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Influence of a solid organic insulator on the arc decomposition and high energy spark decomposition of SF_6 and SF_6-N_2 (10-90) mixtures

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Résumé:
Nous avons étudié et comparé l'influence d'isolants solides organiques (Mégélit, Téflon, polypropylène, polyéthylène, résines époxydes) sur la décomposition par claquages (expérience) et par arc (modèle) du SF_6 pur avec/sans 0,2%H_2O ou O_2 et de SF_6-N_2(10-90). La comparaison a montré que la dégradation de l'isolant provoque et ce, indépendamment de la présence d'impuretés, l'apparition de CF_4 et de traces de S_2F_{10} (moins dans SF_6-N_2 que dans SF_6), une formation plus importante du sous-produit majoritaire (SF_4+SOF_2) et une diminution de SO_2F_2 et que, pour un isolant, la corrélation entre l'accroissement de la production de (SF_4+SOF_2) et le taux de formation de CF_4 est notamment indépendante de la présence d'impuretés. Le modèle a montré que, pour la même quantité d'isolant vaporisé, les isolants contenant des atomes de fluor conduisent à une décomposition moindre du SF_6 par rapport à un isolant n'en contenant pas.

Abstract:
The influence of solid organic insulators (Megelit, Teflon, polypropylene, polyethylene, Nylon, epoxy resins) on spark (experiment) and arc (model) decomposition of pure SF_6, SF_6+0.2%H_2O, SF_6+0.2%O_2 and SF_6-N_2 (10-90) mixtures was studied and compared. This comparison emphasized that the vaporization of an insulator causes, independently of the presence of impurities, the appearance of CF_4 and traces of S_2F_{10} (less in SF_6-N_2 mixture than in pure SF_6), an increased formation of the major SF_6 by-product (SF_4+SOF_2) and a diminution of SO_2F_2; besides, for an insulator, the correlation between the enhancement of (SF_4+SOF_2) production and the formation rate of CF_4 is particularly independent of the presence of impurities. The model showed that, for the same quantity of insulator vaporised, insulators containing fluorine atoms lead to a smaller SF_6 decomposition.

Sulfur hexafluoride (SF_6) is one of the best gaseous dielectrics and is widely used in high voltage circuit breakers and in gas insulated equipment. However SF_6 is expensive, could have a bad impact on environment (greenhouse gas) and forms toxic and corrosive compounds (e-g S_2F_{10}, SOF_2, SOF_4, HF...). That's why industry tries to reduce its quantity in electrical equipment for example by mixing it with N_2.

Indeed it has been shown [1] that mixtures of low concentrations (< 15%) of SF_6 in N_2 show excellent potential for use in gas insulated transmission lines; besides mixtures of SF_6-N_2 (50%-50%) could be used for both electrical insulation and arc/current interruption purpose.

In a circuit breaker, the arc plasma decays in the presence of metal, carbon, nitrogen, oxygen and water coming from partial vaporisation and desorption of the electrodes and nozzle (composed of an organic insulator) under the stress.

The aim of this paper is to show the influence of the vaporization of a solid organic insulator on the arc decomposition of SF_6 and SF_6-N_2 (10%-90%) mixtures by modelisation, and on energy spark decomposition of the same mixtures by experiment. As arcs and high energy sparks are energetically similar, the results of the model are compared to the experimental ones.

Experiment

The sparks were generated by discharging a capacitor (3.59 J per spark) in a cylindrical Monel 400 cell (340cm^3) between a stainless steel point (diameter 1mm; radius of curvature 0.5 mm) and a stainless steel plane (diameter 25mm) in which a small rod of insulator (diameter 5 mm) was inserted just below the point as shown in Figure 1. The distance between the point and the insulator bar was 0.1 mm, the interelectrode gap spacing 0.9 mm.

Before filling with the gas, the cell was submitted to several heating (up to 60°C) pumping cycles and evacuated to a final pressure lower than 1Pa. The gaseous sample was used at a gas pressure of 100 kPa. At the end of each series of sparks the cell content was assayed by gas chromatography. The analytical conditions have been described earlier in detail [2].

The names, the chemical formulae and the temperature of crystalline fusion of the insulators tested are reported in Table1.

Finally reproducibility tests, carried out under the experimental conditions used here, showed that the uncertainty of our data was about ∓ 10%.

Model

The model used to calculate the extinguishing arc plasma composition is a chemical kinetic one based on the equations of