

which correspond to the band gaps (opaque ranges) in transmittance, is usually not accompanied by the appearance of wide ranges with  $|E_x| \approx 1$  or  $|E_y| \approx 1$ . Depending on the location of the gaps for the two polarizations with respect to each other, several typical scenarios of reflection can be realized. Among those, it is worth mentioning the sharp peaks of  $|E_y|$  and plateaus of  $|E_x|$ , both with their magnitude close to unity and wide ranges with  $|E_x| \approx |E_y|$ .

Each of these scenarios can serve as a signature of whether a desired polarization of the reflected wave can be obtained for a separate value or for a rather wide range of variation of  $kD$ . As has been shown, linear, circular, and elliptical polarization can be realized for the same profile, depending on the  $kD$  value. The fact that the slab characteristics exert a strong effect on the number, location, and width of the gaps in transmission results in the fact that the detected effects can be obtained in various combinations. It is expected that these effects will remain present, at least for rather small nonzero incidence angles. The obtained results can be used for the design of polarization-selective/converting reflectors and filters.

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## STUDIES ON THE DIELECTRIC BEHAVIOUR OF POLYPYRROLE AND ITS COMPOSITES WITH POLY (VINYL CHLORIDE)

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**ABSTRACT:** Polypyrrole/poly (vinyl chloride) semi-interpenetrating networks of different compositions are prepared using ammonium per sulfate initiator at room temperature in pellet form and film form and their dielectric properties are studied at different microwave frequencies. An HP 8510 Vector network analyzer interfaced with a computer is used. The cavity-perturbation technique is employed for the study. © 2006 Wiley Periodicals, Inc. *Microwave Opt Technol Lett* 48: 1324–1326, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21628

**Key words:** polypyrrole; poly (vinyl chloride); cavity perturbation technique; dielectric properties

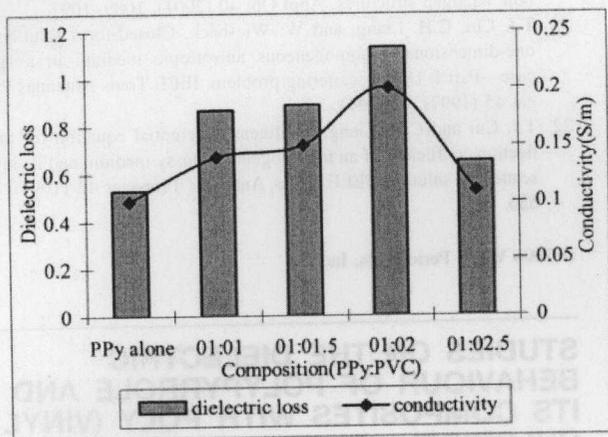
## INTRODUCTION

In recent years, conducting polymers with conjugated double bonds have attracted much attention as advanced materials. Polypyrrole (PPy) is especially promising for commercial applications because of its good environmental stability, facile synthesis, and higher conductivity than many other conducting polymers. Incorporating a conducting polymer into a host polymer substrate to form a blend, composite, or interpenetrated bulk network has been widely used as an approach to combine electrical conductivity with desirable physical properties of polymers [1, 2]. Polypyrrole is considered one of the most promising candidates for the fabrication of conductive blends/composites/interpenetrating networks (IPNs) with industrially important class of polymers [3].

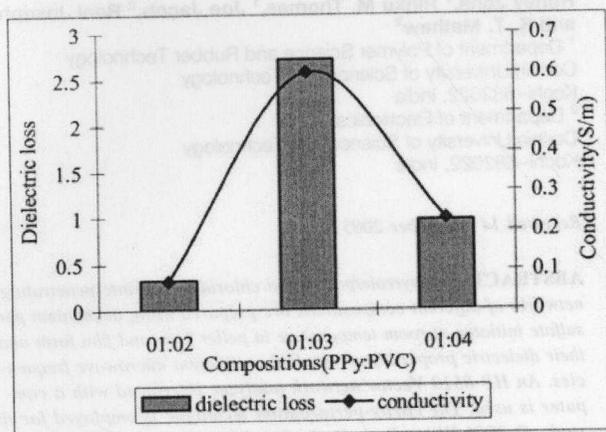
## EXPERIMENTAL

### Preparation

*Polypyrrole.* Chemical oxidative polymerization of pyrrole is carried out using ammonium per sulphate as initiator [4] in the



(a)



(b)

