Characterization of Transparent Fluorescent Silicones for Optical Monitoring of HV Cable Accessories

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Introduction

Current electrical measurements of partial discharges (PD) are very susceptible to electromagnetic interference. Therefore, alternative methods are explored which do not suffer from these limitations and which will be more accurate, reliable, and insensitive to any interference.

One solution to this problem is the optical detection of partial discharges which demands the use of transparent insulation materials for cable accessories, such as optically clear silicones. Highly transparent silicones have not been widely used in high voltage applications so far. The aim of this work was to investigate these materials in terms of their mechanical and electrical properties and compare them to non-transparent silicones which are already used in HV applications. In addition to this, transparent silicones were modified with fluorescent dyes in order to enhance the optical PD detection sensitivity.

Materials

- **PS 60** Reference material: non-transparent, addition-curing, two-component silicone rubber that cures at room temperature, used for cable accessories and insulators
- **PS 76** New material: highly-transparent addition-curing, two-component silicone rubber that cures at high temperature above 120 °C.
- **FD 1** green fluorescent dye functionalised so that it can covalently bind to silicone PS 76.
- **FD 2** orange fluorescent dye functionalised so that it can covalently bind to silicone PS 76.

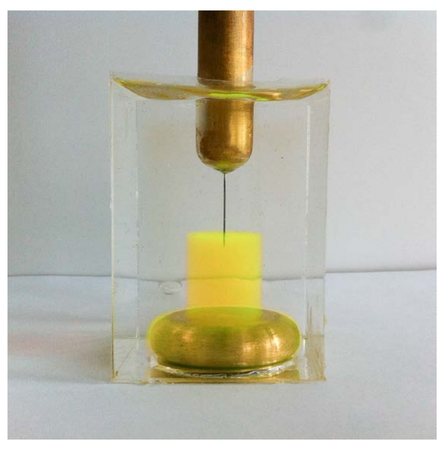
Sample Preparation

Tensile Strength Test
Sheets 100 × 100 × 2 mm, paddle-shaped specimen were die-cut from the sheets, according to DIN EN ISO 527-2 type 5A

Capacity and Dissipation Factor Measurement
Sheets 100 × 100 × 2 mm

Breakdown Voltage Measurement
Sheets 100 × 100 × 0.5 mm

Partial Discharge Measurement
Needle-plate setup, cylindrical sample Ø 20 mm × 20 mm


PD sample


Electrode for Breakdown Tests

Methods

Tensile strength:
DIN 53504, 23 °C, 250 mm/min, 6 samples

Dissipation Factor and Capacity:
1.5 kV, 50 Hz AC, 20 cm², 1 and 4 kg weight, 23 and 90 °C

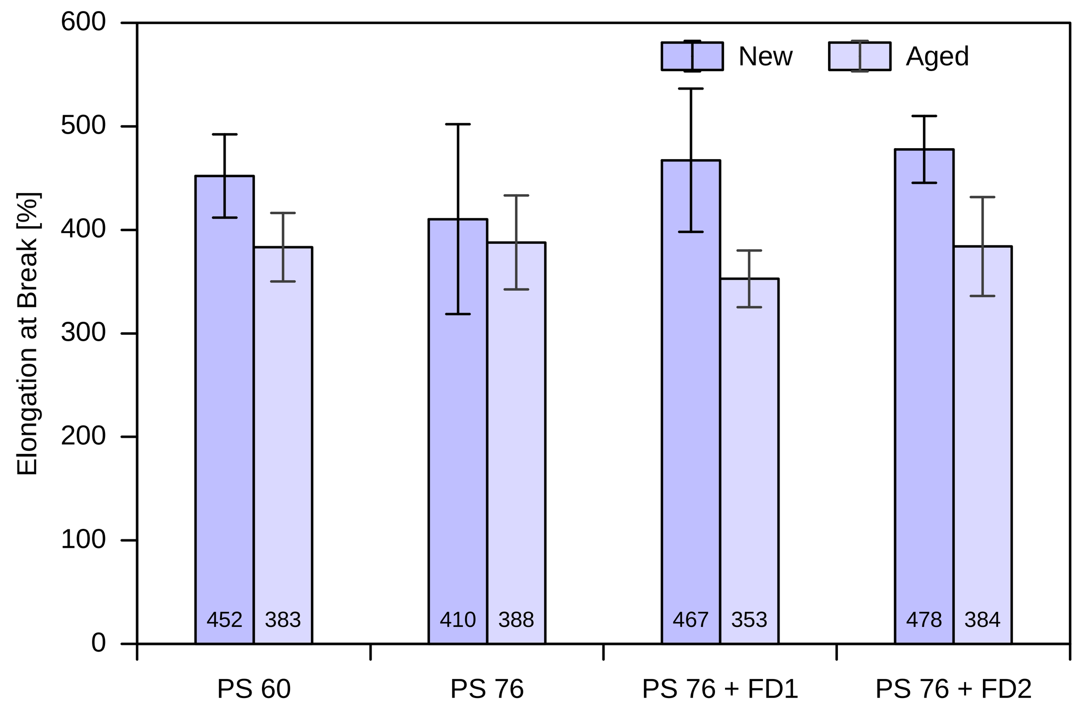
Breakdown Strength:
1 kV steps, 50 Hz AC, spherical electrode

