行政院國家科學委員會專題研究計畫 成果報告

化學結構對聚醚醯亞胺及其奈米複合材料介電性質的影響之研究
研究成果報告(精簡版)

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化學結構對聚醚醯亞胺及其奈米複合材料介電性質之影響

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中　華　民　國　九十八　年　十　月　十二　日

研究摘要

由於積體電路的發展迅速，不僅尺寸隨之縮小化，且使用材料的介電常數也將要求更低。我們探討各種不同化學結構的單體對聚醚醯亞胺及其奈米複合材料的介電性質之影響。從化學結構的改變來降低聚醚醯亞胺的介電常數，實驗數據顯示若使用含有柔軟的醚鏈及較大平面化學結構可有效改變介電性質。介電常數的減少可歸因於二胺中 phenylene ether 會稀釋極性的醯亞胺環，導致介電常數的降低；而且龐大基團會增加自由體積，因此能減少介電常數。我們並使用sol-gel方法於研發出的新穎聚醚醯亞胺中混入SiO_2，製備出具更低介電常數的PEI-無機混成奈米複合材料，除保持其良好的加工性，並能提昇其介電性質、熱安定性及機械性能，可供光電工業使用。

關鍵詞：化學結構，介電材料，聚醯亞胺，聚醚醯亞胺，奈米複合材料，
　　　　溶凝膠法。

英文摘要

Low dielectric constant polyetherimides have been synthesized by incorporating a bisphenol A dianhydride, BPADA, and 2,7-bis(4-aminophenoxy) naphthalene (BAPN), a phenylene ether diamine. The flexible ether and larger planar naphthalene structure of BAPN led to more spacing between polymer molecules, resulting in less efficient chain packing and an increase in the free volume, thus decreasing the dielectric constant. New PEI/silica hybrid nanocomposites were prepared from this novel polyetherimide via sol-gel process. The dielectric constants were further decreased with the incorporation of silica. These synthesized PEI and nanocomposites have high thermal stability and good mechanical properties.

Keywords: Chemical structure, Dielectric materials, Polyimide, Polyetherimide,
　　　　　　Nanocomposite, Sol-gel process.

一、報告內容

1. 前言

In microelectronic device circuits, the propagation velocity of the signal is inversely proportional to the square of dielectric constants (ε) of the propagation medium. Therefore, materials with low ε are required for faster signal propagation in microelectronic devices without cross-talk in new multilevel high-density and high-speed electronic circuits. Polyimides (PIs) are used as protective and insulating materials in microelectronics, because they possess good thermal and mechanical stability, solution processability, and low dielectric constants [1]. Polyetherimides (PEIs) are PIs that contain flexible ether and isopropylidene groups. Ultem 1000, an important commercialized PEI product introduced by GE Plastics, is synthesized via the polycondensation of a dianhydride, BPADA, 4,4'-(4,4'-isopropylidene diphenoxy) bis(phthalic anhydride), with *m*-phenylene diamine (*m*PDA)[2]. This PEI exhibits good solvent solubility, thermal stability and mechanical properties. Although Ultem 1000 has good melt processability and solubility in some solvents, its relatively poor thermal stability limits its application in advanced materials. To improve the thermal properties of Ultem 1000, GE Plastics further introduced Ultem 5000 by substituting *m*PDA with *p*-phenylene diamine (*p*PDA) as one of the monomers [3]. Though the thermal stability improved, it became insoluble in most solvents. This difference in the chemical structure of diamines has resulted in PEIs with different properties. To improve the thermal, mechanical and dielectric properties of these two important PEIs with different diamines, *m*PDA and *p*PDA, we had studied the preparation of hybrid nanocomposites of PEI by the sol-gel process [4].

The dielectric constants for most PEI films are ~3.5 [5]. To reduce the dielectric constant, researchers have utilized fluorine-containing compounds [6-7], prepared hybrid nanocomposites by adding silica [8-9], or introduced voids into polymer film to take advantage of the low dielectric constant of air [10]. Recently, we have reported PEI synthesized via polycondensation of dianhydrides, BPADA and 40% 6FDA [4,4'-(hexafluoroisopropylidene) diphthalic dianhydride] with 1,4-bis(4-aminophenoxy) benzene (*p*BAB) diamine has a lower dielectric constant of 2.78 [11]. We further investigated the effect of chemical structure on the dielectric properties. We have found that PEIs synthesized by reacting dianhydrides, BPADA and 6FDA, with a phenylene ether diamine containing naphthalene [BAPN, 2,7-bis(4-aminophenoxy) naphthalene] have much lower dielectric constants.

The PEI nanocomposites with low dielectric constants, high thermal stability and good mechanical properties were prepared from a novel polyetherimide, synthesized by incorporating BPADA and BAPN, via sol-gel process. The sol-gel process consists of two steps: hydrolysis of inorganic alkoxides to produce hydroxyl groups, followed by polycondensation of the hydrolysis products and residual alkoxyl groups to form a three-dimensional network. The sol-gel process provides a method for preparing a variety of organic-inorganic hybrid materials at the molecular level [9]. The preparation, morphological, thermal, mechanical and dielectric properties of PEI nanocomposites are discussed.

