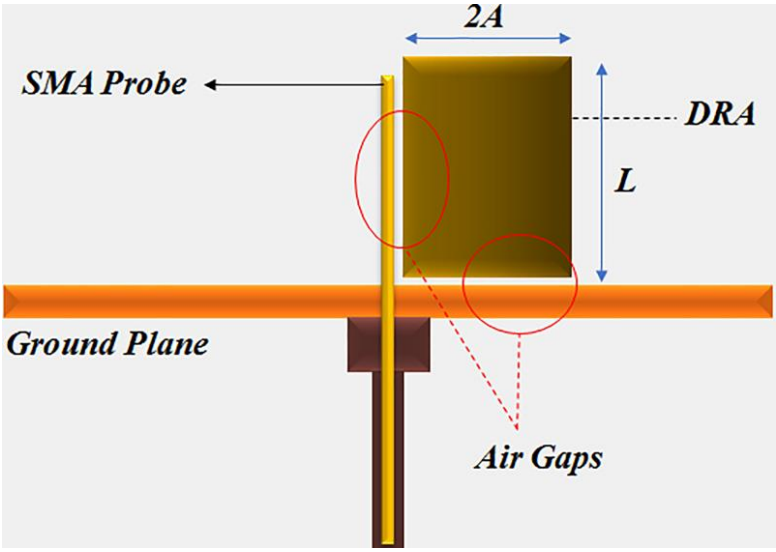


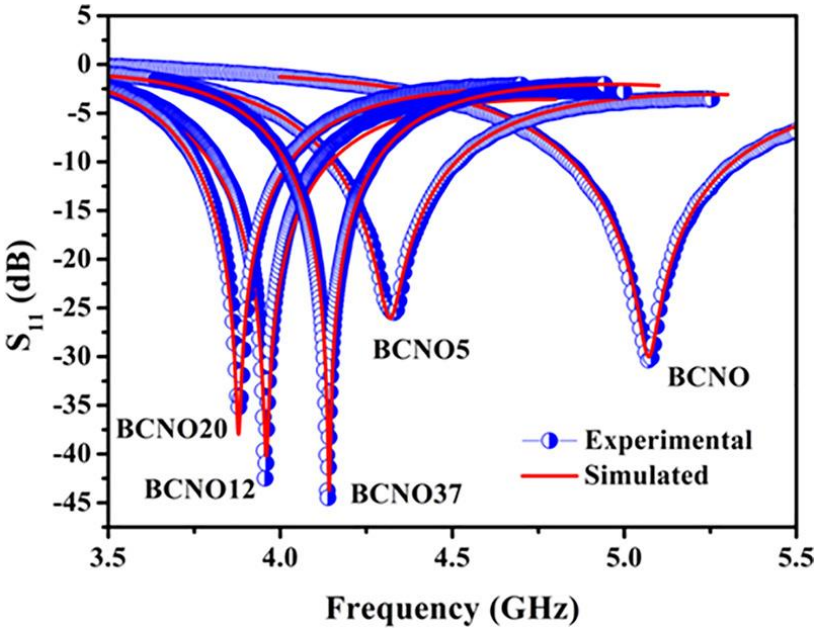
The antenna feed is lateral, considering that the dominant mode is the

HE11δ. Eq. (2) shows the frequency of the fundamental mode.

$$f_{HE11\delta} = \frac{2.735c\varepsilon_r^{-0.436}}{2\pi A}\left[0.543 + 0.589\frac{A}{2L} - 0.050\left(\frac{A}{2L}\right)^2\right]$$

$$Q_{HE11\delta} = 0.013\varepsilon_r^{1.202}\left(2.135\left(\frac{A}{2L}\right) + 228.043\left(\frac{A}{2L}\right)e^{-2.046\left(\frac{A}{2L}\right)0.111\left(\frac{A}{2L}^2\right)}\right)$$

It can be seen that BCNO functions as a DRA as long as the reflection coefficient (S11) is below -10 dB, showing that there is an acceptable minimum reflection. Figure below shows that all samples function as antenna.

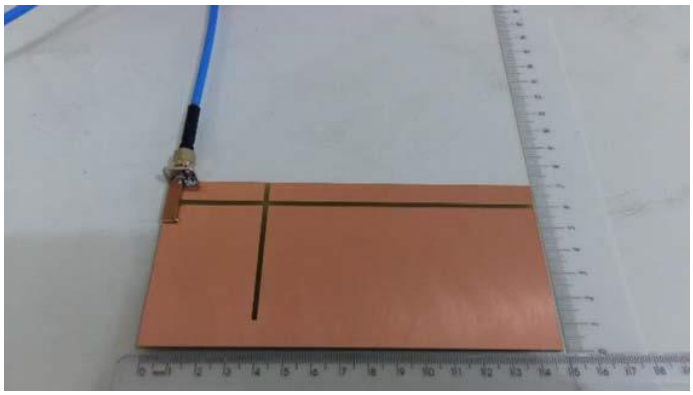


We noticed that there is a narrowing of the DRA's bandwidth of with the addition of CTO, which can be explained by Eq. (3), where the quality factor is a function of the material geometry and the electric constant.