Partial Discharges:
1 kV steps, 50 Hz AC, MPD 540 and APD 500 (Omicron Mtronix), Shielded Test Chamber

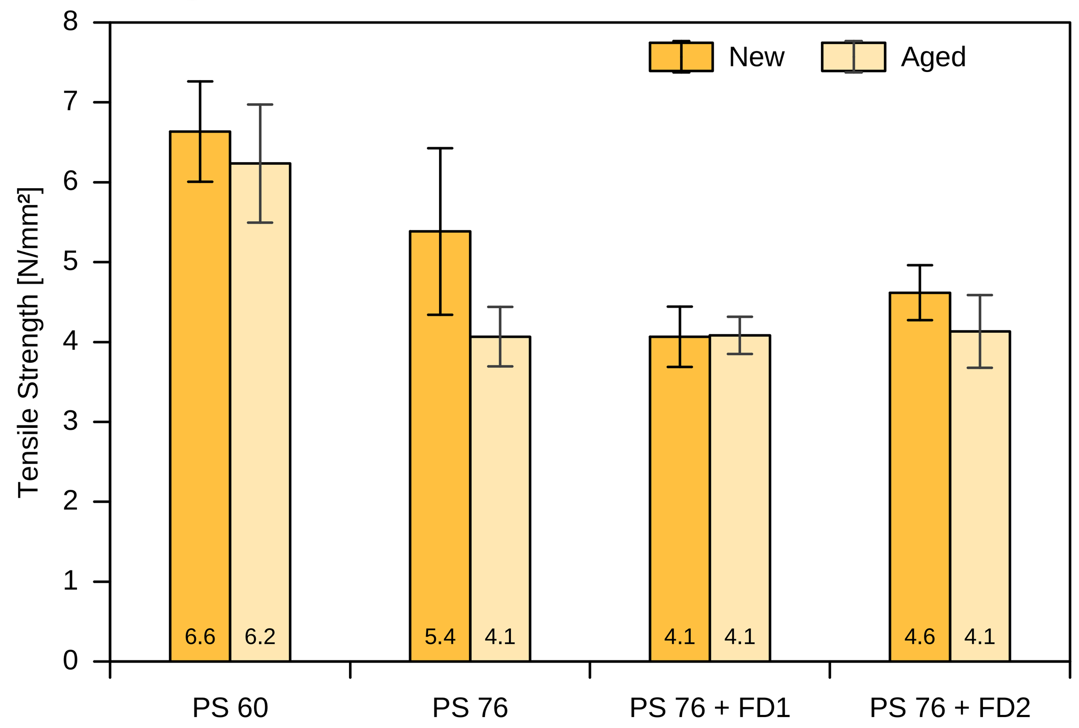
Electrical treeing:
after the PD measurement, 25 kV (AC, 50 Hz), approx. 120 min