2. 研究/實驗方法
2.1 材料與藥品：

Chemicals of reagent grade were purchased from various commercial sources, including BPADA (Aldrich) and 6FDA (Chriskev). BPADA was used after a thermal treatment in vacuum at 150°C to cyclize possible impurities. Diamines *m*PDA, *p*PDA, ODA (4,4'-oxydianiline), *p*BAB, and BAPP (2,2-bis(4-(4-aminophenoxy)phenyl) propane) were purchased from Acros, Tokyo Chemical Inc., and Chriskev Co. 2,7-bis(4-aminophenoxy) naphthalene (BAPN) was prepared from 2,7-dihydroxy- naphthalene according to literature [12]. The silane reagents, tetraethoxysilane [TEOS], 3-aminopropyl triethoxy silane

[APrTEOS], and 3-glycidyloxy propyl trimethoxy silane [GPTMOS] were purchased from Acros. The solvents, *N*-methyl- 2-pyrrolidone [NMP] and toluene (Tedia) were used as received.

2.2 特性分析：

Fourier transfer infrared (FTIR) spectra were recorded on a Bio-Rad Digilab FTS-40 spectrometer. ^{1}H NMR spectra were performed on a Bruker AMX-400 spectrometer with THF-d_8 as the solvent. ^{29}Si solid state NMR spectra were measured using a Bruker Avance-400 spectrometer. The dielectric properties of the polymer films were tested by the Agilent 4284A LCR meter with 16451B dielectric test fixture at 1 MHz frequency. The 16451B employs the parallel plate method, which sandwiches the material between two stainless steel electrodes to form a capacitor. LCR meter is then used to measure the capacitance created from the fixture. The measurements were performed on 0.10-0.12 mm thick, 50 mm diameter polymer films, which were desiccated overnight prior to measurement and were run at room temperature at 50% RH according to ASTM D150. At least five individual determinations were used to calculate the average dielectric constant, with an accuracy of ±0.10. Thermogravimetric analysis (TGA) was performed with a Perkin-Elmer Pyris 1 TGA at a heating rate of 20 ^{o}C /min in N$_2$. Differential scanning calorimetry (DSC) data were obtained from a Perkin-Elmer Pyris Diamond DSC. Samples were scanned at a heating rate of 10 ^{o}C /min under N$_2$. The T_g values were measured as the change of the specific heat in the heat flow curves. X-ray diffractograms (XRD) were obtained at room temperature on a Rigaku RINT 2000, using Ni-filtered CuK$_\alpha$ radiation (40 kV, 100 mA). The morphologies of the fracture surfaces of hybrid materials were observed with a JEOL JSM-6700 scanning electron microscope. The samples for TEM study were examined with a Hitachi TEM H-7500 using an acceleration voltage of 100 KV. Energy-dispersive X-ray (EDX) spectroscopy image of silicon element mapping was recorded on a Hitachi S-4100 microscopy. An Instron universal tester model 4467 was used to study the stress-strain behavior.

2.3 PREPARATION OF THE PEI AND PEI/SILICA NANOCOMPOSITES

2.3.1 Synthesis of polyamic acid (PAA) and PEI

PEI was synthesized by reacting diamine with dianhydrides as illustrated in Scheme 1. Diamine BAPN 3.42 g (0.01 mol) and NMP 29.4 g were placed into a 250-mL three-neck flask under nitrogen purge. The mixture was stirred until the solution was clear. Equal molar (0.01 mol) of dianhydrides, BPADA and 6FDA in various ratios, were added to the diamine solution to make a solution with a 20% solid content. The reaction mixture was stirred for 2 h at 60 ^{o}C and produced a transparent, yellow, viscous solution of PAA. Other PAAs in this study (with various diamines) were prepared by a similar procedure.