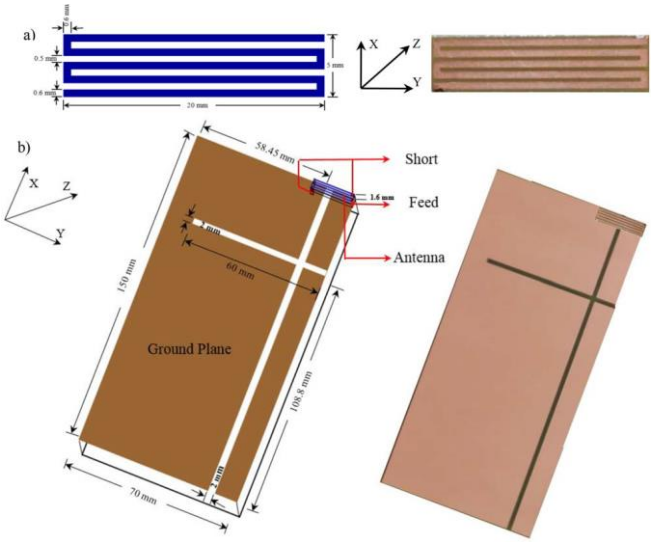
A new planar triple band microstrip-fed Planar Inverted- F Antenna (PIFA) for the use in GSM835 band (698–989 MHz), DCS1940 band (1824–2033 MHz) and Wi-Fi2340 band (2302–2548 MHz) was developed .. A numerical study based on the parameters like ground plane length, height of radiating plate,

feeding point position, shorting plate width, and position, was done to obtain an optimized antenna. The simulation allowed the characterization of the designed antenna as a function of different antenna parameters like S11, resonant frequency, bandwidth, gain, radiation pattern, and electric and magnetic fields distribution. A prototype was fabricated and the agreement with the simulations study was very good. The measured bandwidth of 34.73%, 48.47%, and 38.21% were obtained, respectively. The gain of 4.02 dBi, 2.47 dBi, and 4.93 dBi was also obtained for each band, respectively. The antenna also presents high efficiency of 53.19%, 49.07%, and 62.21%, respectively. The reported results show that this PIFA is suitable for mobile-communication applications.

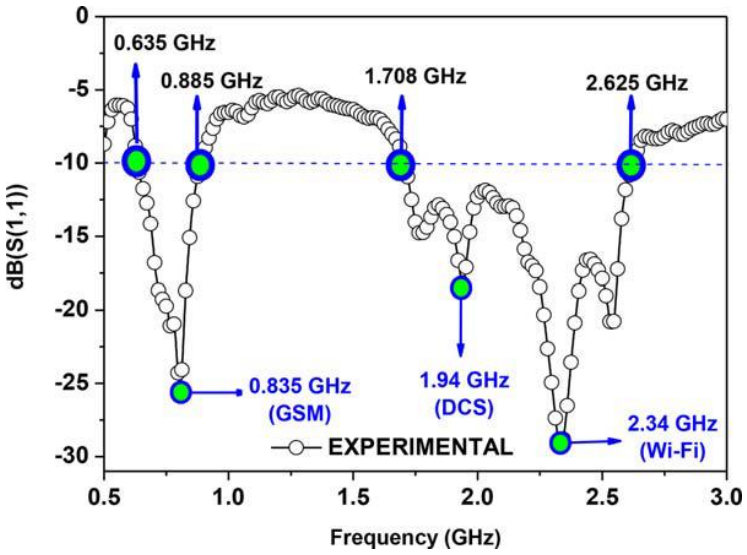
The PIFA380LDE prototype is shown in Figure below.



The antenna and the ground plane are all made of copper plate of thickness 0.2 mm with dimensions 20 X 5 mm2 and 150 X 70 mm2, respectively. Both are attached in FR4 epoxy (ε=4.4) plates of 1.6 mm thickness and with the same area of the antenna and ground plane. The design procedure of the PIFA is straightforward as shown in Figure below, serpentine format has overall length of 102.4 mm and a width of 0.6 mm. The ground plane was made with two crossed slits and to obtain a better bandwidth at low frequency, short circuits have been used between the antenna and the ground plane, according to the configuration shown in Figure (b) below.