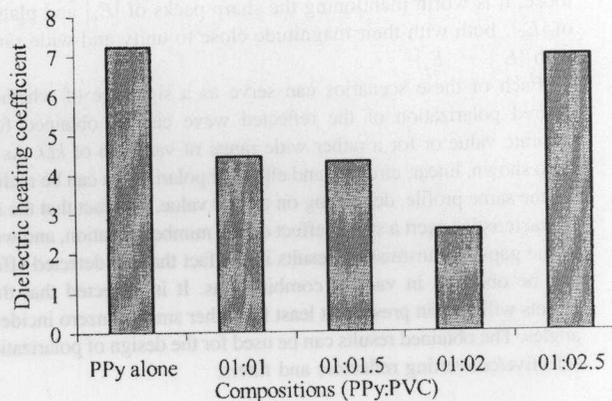
**Figure 1** Variation of dielectric loss conductivity with compositions of (a) PPy:PVC composite (pellet form) and (b) PPy:PVC composite (film form), both at 2.97 GHz

presence of 1M HCl. The polymerization is carried out for 4 h at room temperature. It is then filtered, washed and dried in an oven at 50°C to 60°C for 6 h. The dielectric properties of the all samples are studied using the cavity-perturbation technique.

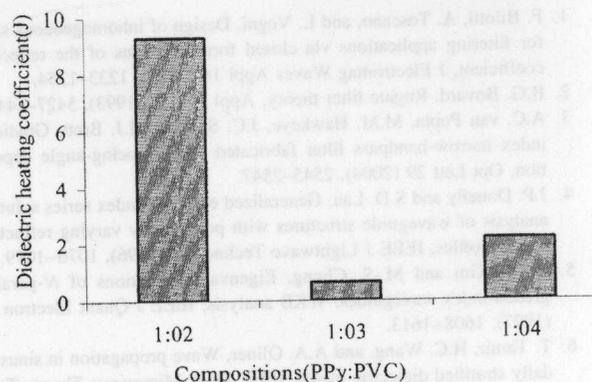
**Preparation of PPy/PVC SIPN.** Chemical oxidative polymerization of pyrrole/polyvinyl chloride SIPN is also prepared by the insitue polymerisation of pyrrole using the above procedure in the presence of polyvinyl chloride powder. Different proportions of 1:1, 1:1.5, 1:2, and 1:2.5 are prepared, the samples are pelletized, and the dielectric properties are measured at the S-band (2–4 GHz). Polypyrrole/polyvinyl chloride (PPy/PVC) SIPN in soluble form is prepared by using emulsion-grade polyvinyl chloride solution in cyclohexanone. It is then made into film by solution casting and doped with 1-M HCl. Different compositions of PPy-PVC SIPNs, (2:1, 1:1, 1:2, and 1:3) are prepared and the dielectric properties are studied.

#### EXPERIMENTAL SETUP AND THEORY

The experimental setup [5] consists of an HP8510 vector network analyzer, a sweep oscillator, an S-parameter test set, and a rectangular cavity resonator. The measurements were done at 25°C in the S-band (2–4 GHz). When a dielectric material is introduced in a cavity resonator at the position of maximum



(a)



(b)

**Figure 2** Variation of the dielectric heating coefficient with compositions of (a) PPy:PVC composite (pellet form) and (b) PPy:PVC composite (film form), both at 2.97 GHz

electric field, the contribution of magnetic field for perturbation is minimum. The field perturbation is given by Kupfer et al. [6]. The real and imaginary parts of the relative complex permittivity are given by

$$\epsilon'_r = 1 + \frac{f_0 - f_s}{2f_s} \left( \frac{V_c}{V_s} \right), \quad \epsilon''_r = \frac{V_c}{4V_s} \left( \frac{Q_0 - Q_s}{Q_0 Q_s} \right)$$

The real part of the complex permittivity,  $\epsilon'_r$  is generally known as dielectric constant and the imaginary part  $\epsilon''_r$  of the complex permittivity is related to the dielectric loss of the material. Here,  $\sigma + \omega\epsilon''_r$  is the effective conductivity of the medium. When the conductivity  $\sigma$  due to free charge is negligibly small (good dielectric) the effective conductivity is due to electric polarization and is reduced to  $\sigma_e = \omega\epsilon''_r = 2\pi f\epsilon_0\epsilon''_r$ . The efficiency of heating is usually compared [5] by means of a comparison coefficient  $J$ , which is defined as  $J = 1/\epsilon_r \tan \delta$  [7]. The absorption of electro-

**TABLE 1** Absorption Coefficient and Skin Depth of Different Compositions of PPy:PVC (Pellet Form) at 2.97 GHz

	Composition (PPy:PVC)			
	1:1	1:1.5	1:2	1:2.5
Absorption coefficient [ $\text{m}^{-1}$ ]	6.56	7.51	11.37	5.25
Skin depth [m]	.16	.133	.088	.191