The PAA solutions were spread on a glass plate using a spin-coater to control the film thickness. The films were thermally dried at 60 ^{o}C for 4 h to remove most of the solvent in a forced air oven. The PAA films were imidized to PEI by heating to 100 ^{o}C, 150°C, 200°C at 1 h each, and 250°C for another hour to achieve fully imidization. The PEI films were then cooled to room temperature, soaked in water, and stripped from the glass.
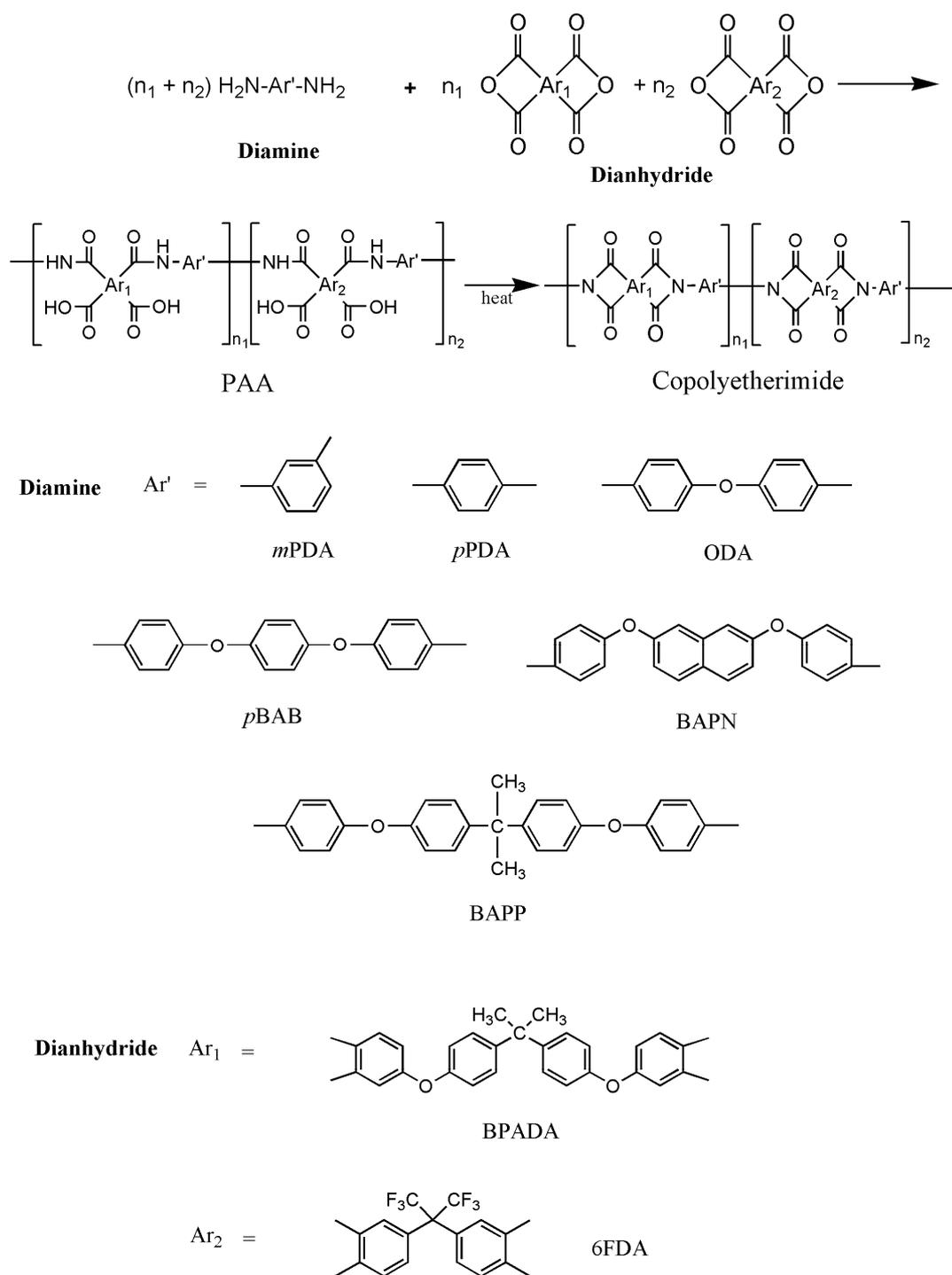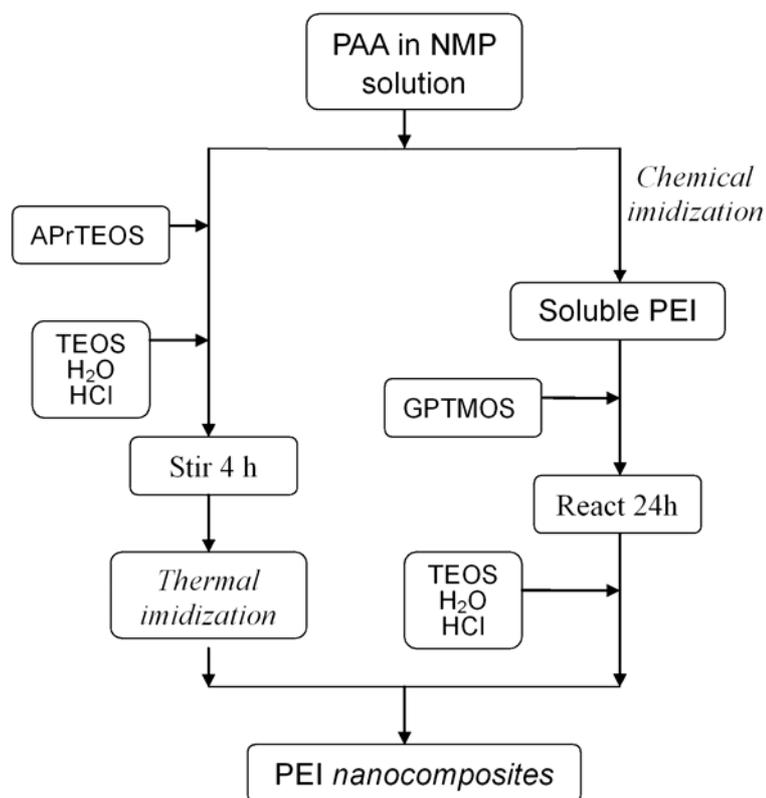
Scheme 1. Synthesis of polyetherimide.

2.3.2 Preparation of the PEI/silica nanocomposite films from PAA

PEI or polyimide nanocomposites were prepared by a two-stage sol-gel process via PAA [13-14]. The procedure was follows (see Scheme 2, left):

In a flask, various amounts of the coupling agent APrTEOS was charged into the above PAA solution and stirred for 1 h. Then, acidic hydrolyzed TEOS solution (acidified by HCl and diluted by water to make the molar ratio TEOS:H_2O =1:4) was added and stirred at 70 $^{\circ}$C for 4 h to produce a hybrid solution. The weight percent of total silica in the hybrid was calculated from the initial amounts of TEOS and coupling agent, assuming a complete reaction. The weight ratio of silica obtained from APrTEOS to that obtained from TEOS was 10/90.