In Figure below, we can see that the antenna prototype operates in three frequency bands in -10 dB, so that the DCS and Wi-Fi bands have a continuous band that covers the 1.708 GHz to 2.625 GHz band for devices offering a bandwidth 900 MHz. In this frequency range one has gain between 2.47 dBi to 4.9 dBi, and the antenna radiation efficiency between 49% and 60% for the prototype.



In this work, we have developed a multiband antenna for use in mobile devices, operating in GSM range with excellent experimental

bandwidth of 291 MHz at -10 dB and continuous band in the DCS and Wi-Fi bands, 1.708 to 2.625 GHz, with bandwidth higher than 917.96 MHz (in 210 dB). These excellent bandwidths were obtained with a miniaturized antenna (20 X 4 mm2) and a ground plane (150 X 70 mm2). These results were obtained due to the excitation of the ground plane, the slots held and the short between the ground plane and the antenna.

In conclusion a new group of materials were studied and potential applications in the RF and microwave area was demonstrated. New antenna devices based on those materials were tested and showed good performances in a wide frequency range.

Archival publications (published) during reporting period:

Supervision of PhD Thesis

1- STUDY OF DIELETRIC ANTENNAS BASED ON THE MATRIX OF COMPOUND (BiNbO4) x- (CaTiO3) 1-x FOR COMMUNICATIONS APPLICATIONS,
ANTONIO JEFFERSON MANGUEIRA SALES, Universidade Federal do Ceará, Programa de Pós-Graduação em Engenharia de Teleinformática (junho, 2016)

2- STUDY OF STRUCTURAL AND ELECTRICAL PROPERTIES OF SrBi4Ti4O15 (SBTi) ADDED OF PbO AND V2O5 TO APPLICATIONS IN DIELETRIC RESONATOR ANTENNAS,
CAUBY AMORIM RODRIGUES JUNIOR, Universidade Federal do Ceará, Programa de Pós-Graduação em Engenharia Elétrica (agosto, 2017) (Co-Orientador)

3- STUDY OF DIELETRIC AND ELECTRICAL PROPERTIES OF MATRIX Mg4Nb2O9 FOR APPLICATIONS IN RADIO FREQUENCY COMPONENTS AND MICROWAVES,
José Miranda da Silva Filho, Universidade Federal do Ceará, Programa de Pós-Graduação em Engenharia de Teleinformática (outubro, 2017)

4- NUMERICAL AND EXPERIMENTAL STUDY OF THE Sr2CoNbO6 MATRIX ADDED WITH TiO2 FOR APPLICATIONS IN HIGH-FREQUENCY DIELECTRIC RESONATORS,

JOSÉ EDUARDO VASCONCELOS DE MORAIS, Universidade Federal do Ceará, Programa de Pós-Graduação em Engenharia de Teleinformática (abril, 2018)

5- STUDY OF THE STRUCTURAL AND DIELECTRIC PROPERTIES OF the BiVO4 Matrix and the Effects of Addition of TiO2 and CaTiO3 for Applications in Microbial Engineering,
RONALDO GLAUBER MAIA DE OLIVEIRA, Universidade Federal do Ceará, Programa de Pós-Graduação em Engenharia de Teleinformática (janeiro, 2019)

6- PHOTOLUMINESCENT PROPERTIES OF THE CERAMIC MATRIX BaBi2Nb2O9 (BBN) TRI-DOOPED WITH Er 3+ / Tm 3+ / Yb 3+
MARCELLO XAVIER FAÇANHA, Universidade Federal do Ceará, Programa de Pós-Graduação em QUIMICA (janeiro, 2019)

Supervision of MSc Thesis

1- ANTENNAS THERMAL STABILITY STUDY Al2O3 - CaTiO3 BASED DIELETRIC RESONATORS
LINDEMBERG DE SOUSA OLIVEIRA- Programa de Pós-Graduação em Engenharia de Telecomunicação do Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Fortaleza (Janeiro- 2016)

2- **STRONG MAGNETIC COUPLING IN RADIO FREQUENCY (RF),**JOSÉ HELDER DE AGUIAR CÂMARA, Programa de Pós-Graduação em Engenharia de Telecomunicação do Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Fortaleza, (Co-Orientador) (Maio- 2016)

3-NUMERICAL AND EXPERIMENTAL STUDY OF MAGNETO-DIELECTRIC ANTENNA FOR USE IN CELLULAR MOBILE COMMUNICATION SYSTEMS -
WALDERLE YASMIN ARRUDA SILVEIRA- Programa de Pós-Graduação em Engenharia de Telecomunicação do Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Fortaleza (Fevereiro- 2017)

