Nanocomposite coatings for high temperature insulation of electrical wires

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INTRODUCTION

Organic polymers and inorganic materials (ceramics / glasses) are both electrical insulators, widely used in different applications according to their inherent nature. Polymers possess high dielectric strength and mechanical flexibility, thus are usually applied to conductor wire insulation, whilst ceramics have very high temperature stability but mechanical brittleness, and hence are mostly used in applications where high temperature is essential while mechanical flexibility is not. For wire insulation, polymers place an up-limit on service temperature, with the highest temperature rating being 240°C at present market from polyimide enamelled wires, e.g. NEMA MW16-C. There is, however, a significant design need for flexible and versatile insulation materials capable of operating at temperatures well above polymer insulation, particularly for some emerging technologies such as more electric aircraft and downhole applications [1,2]. This work presents a type of nanocomposite coatings for wire insulation to offer excellent thermal stability far beyond polymer enamels can reach whilst maintains moderate flexibility.

EXPERIMENTAL

Nanocomposite coatings were compounded from silicon-containing inorganic-organic nano-hybrids and particulate ceramics.

Nano-hybrids were synthesised from organosilanes via conventional sol-gel process using phophormolybidic acid as the catalyst. A mixture of organosilanes bearing non-hydrolysable methyl, glycidyloxypropyl and phenyl groups was selected for optimal properties of the nano-hybrids.

Particulate ceramics were a mixture of vermiculite and talc, which was ball-milled to micron size in wet condition.

Nanocomposite coatings were prepared by mixing the nano-hybrids with the ceramic slurry and kept ball-milling for a period of time to ensure well dispersion of the components. The mass ratio of nano-hybrid to ceramic was in the range of 70:30 to 60:40.

A reel-to-reel continuous coating process is employed to fabricate insulated wires with nanocomposite coatings, which mimics commercial production lines. Conductor wires used in this case were nickel-plated copper wires.

RESULTS AND DISCUSSION

Thermal performance of the nano-hybrids were first studied for screening suitable nano-hybrids and an example is given in Fig. 1. The methyl starts decomposition at 418°C in air or 660°C in argon. When compounding with ceramic particles, the temperature rises to 505°C (50% silica), showing the nano-hybrid has well enough thermal stability.

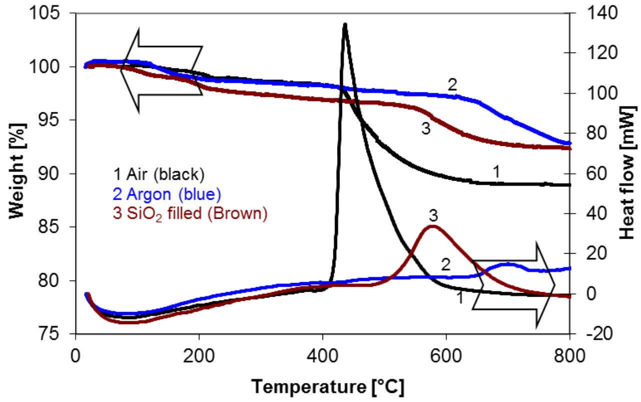

Fig. 1 Thermal behaviour of silicon-containing nano-hybrid with methyl as the organic moiety

The insulated wires thus fabricated under optimal coating formulations and operating parameters have uniform and smooth nanocomposite coats on surface as depicted in Fig. 2. The coated wires can be bent to certain radius for coil manufacture and can withstand over 1100V AC potential after heat treatment at 500°C.

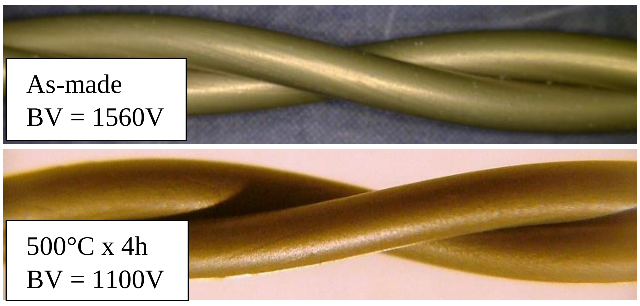

Fig. 2 Typical nanocomposite coated wire in twisted form

CONCLUSION

Nanocomposite coatings comprising silicon-based inorganic-organic nano-hybrids and particulate ceramics are successfully developed and applied to prepare insulated electric wires with moderate mechanical flexibility and thermal stability up to 500°C, providing a new wire member with significant potentials in emerging technologies.

REFERENCES

[1] J.A Rosero et al. IEEE Aerospace and Electronic Systems Magazine, 22, 3-9 (2007).

[2] J. Thompson et al. SPE/ICoTA Coiled Tubing & Well Intervention Conference and Exhibition, 5-6 April 2011

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