Results

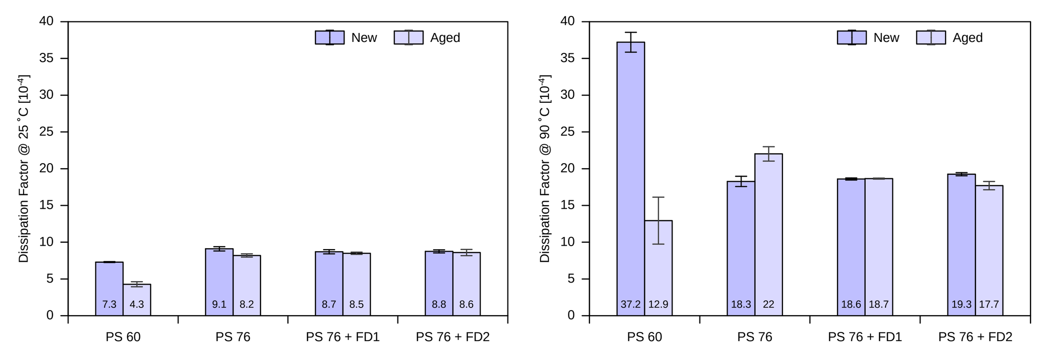
Elongation at Break



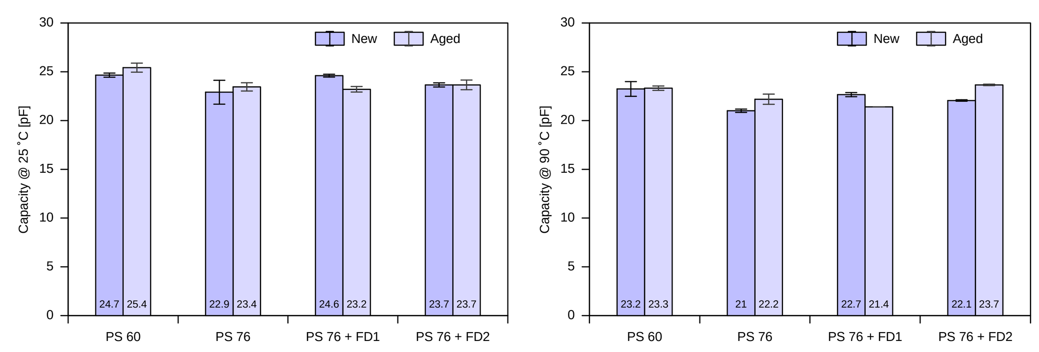
Tensile Strength



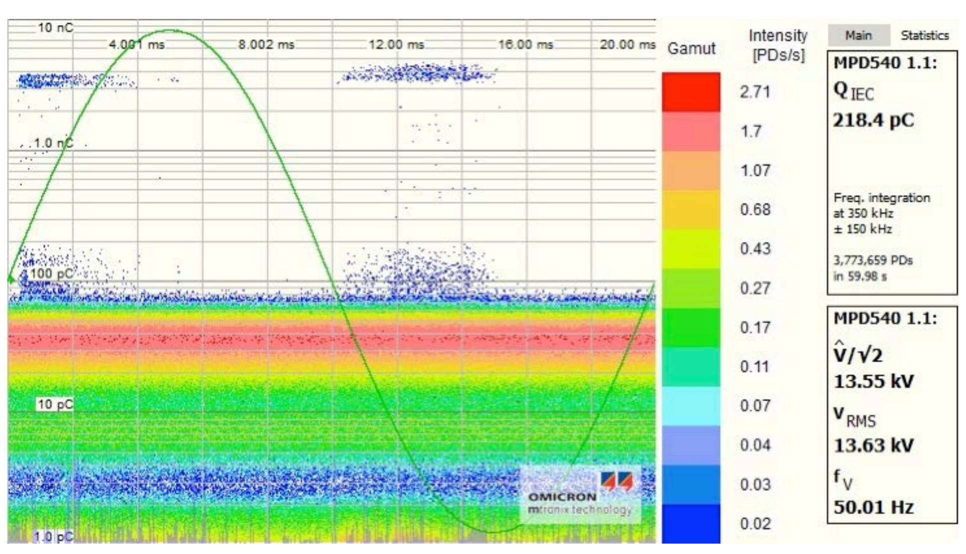
Dissipation Factor

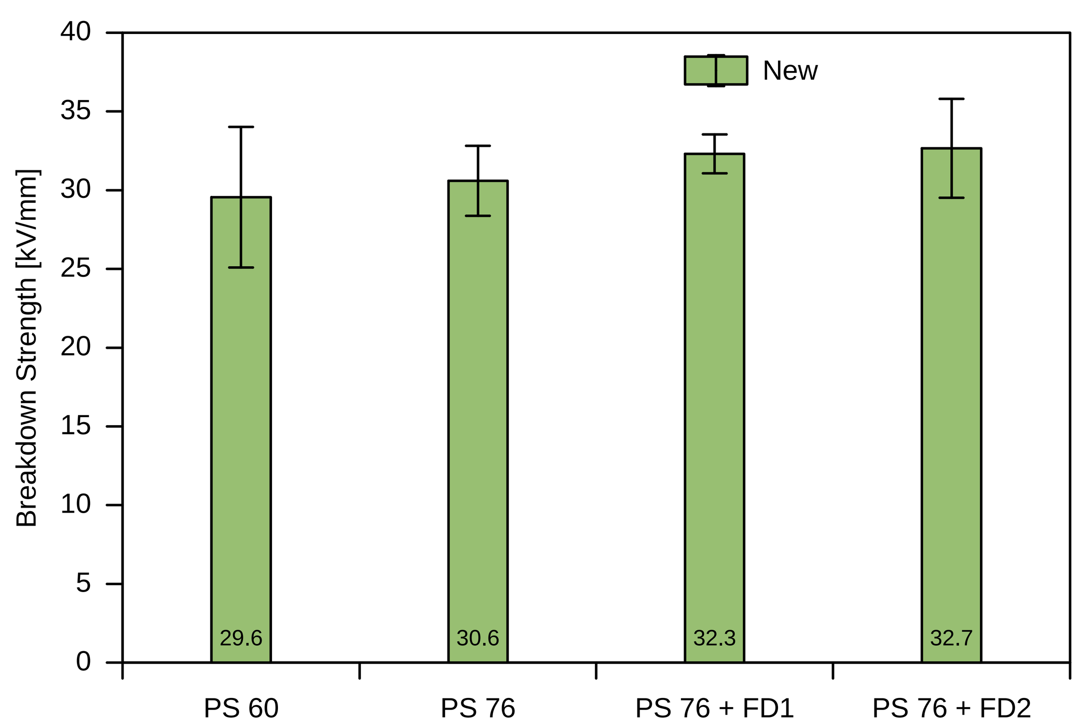


Capacity

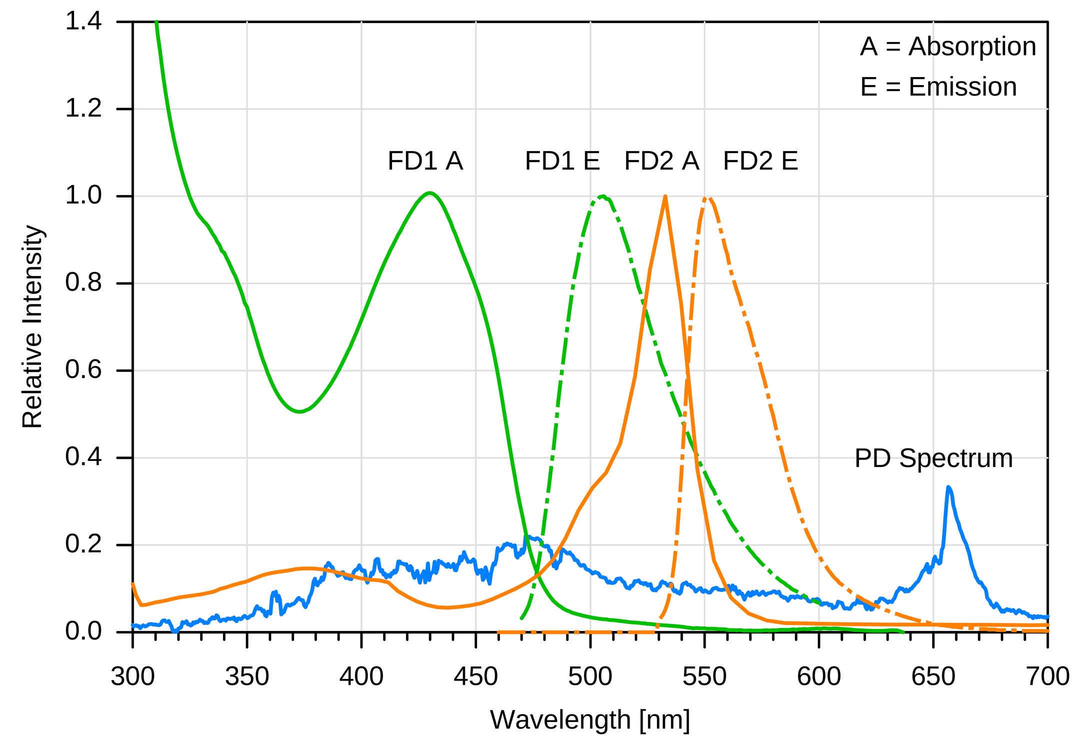


Breakdown Strength

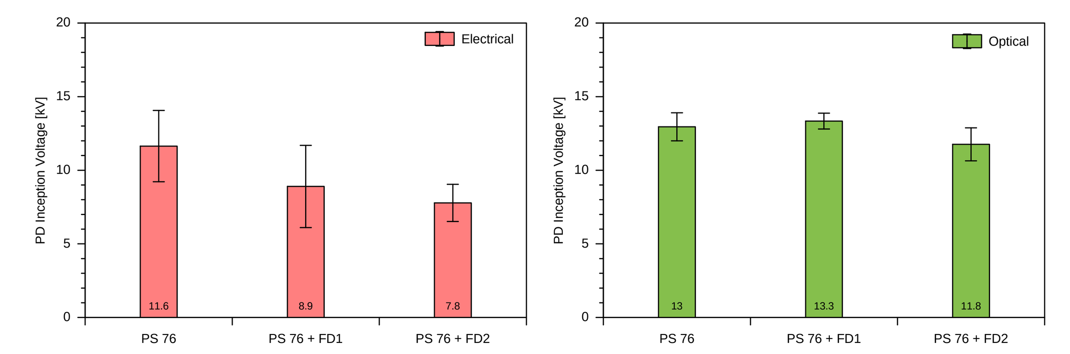




Fluorescent Dye Characterization



Partial Discharge Inception Voltage



Electrical Treeing


PS 76 PS 76 + FD 1 PS 76 + FD 2

Conclusions

1. Elongation at break of the new materials is in the same range as that of the reference material (ca. 400%). Thermal ageing decreases elongation by 15% for the reference and up to 25% for PS 76 modified with FD1.
2. Tensile strength of the new materials is ca. 35% lower than for PS 60 (6.6 N/mm²) which is still considered to be in the usable range. Thermal ageing decreases tensile strength by 7 to 25%. Interestingly, the addition of fluorescent dyes stabilizes the new material against thermal ageing.
3. All tested materials are equivalent in terms of breakdown strength and capacity. Differences were observed for the dissipation factor. While the reference material shows a 5-fold increase of dissipation factor from room temperature to 90 °C, the new materials only show a 2-fold increase. Thermal ageing slightly decreases or does not change the dissipation factor for most of the materials.
4. The optical system detects partial discharges at slightly higher voltage than the electrical system due to the grey filter. However, the detection threshold is still far below the inception voltage of tree growth.
5. The addition of fluorescent dyes leads to the formation of a halo effect around the tree structures. Treeing time was slightly shorter for the modified materials.
6. The new transparent silicone materials modified with fluorescent dyes have properties comparable to the industrial reference material. The added value of transparency and fluorescence make them suitable materials for novel diagnostic applications in HV cable accessories and insulators. Such applications include on-line monitoring of partial discharge formation, short circuit prevention systems, live localization of HV cable defects.

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