Comparison of Producing Processes of Polyimide Film

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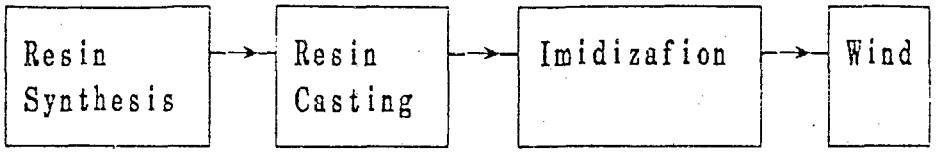
1. Introduction

Polyimide (PI) film has made great progress in China since it appeared in early 1970s. Now almost 20 factories produce more than 200 tons of PI film per year in China. The properties of the products are reaching the advanced international level. Specification of PI film covers 0.012mm to 0.125mm in thickness and 300mm to over 1000mm in width. The production of PI film per line has been increased from 20 tons to over 100 tons per year in China. The field of application includes not only insulation of motors, but also flexible printed circuits (FPC), cable-wiring insulation, large-scale capacitor, heater-insulation, and indoor wires. Chronologically, Casting, impregnation, and orientation processes were invented as PI film producing technology in China. Expected according to the trend of present development, during 1995 to 2000 the output of PI film in China will be over 500 tons per year, and producing level will be highly improved. The competition of different processes and their products is getting tongher. Their share of market will be generally changed, or re-allotted.

2. Comparison of the Processes

Three mentioned processes are described in graphs below.

① Casting



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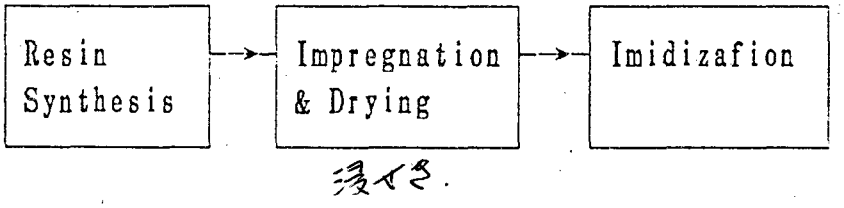
② Impregnation



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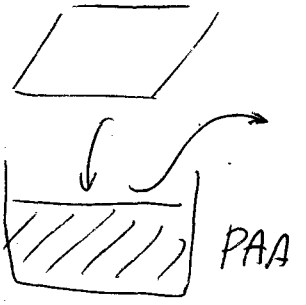
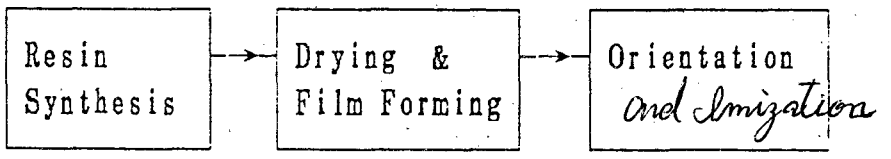
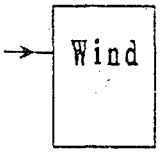


③ Orientation





Some properties of PI film relate to the producing process, such as tensile strength, dielectric strength, dissipation factor. Among them, tensile strength is the most influenced. (Tab. 1)

Tab.1 Tensile Strength of PI Films in Different Processes

Item	Unit	Casting	Impregnation	Orientation	Kapton® H (Dupont)
Tensile Strength	MPa	152	135	175	180
Thickness	μm	25～70	30～60	12～125	7.5～125

Besides, exterior appearance, length, and thickness of PI film are also influerced.

Because of the specific situation and development in China, the PI film products made by impregnation process gain the biggest share of market, which is about 50 to 60 per cent. Casting PI film products share 30 per cent approximately. Orientating PI film products share 10 per cent.

3. Comparison of Micro-Structure of PI Film

Actually, differences in the properties of the film caused by different producing technology are connected with the micro-stucture of polymer.

(1) Composation

PMDA-ODA
Kapton Type.

The polyimide mentioned in this article is composed of pyromellitic acid and 4, 4'-diamino diphenyl ether.

(2) Crystallization

The films in Tab. 1 are all low-crystallization polymer. Their crystallinity is shown in Tab. 2.

