Process-related mechanical properties of conductive Nanocomposites based on CNT-filled Polypropylen

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Abstract

The increasing miniaturisation of products including electronic and mechatronic assemblies leads to a maximal integration of functions and developments of manufacturing technologies for very small multi-component devices. For this purpose the micro injection moulding technology for plastic based micro parts is outstandingly appropriated. This technology is able to produce plastic parts with a high degree of shape-freedom in a high quantity without post processing. The flexibility of this process allows the combination of different materials and the integration of metallic and ceramic inserts as well as electronic or magnetic functional parts [1, 2].

Compared to inherent conductive plastics, filled polymers gain their electrical conductivity through additives, e.g. metals or carbon in different modifications [3]. Depending on volume fraction and filling material, the electrical resistivity can be influenced in a wide range. Especially nano carbon tubes are appropriate to build a conductive network with a low filling material concentration, the so-called percolation threshold [4]. The typical curve of electrical conductivity depending on additive volume fraction shows fig. 1.

A characteristic of the injection moulding process is a distinct molecular orientation, which is caused by the flow of polymer melt induced shear and stretching forces [5]. Unlike the extrusion and compression moulding processes, the process forces are high enough to align the additives accordingly [6]. With regard to a shift of the percolation threshold to higher levels of carbon nano tube with an increasing orientation of the additives in the matrix, it is important to minimize this negative influence by a process optimization [7, 8].

The focus of the investigation is the influence of injection speed, melt temperature, cavity temperature and holding pressure were on the orientation of the nano tubes within the polymer matrix. Hence mainly the injection speed and the melt temperature have decisive influence on the mechanical properties and on the conductivity of the composites.

Since an increasing injection speed leads to a significant decrease in the yield modulus (fig. 2a), in the strength as well as in the electrical conductivity by several orders of magnitude, an increase of melt temperature leads to improved electrical conductivity but to decrease in the yield modulus (fig. 2b) and also the strength. The influence of the melt temperature is significantly lower compared to the injection speed and the effect of cavity temperature as well as holding pressure is only marginal.

Particularly for the PP matrix plastic, these results could be detected with high significance. They thus contradict the well-known phenomenon from the conventional injection molding of an increase in strength with increase in energy input by increasing the focus and distribution of carbon nano tubes within the polymer matrix [8].

It can therefore be assumed that the orientation and distribution of carbon nano tubes have smaller influence on the mechanical properties of the micro-injection molded nanocomposites. As possible causes for the progression of results in micro injection molding, there are two explanations: With the increase of energy input the aspect ratio of carbon nanotubes changes and by increasing the energy input the molecular structure of the matrix resins changes.

References

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Figures

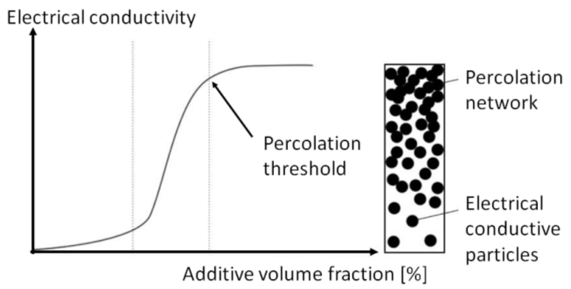

Figure 1: *Electrical conductivity depending on additive volume fraction [9]*

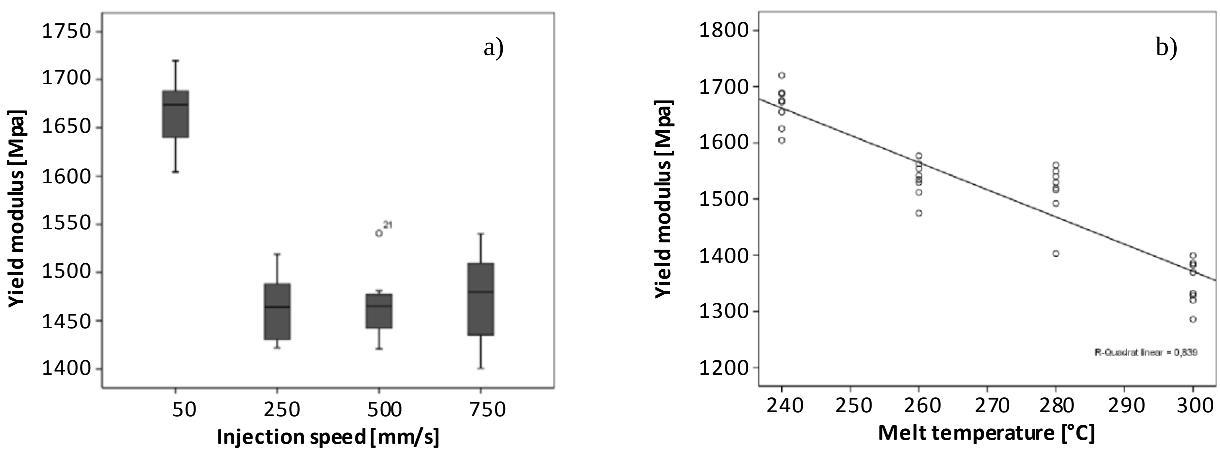

Figure 2: *a) Yield modulus depends on the injection speed of PP with 5-wt% CNT;*
b) Yield modulus depends on the melt temperature of PP with 5-wt% CNT