The hybrid PAA solution was spread on a glass plate using a spin-coater to obtain a PAA hybrid film. The thermal imidization procedures were the same as mentioned above for PEI films. After drying the aforementioned films at 110 ^{o}C for 24 h in vacuum, the PEI/silica hybrid films were obtained.

```
                    PAA in NMP
                      solution
                          |
                          |
          +---------------+---------------+
          |                               |  Chemical
          |                               |  imidization
 APrTEOS -->                              |
          |                          Soluble PEI
          |                               |
 TEOS     |                 GPTMOS ------>|
 H2O   -->|                               |
 HCl      |                          React 24h
          |                               |
       Stir 4 h           TEOS            |
          |               H2O  --------->|
          |               HCl             |
       Thermal                            |
      imidization                         |
          |                               |
          +---------------+---------------+
                          |
                   PEI nanocomposites
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Scheme 2. Synthesis of PEI nanocomposites *via* the sol-gel process.

2.3.3 Preparation of the nanocomposites from soluble PEI

For a soluble polyetherimide, the nanocomposite can also be prepared utilizing a novel sol-gel process after chemical imidization [9]. GPTMOS was charged into a PEI solution and stirred at 70^{o}C for 24 h to complete the reaction. Then, the acidic hydrolyzed TEOS solution was added and stirred for 6 h to produce a hybrid solution (see Scheme 2, right). The rest of the steps are the same as the procedure described above.

3. 結果與討論

3.1 CHEMICAL STRUCTURES

The structures of the PEIs were confirmed by IR and [1]H NMR. The FT-IR spectra are shown in Figure 1. It exhibits characteristic imide group absorptions at 1777 and 1720 cm[-1] (typical of imide carbonyl asymmetrical and symmetrical stretch), at 1374 and 744cm[-1] (C-N stretching and bending), and at 1238 cm[-1] (aromatic ether C-O-C). There is little variation in the IR spectra among various diamines.
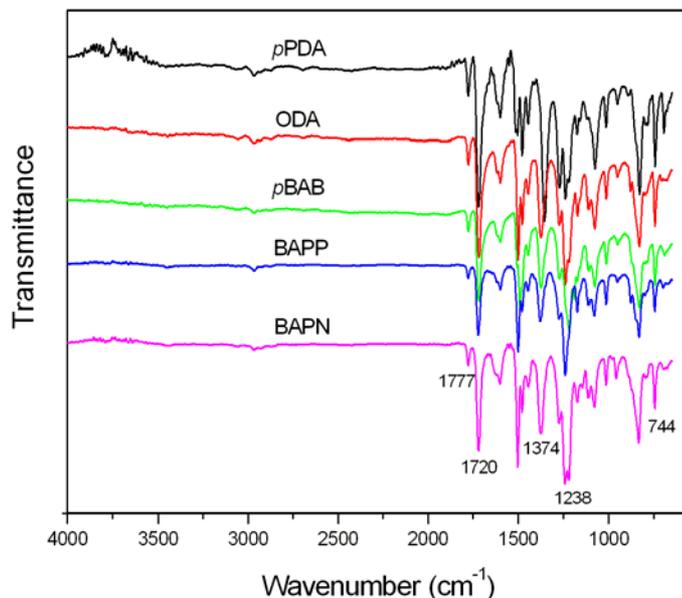

Figure 1. FT-IR spectra of polyetherimides with various diamines.

Figure 2 illustrates the [1]H NMR (THF-d_8) spectrum of PEI synthesized via the polycondensation of BPADA with BAPN. The spectrum is divided into two parts, with the first showing the aromatic protons in the downfield region, δ (ppm) 7.0~8.0 (28H, phenyl), and the second with the methyl protons in the upfield region. δ 1.9~3.0 (6H, -CH$_3$). All of the spectroscopic data obtained were in good agreement with the proposed structure.

When looking into the [29]Si NMR spectra (Figure 3) of PEI/silica hybrids, it provided information about the silicon environment in the nanocomposites and confirmed preservation of the Si–C bonds in the composites.
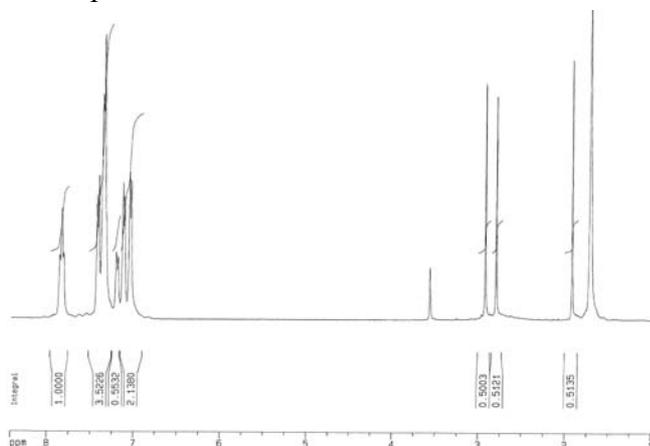

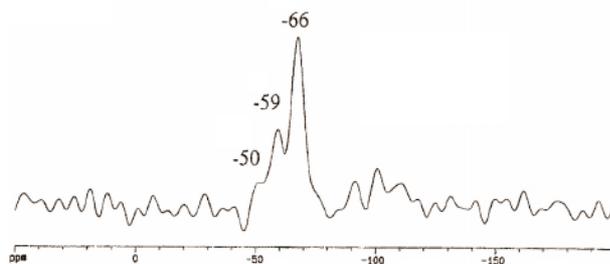**Figure 2.** [1]H NMR spectrum of PEI synthesized by BPADA with BAPN.

Figure 3. ^{29}Si NMR spectrum of PEI nanocomposite PN10.

3.2 THE EFFECT OF CHEMICAL STRUCTURE ON DIELECTRIC PROPERTIES

