MECHANICAL TESTING OF KAPTON FILMS

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1. Introduction

Kapton is a material developed by DuPont company that is commonly used for insulation of electric and electronic devices. It offers excellent physical, electrical, thermal and chemical resistant characteristics. It is a polyimide (PI) and it is usually available in a form of a homogeneous film wound onto a drum. There exist several types of Kapton [1]. Kapton CRC100 [2] has been developed for use as an electrically insulating material for high voltage environments where the potential for corona discharge is present (in motor and generator applications as magnet wire, turn to turn strand, coil, slot liner and ground insulation materials; it can be laminated too). Kapton HN [3] general-purpose film has been used successfully in applications at temperatures as low as –269°C and as high as +400°C. It can be laminated, metallized, punched, formed or adhesive-coated. Other manufacturers produce similar polyimide films, e.g. the Chinese Kingzom company. The manufacturers mostly provide measured values of mechanical quantities, such as the tensile strength and tensile modulus, obtained only either along one direction of testing, which can be sufficient only if the material could be regarded as isotropic, or along two directions (machine and transverse), which would suggest that the material is orthotropic.

The goal of this work is to compare stiffness and strength properties of three different films (only two known [2, 3]), analyze the dependence on strain-rate, and quantify the expected material anisotropy. The tensile tests were performed according to CSN EN ISO 527-3 and ASTM D-882-02.

2. Tensile modulus and strength

Five rectangular specimens having dimensions 100 mm × 10 mm and thickness 27 μm (datasheet value is 25 μm) were cut using scalpel from each tested material. The longer side was aligned with the longitudinal (machine) direction of the film. The specimens were loaded up to break using hydraulic jaws (see Fig. 1) and constant crosshead velocity 50 mm/min. The measured values are displayed in Tab. 1. The values of Young's modulus were obtained from the linear parts of the stress–strain diagrams for the range of stress between 5 MPa and 50 MPa (see Fig. 2).

The measuring of deformation proved to be complicated using standard extensometer with sensor arms as they can easily displace the thin specimens to the sides. Therefore, three methods for the measurement of elongation (or strain) of specimens were compared – extensometer (central part of specimen), crosshead (whole specimen), and DIC using digital camera (central part of specimen). An example of displacement field obtained using DIC is shown in Fig. 3.

Fig. 1. Specimen during (left) and after the test (right).

3. Strain rate effect

The dependency of stress–strain to strain-rate was analyzed on Kapton 100CRC (best candidate for our project). Three velocities of the crosshead were used, namely 50 mm/min, 100 mm/min, and 200 mm/min. Three samples for each velocity were tested. The strain-rate effect was found negligible especially in the linear part of the curves.

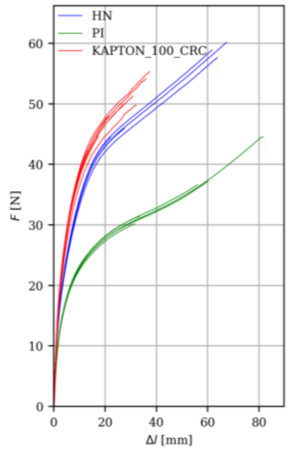

Fig. 2. Stiffness and strength comparison for the three tested materials.

Table 1. Comparison of tested materials' properties.

Material	Modulus [Pa]	Strength [Pa]
Kapton 100CRC	3.80×10^9	188.17×10^6
Kapton HN	2.86×10^9	197.91×10^6
Unknown PI	1.70×10^9	133.30×10^6

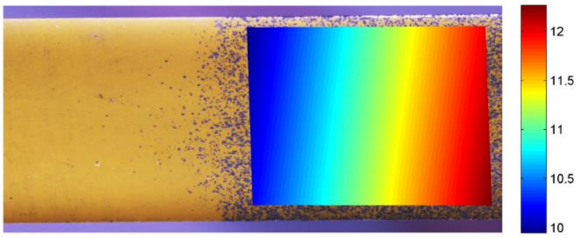

Fig. 3 DIC contours of longitudinal displacement [mm] on a specimen with a sprayed random pattern.

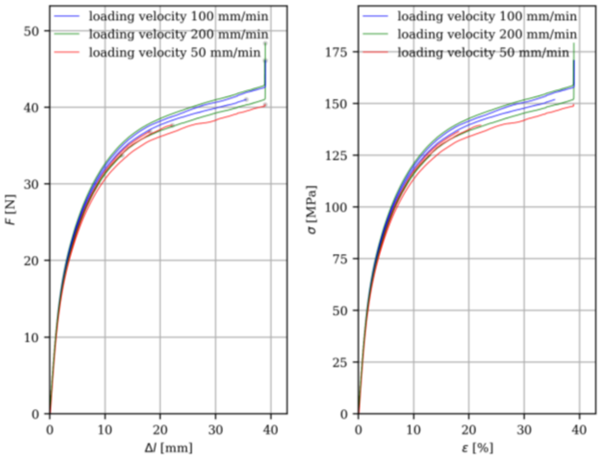

Fig. 4. Stiffness and strength for different strain-rates.

4. Anisotropy

The tests were performed on samples made of Kapton 100CRC with three different material orientation (1~0°, 2~90°, and 3~45°) with respect to the longitudinal axis of the film.

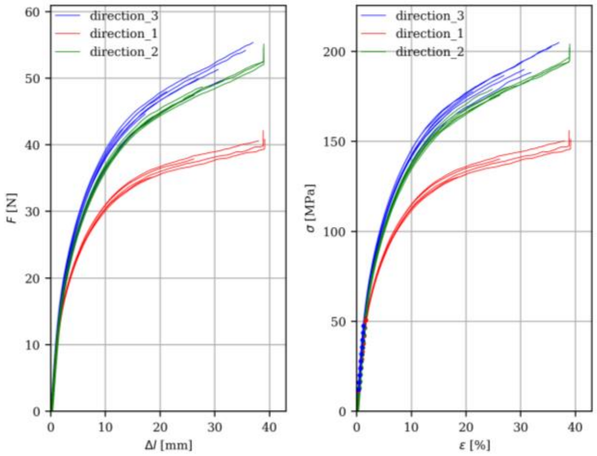

Fig. 4. Stiffness and strength comparison in three different directions of Kapton 100CRC.

Table 2. Directional dependency of stiffness and strength of Kapton 100CRC

Direction	Modulus [Pa]	Strength [Pa]
1	2.96×10^9	142.84×10^6
2	3.68×10^9	190.57×10^6
3	3.85×10^9	188.17×10^6
datasheet [2]	3.48×10^9	227.00×10^6

5. Conclusions

It was shown that the properties of various versions of polyimide films in general can be significantly different. Moreover, the material exhibits anisotropic properties, most likely orthotropic due to the manufacturing process. The strain-rate effect (at least for the tested machine direction and velocity range) was found negligible.

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