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Polyimide Coated Capillary Tubing: Internal Pressure Capabilities >

JOE MACOMBER AND CRAIG R. FOREST
MOLEX INCORPORATED

Polyimide coated fused silica capillary tubing is of growing importance in the field of Liquid Chromatography. This application note discusses the internal pressure handling capabilities of fused silica capillary from a theoretical standpoint.

Introduction

As LC systems miniaturize and move toward smaller i.d. columns packed with sub-2 μ m particles, capillary is proving to be a popular column support. With the use of these columns comes the need for high pressures to offset the inherent decrease in column permeability. In addition, capillary is frequently employed as transfer line within these systems to minimize band broadening between injectors, columns and detectors. Both the column and associated transfer lines can be exposed to very high system pressures. Fused silica capillary tubing has been shown to provide the mechanical strength required for systems operation at pressures exceeding 28kpsi (1,2). Patel *et al.* has demonstrated the use of 10 μ m i.d. fused silica tubing at run pressures over 100kpsi (3).

When using fused silica capillary in a high pressure system, selection of an appropriate tubing size is critical. Failure to employ tubing of sufficient mechanical strength can be dangerous and lead to system failure. This application note discusses capillary strength and related considerations.

Mechanical Strength of Capillary Tubing

The theoretical internal pressure capability of fused silica capillary has been calculated using Roark's formulas (4). Required inputs are the capillary i.d., capillary glass o.d. and the internal pressure to which the capillary is exposed. One must calculate the radial, tangential and longitudinal stress on the capillary due to the applied internal pressure. Failure occurs if any one of these stresses exceeds the yield stress of the fused silica. Although a number of different values for yield stress have been reported, the value of 5.88×10^9 Pa (852.6kpsi) is recommended herein (5). It should be noted that this yield stress is more than 10 times greater than that of commonly used polymeric tubing found in low pressure systems.

In most cases, tangential stress causes failure. Tangential stress as a function of radial distance from the capillary center can be calculated using Equation 1.

$$\sigma_t(r) = ((pr_i^2)/(r_o^2 - r_i^2))(1 + (r_o^2/r^2)) \quad (1)$$

Where: σ_t is the tangential stress, p is the internal pressure applied, r_i is $\frac{1}{2}$ the capillary i.d., r_o is $\frac{1}{2}$ the capillary glass o.d. (not including the polyimide coating), and r is a radius value within the tubing wall.

The highest stress in the wall occurs where r is equal to r_i , which is at the internal wall of the capillary. This equation suggests that the TSP010375 capillary (i.d. = 10 μ m & o.d. = 323 μ m) pressurized to ~103kpsi by Patel *et al.* offered a safety factor of ~8 (3).

Other Important Considerations

A number of factors can reduce the effective operating limit. These include i.d. contamination from cutting or cleaving debris, damage to the i.d. from packing media, the use of aggressive or unfiltered solvents that may attack or damage the i.d. surface, long term exposure of the i.d. to the environment, external handling damage to the o.d. and other cumulative applied stresses such as bending or twisting of the capillary while at high pressure. Introduction of flaws into the fused silica i.d. or o.d., or the addition of other stresses, will lower the effective yield strength and can lead to premature failure at lower than expected pressures. Appropriate laboratory safety precautions should always be taken when working at high pressure and an appropriate safety factor should be determined and employed. High pressure usage concerns have been outlined previously (6).

Conclusion

Fused silica capillary is proving to be a key component in high pressure LC systems due to its outstanding strength properties. Guidelines for determining the applied stress, as well as other considerations, have been discussed.

References

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