Basic understanding of influence of molecular structure on dielectric properties of polymer provides guidance on the engineering of appropriate electric insulating materials [15]. The chemical structure can affect the dielectric properties of polyimide [16-17]. The dielectric constants of PEI/silica nanocomposite films prepared by synthesis BPADA with *m*PDA or *p*PDA are shown in Figure 4. The dielectric constant decreased with increasing amounts of silica. The decreased dielectric constants may be attributed to the reduction in the freedom of orientation of the silica and main-chain flexibility of the PEI matrix [8]. The dielectric constant for *p*PEI is slightly higher than that of *m*PEI. This is caused by the better dielectric behavior associated with *p*PEI [3].
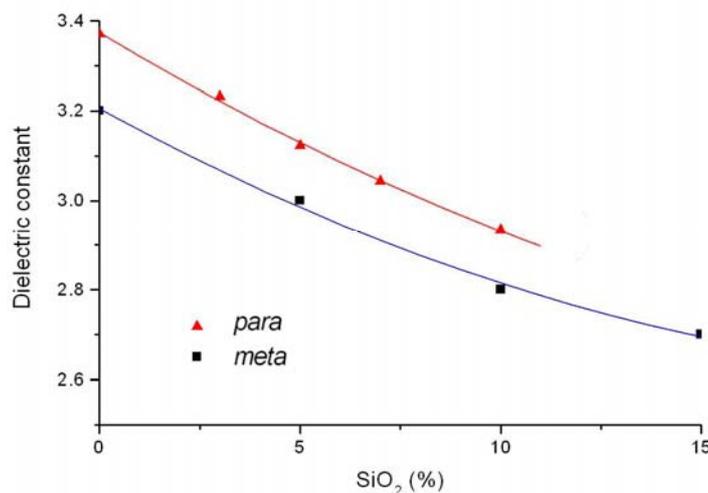

Figure 4. Dielectric constants of PEI nanocomposites with various SiO$_2$ content.

Correlation between high free volume and low dielectric constant has been previously reported for polyimides [18]. The introduction of free volume in a polymer decreases the number of polarizable groups per unit volume, resulting in lower values for ε. Free volume in polyimides have been enhanced by the addition of pendant groups, flexible bridging units, and bulky groups which limit chain packing density. The incorporation of fluorine into polyimides has been shown to lower dielectric constants due to a combination of lower electronic polarizability and larger free volume [6].

To decrease the dielectric constant of PEI, we incorporated 6FDA as one of the dianhydride monomers. 6FDA may decrease the dielectric constant by the bulky CF$_3$ groups that decrease chain packing efficiency and increase free volume, and by the strong electronegativity of fluorine that creates permanent dipole moments in CF$_3$ groups [19]. To further reduce the dielectric constants of PEIs, we increased free volume by replacing phenylene diamine with phenylene ether diamines, including ODA, *p*BAB, BAPP, and BAPN.

The results in Figure 5 show that these dielectric constants decrease with increasing phenylene ether units. Decreases in the dielectric constants may result from the phenylene ethers units in diamine that induce the dilution effect of the polar imide ring [20]. The PEI (**m**) synthesized with BAPN diamine exhibited a lower dielectric constant of 2.92; PEI (**o**) synthesized with dianhydride containing 50% 6FDA and diamine BAPN showed the lowest dielectric constant of 2.3.
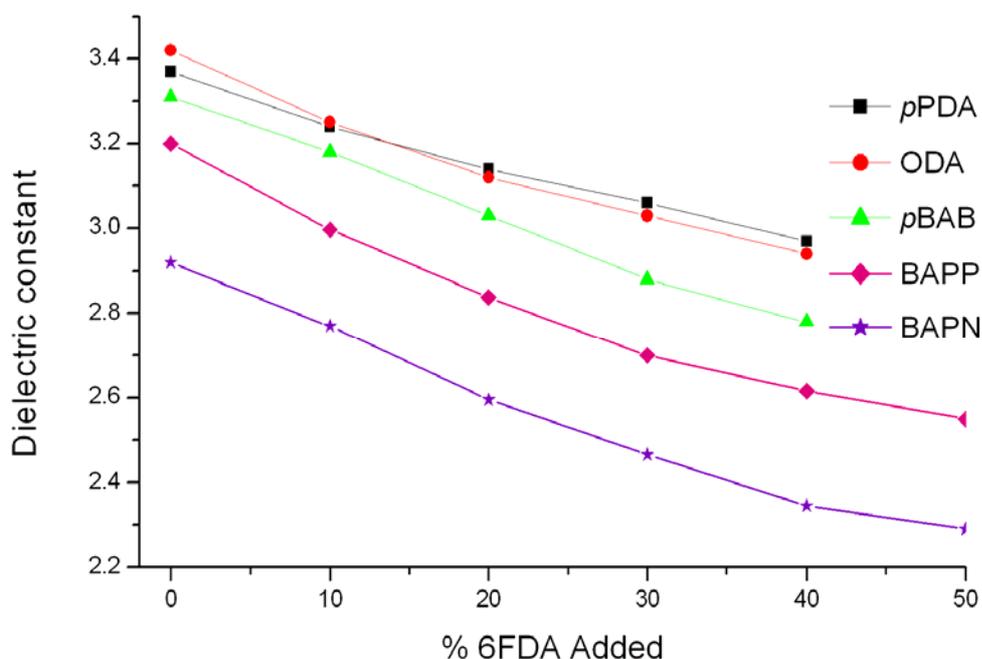

Figure 5. Dielectric constants of PEIs measured at 1 MHz.

As discussed above, the dielectric constant could be reduced by increasing the free volume of the molecule or by decreasing the polarization. The flexible ether and larger planar naphthalene structure of BAPN diamine led to more spacing between polymer molecules, resulting in less efficient chain packing and an increase in the free volume of the polymer, thus decreasing the dielectric constant.

The chemical structure affects the thermal properties of polymers [21]. The thermal properties of PEIs are tabulated in Table 1. The glass transition temperatures (T_g) increased as the content of 6FDA increased, since fluorine groups enhanced the thermal stability [7]. T_g gradually decreased with PEI containing longer phenylene ether units due to the flexibility of the polymer chains. The thermal decomposition temperature (T_d) at 10 % weight loss in nitrogen stayed in the range of 532–568 ^{o}C. The T_d values increased with increasing 6FDA content. The TGA data demonstrates the high thermal stability of these PEIs.