4- STUDY ON THE INTENSITY OF NON-IONIZING ELECTROMAGNETIC RADIATION, ISSUED BY ANTENNA TRANSMITTERS OF CELLULAR TELEPHONY, RADIO AND TELEVISION IN THE CITY OF FORTALEZA.
ELDO ALMEIDA SILVA- Programa de Pós-Graduação em Engenharia de Telecomunicação do Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Fortaleza , (Co-Orientador) (Junho- 2017)

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ROTERDAN FERNANDES ABREU- Programa de Pós-Graduação em Engenharia de Telecomunicação do Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Fortaleza, (Co-Orientador) (Novembro- 2017)

7- STUDY OF PROPERTIES IN MICROWAVE OF DIELECTRIC RESONATORS BASED ON SrBi2Nb2O9 WITH ADDITION OF BI2O3 AND ITS APPLICATIONS IN ANTENNAS IN THE "S" BAND
SAMUEL OLIVEIRA SATURNO- Programa de Pós-Graduação em Engenharia de Telecomunicação do Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Fortaleza (Novembro- 2017)

8- STUDY OF NEW SOURCES FOR LASERS AND LED'S: FLUORESCENCE ANALYSIS UPCONVERSION OF THE MATRIX LaNbO4 CO-DOOPED WITH THE RARE TERM IONS Tm3 + EYb 3+
FELIPE ARARIPE GOMES DA SILVA-- Programa de Pós-Graduação em Engenharia de Telecomunicação do Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Fortaleza (Janeiro- 2018)

9- MAGNETO-DIELECTRIC RESONATORS BASED IN [SrFe12O19 (SFO) 1-X-BiFeO3 (BFO) X] FOR USE ON THE C BAND COMMUNICATIONS /VALÉRIA LIMA BESSA- Programa de Pós-Graduação em Engenharia de Telecomunicação do Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Fortaleza (Março- 2018)

10-HIGH THERMAL STABILITY OF THE Li2TiO3 MATRIX WITH ADDITIONS OF AL2O3 IN RADIOFREQUENCY AND MICROWAVE REGIONS, VITOR CARVALHO MARTINS, Programa de Pós-Graduação em QUIMICA, UNIVERSIDADE FEDERAL DO CEARÁ, Ceará, Fortaleza (Julho- 2018)

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1- DESIGN AND SIMULATION OF $Na_2Nb_4O_{11}$ DIELECTRIC RESONATOR ANTENNA ADDED WITH Bi2O3 FOR MICROWAVE APPLICATIONS
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Digital Object Identifier (DOI): 10.14209/jcis.2016.13

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12-PERFORMANCE OF MICROSTRIP PATCH ANTENNA DUE EBG/PBG ARRANGEMENTS INSERTION
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13-COMPACT TRIPLE-BAND PIFA WITH HIGH BANDWIDTH AND GAIN FOR MULTIPLE MOBILE SERVICES
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15-Effect of V2O5 Addition on the Phase Composition of Bi5FeTi3O15 Ceramic and RF/Microwave Dielectric Properties
F.A.A. AGUIAR, A.J.M. SALES, B.S. ARAU JO, K.D.A. SABO IA, M.C. CAMPOS FILHO, A.S.B. SOMBRA, A.P. AYALA, and P.B.A. FECHINE
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16-Experimental and numerical investigation of the microwave dielectric properties of the MgTiO3 ceramic matrix added with CaCu 3Ti 4O12
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Journal of ELECTRONIC MATERIALS
2017 The Minerals, Metals & Materials Society
DOI: 10.1007/s11664-017-5541-6

19-Impedance Spectroscopy Analysis of Mg4Nb2O9 Ceramics with Different Additions of V2O5 for Microwave and Radio Frequency Applications
J.M.S. FILHO, C.A. RODRIGUES JUNIOR, D.G. SOUSA,R.G.M. OLIVEIRA, M.M. COSTA, G.C. BARROSO, and A.S.B. SOMBRA
Journal of ELECTRONIC MATERIALS, Volume 46, Issue 7, pp 4344–4352
2017 The Minerals, Metals & Materials Society
DOI: 10.1007/s11664-017-5324-0

20- A self-assembly of graphene oxide@Fe3O4/metallophthalocyanine nanohybrid materials: synthesis, characterization, dielectric and thermal properties
A. E. C. Junior, J. P. F. Mota, S. M. A. Pontes, F. J. N. Maia,
C. S. Clemente, P. B. A. Fechine,F. Bohn, A. J. M. Sales, A. S. B. Sombra,
L. Carbone, G. Mele, D. Lomonaco, and S. E. Mazzetto
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Changes in research objectives, if any: xxxxx

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