Tab.2 Crystallinity of PI Films in Different Processes

	Unit	Casting PI film	PI film by Impregnation	Orientating PI film	Kapton® H (Dupont)
Crystallinity*	%	13.0	12.5	15.6	18.0

* Measured by x-ray diffration

(3) Crystal Orientation

Because of the constraction in producing processes, crystals in PI film are oriented to a certain extent. We measured the half-width of crystal-orienting peak at 5.5 ° of diffraction, then calculated the relative orientation degree according to the formala,

$$R\,\% = \frac{180 - H}{180}$$

The resalts are shown in Tab. 3

Tab. 3 Relative Orientation Degree of PI Films in Different Processes

	Unit	Casting PI film	PI film by Impregnation	Orientating PI film	Kapton® H (Dupont)
R	%	64	58	78	82

(4) Molecular Orientation

Index of bi-refraction shows the molecular orientation in films. (Tab. 4)

Tab. 4 Index of Bi-Refraction of PI Films in Different Processes

	Cast -ing	Impregnation	Orientation	Kapton® H (Dupont)
Indes of Bi-refraction	0.06	0.04	0.10	0.12

The results in Tab. 3 and Tab. 4 have the same tendency. The tendency of molecular orientation explains why the tensile strength of orientation film product is bigger than those of casting and impregration products.

4. Comparison of Process Capability

(1) Casting

During imidization in casting process, tension control is difficult for PI films thinner than 25μm. The phenomena such as side-of-wind wrinkling and uneven shrinkage are often observed. Therefore, casting technology is difficault to produce PI films which thickness are lower than 25μm.

(2) Impregantion

Although tension control is relatively easy to meet the

requirement, to peel the thinner films from the impregrating belt becomes a restriction to this technology.

(3) Orientation

All specification of PI film in range of 12～25 μm can be produced by this process. The appearance of orientation PI film is beffer than those of casting and impregaating PI film.

5. Comparison of Cost of Procuction

On the basis of 50 tons scale of production, analysis includes depreciation of fixed asset, number of personnel on line, and cost of raw materials and electric power.

(1) Depreciation of Fixed Asset

Among three processes, impregration requiring the smallest workshop area, the most simple machine, and the least investment. Orientation is a new technology developed in last 1980s, which has more advantages than other processes. The workshop for orienting PI film occupies the largest area, and the machine is relatively complicated and expensive. Orientation thus needs the most investment. The ratio of investment for impregration, casting, and orientation is about 1 : 2 : 5.

(2) Number of Personnel on Line

The number of maintenance person and worker for the synthesis operation is similar in three processes. The ratio of the least personnel on the production line of impregnation, cast, and orientation is 15 : 9 : 11.

(3) Cost of Row Materials

The orientation process consumes more major materials. The impregnation process needs more solvent and other supplementary agents. The ratio of consumption of all materials in impregnation, cast, and orientation is 24 : 20 : 21.

(4) Cost of Electric Power

The ratio of power consumption in impregnation, cast, and orientation process is 5 : 6 : 9, determined by present design level.

(5) Comparison of Whole Cost

The ratio of whole cost of impregnation, casting, and orientation process is 14 : 12.5 : 14, calculated only by depreciation of fixed asset, personnel cost, and cost of raw materials and power.

6. Forecast

(1) Concerning only the properties of PI film, orientation PI film is the best one, casting PI film the next, then PI film by impregnation process. In recent years, Chinese national standards will reach the level of IEC standards, which impregnating PI film products can hardly meat. But because of the specific situation of Chinese industry, the impregnation process and its products will exist for some time.

(2) Having the advantages of lower cost, less risk for investment and better quality, the general level of casting process in China is quite high. This determines that the casting process will exist for a relatively long time.

(3) With high quality and full specifications, orientation PI film will develop and occupy the market of PI film in several years in the futare. But in present years, competition is tough. The strategy for the manufacturers who are employing orientation process is to develop recovery technology of lefrover materials and solvent uapor, reduce the production costs, and with competitive price, enter the internotional market as soon as possible.

Reference

1. Chao Aiai, etc. The Effect of Aggregative Structure of PI Film to Its Properties.
   The first Conference of Insalation Materials and Technology,
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