As expected, all the above PEIs failed to show any crystallinity. The XRD spectra were broad and had no significant or obvious peaks, indicating that the PEIs were amorphous polymer structures. The synthesized PEIs have good mechanical properties. Both the tensile strength and the modulus decreased with the PEI containing longer phenylene ether units. This could be attributed to the increase of flexibility in the polymer chain.

Table 1. The code and thermal properties of PEIs.

Code	Dianhydride BPADA/6FDA (mole ratio)	Diamine	T_g (°C)	$T_{d,10\%}$ (°C)
a	100/0	pPDA	225	549
b	80/20	pPDA	240	551
c	60/40	pPDA	255	559
d	100/0	ODA	217	532
e	80/20	ODA	230	558
f	60/40	ODA	246	568
g	100/0	pBAB	205	545
h	80/20	pBAB	214	549
i	60/40	pBAB	222	564
j	100/0	BAPP	232	572
k	70/30	BAPP	249	575
l	50/50	BAPP	259	577
m	100/0	BAPN	218	572
n	70/30	BAPN	227	574
o	50/50	BAPN	255	578

3.3 PREPARATION OF THE PEI/SILICA NANOCOMPOSITES WITH LOW ε

We had studied the preparation of PEI nanocomposites by intercalation of polymers with clay [22]. The thermal properties of PEI-clay nanocomposites improved over pristine PEI, but the physical test results showed that the films became brittle as the organoclay content increased over 2%. This indicated that the organoclay was not suitable for the preparation of the PEI nanocomposites. On the other hand, PEI nanocomposites with improved thermal, mechanical and dielectric properties were successfully prepared via a sol-gel process [22].

In this article, we follow the recent findings in our lab that the PEI synthesized by BPADA dianhydride and BAPN diamine has a lower dielectric constant, to prepare the new PEI/silica hybrid nanocomposites via the sol-gel process.
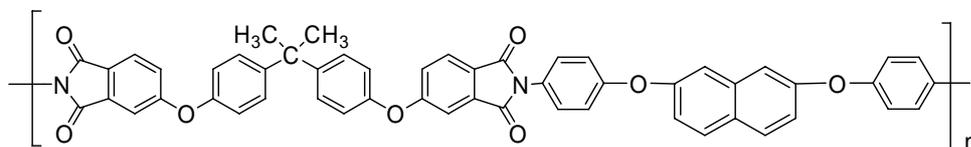
BPADA-BAPN

The experimental conditions for preparing PEI/silica hybrids are listed in Table 2. The amount of coupling agent and hydrolyzed TEOS solution used varied with the SiO$_2$ content.

The morphology of the PEI/silica nanocomposites was examined by XRD, SEM, and TEM. XRD showed no peak, indicating an amorphous polymer structure for these PEI nanocomposites. The SEM of the fracture surfaces showed a finely interconnected or co-continuous phase for PEI nanocomposite PN10 (Figure 6). This image elucidates that the coupling agent improved the miscibility between polymer and silica phases in hybrid nanocomposite. From the TEM of PN10, one can see that the shape of the included silica particles is round and the particle sizes within the hybrid films is ＜100 nm (Figure 7). Figure

8 shows the Si-mapping image of EDX on the cross section of hybrid PN10 film. The bright spots corresponding to silicon elements were found dispersed homogeneously in black background (i.e., polymer matrix) at 3000 magnification (scale bar 10 μm). This indicates that nanocomposites can be successfully made by the sol-gel process.

Table 2. The preparation, thermal, mechanical and dielectric properties of PEI/silica nanocomposites.

SiO$_2$(%)	0	5	10	15
Code	PEI(**m**)	PN05	PN10	PN15
APrTEOS (g)	0	0.161	0.340	0.540
TEOS (g)	0	1.37	2.88	4.58
H$_2$O (g)	0	0.47	1.00	1.58
T_g (^{o}C)	218	222	226	225
$T_{d, 10\%}$ (^{o}C)	572	576	585	574
Tensile strength (MPa)	98	105	114	95
Dielectric constant	2.92	2.77	2.61	2.76

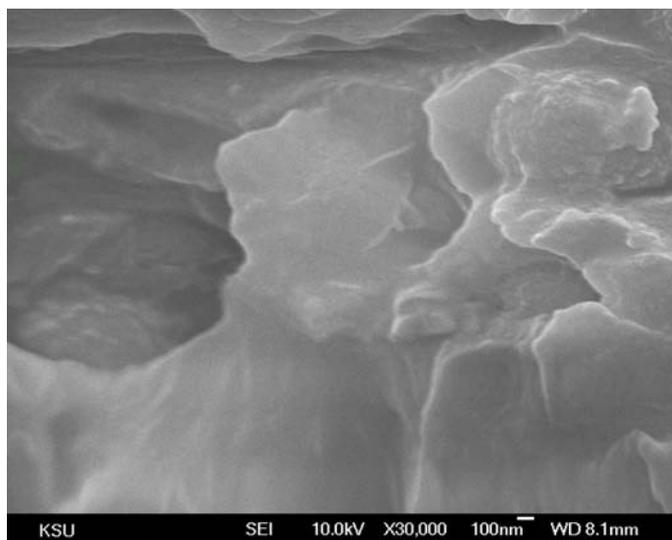Basis: BPADA and BAPN diamine 0.01mole.

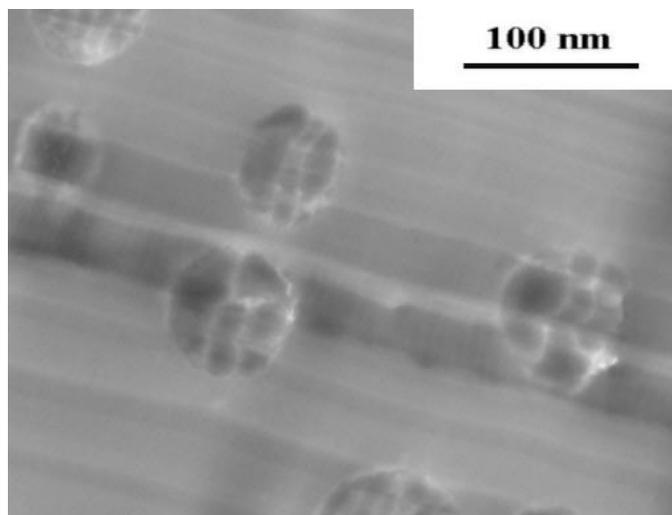**Figure 6.**   SEM micrograph of the fracture surface of a PEI nanocomposite.