**TABLE 2** Absorption Coefficient and Skin Depth of Different Compositions of PPy:PVC (Film Form) at 2.97 GHz

	Composition (PPy:PVC)		
	1:2	1:3	1:4
Absorption coefficient [ $m^{-1}$ ]	4.5	27.61	22
Skin depth [m]	.22	.04	.07

magnetic waves when it passes through the medium is given by the absorption coefficient [7] ( $\alpha_p$ ), which is defined as absorption coefficient ( $\alpha_p$ ) =  $\epsilon''_d/fnc$ , where  $n = \sqrt{\epsilon^*}$  and  $c$  is the velocity of light. Penetration depth, also called skin depth, is basically the effective distance of penetration of an electromagnetic wave into the material [8], skin depth ( $\delta_p$ ) =  $1/\alpha_p$ .

## RESULTS AND DISCUSSION

### Variation of Dielectric Properties with Compositions

**Dielectric Loss and Conductivity.** Figures 1(a) and 1(b) show the dielectric loss and conductivity of different compositions of PPy:PVC SIPN in pellet and film forms, respectively, at 2.97 GHz. It was clear from the figure that the dielectric loss and conductivity increases with increase in PVC content and it reaches a maximum at 1:2 proportion in pellet form and 1:3 in film form. This is due to the interfacial polarisation of the matrix [9], consisting of two materials having different dielectric constants.

**Dielectric Heating Coefficient  $J$ .** It is clear from Figures 2(a) and 2(b) that the dielectric heating coefficient is minimum for 1:2 composition in the case of pellet form and 1:3 in the case of film form. These compositions are suitable for dielectric heating applications.

**Absorption Coefficient and Skin Depth.** Tables 1 and 2 show the variation of the absorption coefficient and the skin depth of different compositions of SIPNs in pellet and film forms, respectively, at 2.97 GHz. Since the absorption coefficient is directly related to the dielectric-loss factor, the absorption coefficient is higher for 1:2 composition in pellet form and 1:3 in the case of film form. The skin depth is least for these compositions.

From all these properties, the 1:2 PPy:PVC composition in the case of pellet form and 1:3 composition in the case of film is optimized.

**Comparison of Pellet and Film Form of PPy:PVC SIPN.** Table 3 shows the dielectric properties of SIPNs of pellet (1:2 PPy:PVC composition) and film (1:3, which exhibits better results than the 1:2 film) forms. It is clear from the table that the conductivity and absorption coefficient are higher for the film sample and the dielectric heating coefficient and skin depth are lower for the film samples, due to the better dilution effect of the film samples.

**TABLE 3** Comparison of the Dielectric Properties of Pellet and Film Forms of PPy:PVC Composite

	PPy:PVC (Pellet Form)	PPy:PVC (Film Form)
Conductivity [S/m]	0.2	0.602
Dielectric heating coefficient $J$	2.56	0.63
Absorption coefficient [ $m^{-1}$ ]	11.36	38.97
Skin depth [m]	0.09	0.03

## CONCLUSION

The film form of SIPN is superior to pellet form in terms of conductivity, heating coefficient, absorption coefficient, and skin depth. The dielectric loss and conductivity are higher for the 1:2 PPy:PVC composition in pellet form and the 1:3 composition in film form. The dielectric heating coefficient is minimum for the 1:2 composition for pellet samples and the 1:3 composition for film samples. The absorption coefficients of the 1:2 composition for pellet samples and the 1:3 composition for film samples are high. The skin depths of the 1:2 composition for pellet samples and the 1:3 composition for film samples are less.

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## NEW OPTICAL RECEIVER USING TWO CASCADED $LiNbO_3$ MACH-ZEHNDER MODULATORS AS OPTICAL TIME-DIVISION DEMULTIPLEXER

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**ABSTRACT:** A new optical receiver is proposed for optical time-division multiplexing (OTDM) systems, which uses two cascaded  $LiNbO_3$  Mach-Zehnder intensity modulators as an ultrafast electrooptic (EO) time gate to demultiplex the OTDM data. Compared to optical fiber-based time-division demultiplexers, the newly designed EO time gates have the advantages of compactness, low power consumption, and high operation stability. With the Gaussian approximation of time-switching window for such EO gates, an analytical method is presented to efficiently evaluate the performance of this type of OTDM receiver employing PIN and avalanche photodiodes, respectively. © 2006 Wiley Periodicals, Inc. *Microwave Opt Technol Lett* 48: 1326–1330, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21627

**Key words:** optical receiver;  $LiNbO_3$  Mach-Zehnder modulators; optical time-division demultiplexer