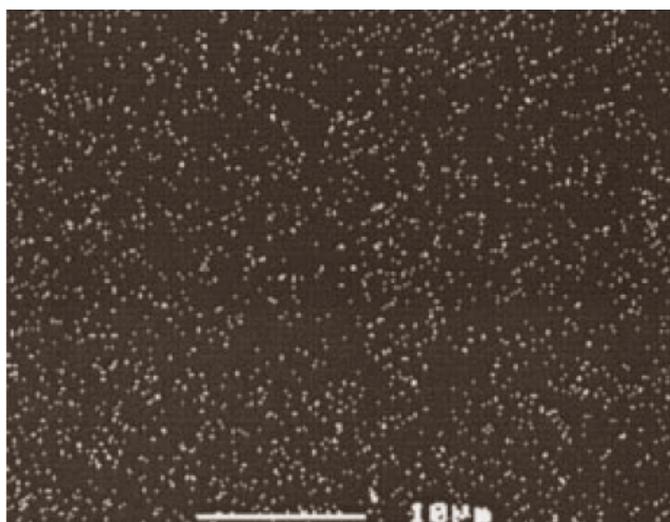**Figure 7.**   TEM micrograph of a PEI nanocomposite.

Figure 8. Si-mapping image of EDX on a PEI nanocomposite PN10.

The T_g of hybrids increased gradually with increasing silica content. This increase can be attributed to the strong interaction between the organic polymer matrix and the inorganic silica that increased the restricting strength of silica on PEI molecules [8]. However, at higher SiO_2 content, T_g started to decrease slightly due to microphase separation. The thermal decomposition temperatures at 10% weight loss ($T_{d,10\%}$) in nitrogen (Table 2) had similar trends as T_g. $T_{d,10\%}$ increased gradually with increasing silica content, but decreased at higher SiO_2 content. This may result from the Si–OH residual groups (formed through the hydrolysis of TEOS and APrTEOS), which increases with the silica content due to the incomplete condensation reaction in nanocomposites [23]. Nevertheless, $T_{d,10\%}$ values above 550 ^{o}C indicate that the PEI/silica nanocomposites have a high thermal stability.

As we have discussed, the dielectric constant decreased with increasing amounts of silica. However, at higher silica content (more than 10%), the aggregation of silica resulted in the increase of the dielectric constant.

4. 結論

Polyetherimides (PEIs) with low dielectric constants have been synthesized by incorporating fluorinated dianhydride and phenylene ether diamines, such as BAPN. The dielectric constant of PEI decreased with increasing amounts of 6FDA content and phenylene ether units. Besides the contribution of fluorine to lower dielectric constants, the decrease in the dielectric constant is mainly due to the flexible and large planar chemical structure of BAPN diamine, which increased the free volume of polymer. PEI nanocomposites with improved thermal, mechanical, and dielectric properties were prepared via the sol-gel process from PEI synthesized by BPADA with BAPN. The dielectric constants were decreased with the incorporation of silica. The synthesized PEI and nanocomposite films have high thermal stability and good mechanical properties. Thus, these polymer nanocomposites may be candidates for high-performance microelectronic applications.

5. 參考文獻

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致謝

二、計畫成果自評

　　本研究計畫報告的內容與原定計畫相符、並達成預期目標。在過去一年由於國科會的補助，我們已經將本研究報告投稿並成功發表在國際知名期刊：

Bor-Kuan Chen, J.-U. Du, C.-W. Hou, The effects of chemical structure on the dielectric properties of polyetherimide and nanocomposites, *IEEE Transactions on Dielectrics and Electrical Insulation,* 15(1); 127-133 (2008)

　　對於人才培育成果，參與本計畫之學生由執行計畫過程學習到高分子合成技術、使用精密儀器分析物理、化學、熱及機械性質，且由整理實驗數據來培養學生對於高分子科學實驗方面之知識及應用，可提昇學生之學術研究能力以備將來進入研究所繼續深造；並同時培育國內有關高分子科學方面之人才。

可供推廣之研發成果資料表

<table>
<tr><td colspan="2">□ 可申請專利　　■ 可技術移轉　　　　　　　日期：98年10月11日</td></tr>
<tr>
<td>國科會補助計畫</td>
<td>計畫名稱:化學結構對聚醚醯亞胺及其奈米複合材料介電性質之影響

計畫主持人:陳伯寬

計畫編號:**NSC 97-2221-E-168-009**
學門領域:高分子</td>
</tr>
<tr>
<td>技術/創作名稱</td>
<td>低介電性質之聚醚醯亞胺及其奈米複合材料</td>
</tr>
<tr>
<td>發明人/創作人</td>
<td>陳伯寬</td>
</tr>
<tr>
<td rowspan="2">技術說明</td>
<td>中文:
　我們探討各種不同化學結構的單體對聚醚醯亞胺及其奈米複合材料的介電性質之影響。從化學結構的改變來降低聚醚醯亞胺的介電常數,實驗數據顯示若使用含有柔軟的醚鏈及較大平面化學結構可有效改變介電性質。介電常數的減少可歸因於二胺中 phenylene ether 會稀釋極性的醯亞胺環,導致介電常數的降低;而且龐大基團會增加自由體積,因此能減少介電常數。我們並使用 sol-gel方法於研發出的新穎聚醚醯亞胺中混入SiO_2,製備出具更低介電常數的PEI-無機混成奈米複合材料,除保持其良好的加工性,並能提昇其介電性質、熱安定性及機械性能。</td>
</tr>
<tr>
<td>英文:
　　Low dielectric constant polyetherimides have been synthesized by incorporating a bisphenol A dianhydride, BPADA, and 2,7-bis(4-aminophenoxy) naphthalene (BAPN), a phenylene ether diamine. The flexible ether and larger planar naphthalene structure of BAPN led to more spacing between polymer molecules, resulting in less efficient chain packing and an increase in the free volume, thus decreasing the dielectric constant. New PEI/silica hybrid nanocomposites were prepared from this novel polyetherimide via sol-gel process. The dielectric constants were further decreased with the incorporation of silica. These synthesized PEI and nanocomposites have high thermal stability and good mechanical properties.</td>
</tr>
<tr>
<td>可利用之產業
及
可開發之產品</td>
<td>電子工業使用之聚醯亞胺產品,如軟性 PCB,LCD。</td>
</tr>
</table>

技術特點	使用含有柔軟的醚鏈及較大平面化學結構可有效改變介電性質。介電常數的減少可歸因於二胺中 phenylene ether 會稀釋極性的醯亞胺環，導致介電常數的降低；而且龐大基團會增加自由體積，因此能減少介電常數。
推廣及運用的價值	由於積體電路的發展迅速，不僅尺寸隨之縮小化，且使用材料的介電常數也將要求更低。我們探討各種不同化學結構的單體對聚醚醯亞胺的介電性質之影響。我們並使用溶凝膠法於研發出的新穎聚醚醯亞胺中混入SiO_2，製備出具更低介電常數的PEI-無機混成奈米複合材料，除保持其良好的加工性，並能提昇其介電性質、熱安定性及機械性能，可供光電工業使用。

※　1. 每項研發成果請填寫一式二份，一份隨成果報告送繳本會，一份送　貴單位
　　　研發成果推廣單位（如技術移轉中心）。

※　2. 本項研發成果若尚未申請專利，請勿揭露可申請專利之主要內容。

※　3. 本表若不敷使用，請自行影印使用。

行政院國家科學委員會補助國內專家學者出席國際學術會議報告

報告人姓名	陳伯寬	服務機構及職稱	崑 山 科 技 大 學 教 授
會議 時間 地點	6 月 28~7 月 3 日 新加坡市	本會核定補助文號	NSC 97-2221-E-168-009
會議名稱	(中文) 2009 年高科技材料國際會議 (英文) ICMAT 2009		
發表論文題目	(中文) 增韌型生物可分解性高分子生醫材料之研究 (英文) The study of toughening biodegradable polymers as biomedical materials		

報告內容應包括下列各項：

一、參加會議經過

本國際研討會由新加坡材料學會主辦，大會中邀請有多位諾貝爾獎得主演講。
研討會共分23 組，內容非常豐富及精彩！
另外，還有檢測奈米材料的儀器廠商參展各種儀器設備。

二、與會心得
有以下幾點重要心得：

1. 此國際研討會主軸有二大方向：”生醫材料” 及” 奈米科技”。
2. 中國學者參加頗為踴躍，許多研究生皆能參加。
3. 職於會議中也發表論文一篇(請見附件)。
4. 新加坡大學致力於提升其國際地位不遺餘力。

三、考察參觀活動(無是項活動者省略)
    無

四、建議
    台灣也應定期舉辦國際會議，可提高學術地位及帶動觀光產業。

五、攜回資料名稱及內容

    ICMAT 2009會議手冊及論文摘要一本和光碟一片。

六、其他

The study of toughening biodegradable polymers as biomedical materials

Research interest in biodegradable polymers continues to grow, especially in the application of biomedical materials. The most important attributes of a biodegradable polymer pertains to its biocompatibility and that of the products of its degradation. Though PLA and PHB are biodegradable, their physical and mechanical properties need to be improved for biomedical application. In addition, the stress field induced by the implant largely affects the healing and remodeling of the natural tissue surrounding it, therefore, tailoring the implant so that its mechanical behavior mimics that of the host tissue, is of utmost importance. Since the vast majority of the biodegradable polymers in clinical use are rather stiff materials exhibiting limited extendibility, they are unsuitable for use in numerous applications. Aiming to expand the clinical applicability of biodegradable polymers, we developed a family of toughening biodegradable polymers for use as biomedical materials, tailored to meet various applications.

Our working concept is to copolymerize lactide or PLA and PEG and synthesize PLA-PEO copolymers. In order to improve the flexibility and strength of biodegradable polymer, we also add a biodegradable plasticizer. We investigated various combinations of reaction conditions to obtain optimal results to improve the toughness of biodegradable PLA and other polymers. These synthesized biodegradable copolymers are expected to have increased strength, good mechanical properties, and improved biocompatibility. Thus, these modified biodegradable polymers can be applied as biomedical materials.