Doty Spinner Assembly Materials

Doty spinners utilize super-precision, wear-resistant ceramic stators of silicon nitride or zirconia. MAS spinner materials must be chosen carefully based on background signals and temperature ranges. Ceramic rotors and plastic caps of various materials are available to provide fast spinning with limited background problems.

Material	Material Specifications			Turbine Cap Specifications	
	Upper Temp	Major Constituents	Minor Elements	Recommended Use	Cap VT Operation Range
Silicon Nitride	1400°C *	98% Si_3N_4	2% Y_2O_3, .005 Al	High Temp probe (750°C)	21°C to 750°C
Zirconia	650°C *	94 ZrO_2, 4 Y_2O_3	Hf, 0.3% Si, .02 Al	----------	----------
Macor	650°C *	Al, Si, O, B, K	2% F, Mg	for High Speed and Standard probes only – Macor o-ring caps	-60°C to 250°C
Kel-F	160°C *	F, C, Cl		proton & carbon studies	-20°C to 70°C.
GF Torlon	260°C*	H, C, O, Si	Ti, N	fast spinning, wide temperature range, wear resistant, low ^{19}F	-120°C to 160°C *(glued in with epoxy -170°C to 250°C)*
Aurum	240°C *	H, C, O	N	fast spinning and low ^{29}Si or low ^{19}F	-30°C to 80°C
Torlon	260°C*	H, C, O	Ti, N	fast spinning and low ^{29}Si or low ^{19}F	-30°C to 80°C
Vespel	300°C *	H, C, O	N	special extended VT caps	-270°C to 240°C

*** Note:** This chart represents only material characteristics. Check the Probe Specifications.
Non-spinning parts can tolerate different temperatures than turbine caps spinning on rotors.

Ceramics

Silicon Nitride: With a density of about 3.18 g/cm^3 and a (working) tensile strength of 700 MPa, silicon nitride has the highest strength-to-weight ratio of any ceramic available today. Its hardness and toughness make it very difficult to grind, but it has the lowest dielectric loss and lowest permittivity of any engineering ceramic, making it the best choice for high frequencies. A HIPed (Hot Isostatic Pressed) variety is available with improved strength and dielectric properties. Its superior electrical properties make it the preferred material for most applications (often, even for silicon and nitrogen), because of silicon's long T_1 and nitrogen's low natural abundance. The color is black. The only additive or impurity greater than 200 ppm in this new material is yttria. Silicon nitride stators, housings, and rotors are available in all sizes. This material is required for fastest spinning.

Zirconia: This yttria-stabilized, high-purity material is glossy white and has a density of about 6 g/cm^3 and a (working) tensile strength of 700 MPa. Alumina content can be kept below 100 ppm. Zirconia is less expensive than silicon nitride, but the safe spinning speed for zirconia rotors is lower than that of silicon nitride.

Macor: This white, machineable, boro-silicate glass-ceramic is loaded with synthetic mica to inhibit crack propagation. It is easily machined with conventional tooling. Macor housings may be provided for carbon and proton studies at temperatures over 160°C in our standard speed MAS probes. Macor is useable up to 650°C, but it has very poor thermal shock tolerance. Macor rotors are only available for the high speed and standard spinners. Macor rotors are made with a thicker wall and are machined with an integral turbine at one end. Standard speed rotors require a plug-cap at the open end, while high-speed rotors require a rear turbine. Macor rotors are recommended for wet samples, air-sensitive samples, and temperatures from -150°C to 250°C. Major constituents: Al, Si, O, B, K, F.

Boron Nitride: The hexagonal hot-pressed variety, with 6% calcium borate binder, is easily machineable and is used for disposable inserts in the high-temperature ceramic rotors. The material is soft enough to scratch easily and may absorb up to 1% moisture.

SPINNER ASSEMBLY MATERIALS

Plastics

Improved MAS Turbine Caps – Glass-fiber-reinforced Torlon (GFT): Glass-fiber-reinforced Torlon grade 5030 will be used for some MAS turbine caps for greatly improved VT performance and all-around better reliability and performance. This new material stands out from the rest with respect to isotropic thermal expansion (only 16E-6/°C), tensile strength at 200°C (120 MPa), and heat distortion temperature (282°C). It also has rather low moisture absorption, high wear resistance, and high impact strength. These caps are the most wear resistant and have the widest temperature range. GFT is not recommended for proton studies, or for some silicon and some carbon studies. Caps may be used from -120°C to 160°C repeatedly (or when glued in with epoxy from -170°C to 250°C). *GFT caps are being phased in. DI probes, XC4 and XC5 are the first probes to use this turbine cap material.*

Kel-F: A translucent white plastic, Kel-F is background free for all nuclei except F, Cl, and C. Kel-F is also excellent for carbon studies since the strong fluorine coupling effectively broadens the Kel-F carbon signal, and there are no protons to cross polarize. Unfortunately, Kel-F is not as strong as the other cap materials and is thus restricted to lower spinning speeds. Kel-F turbine caps can be used at temperatures from -20°C to 70°C. (In non-spinning parts of the spinner assembly, the upper temperature limit is 150°C.)

Aurum*: This dark brown to black thermoplastic polyimide has excellent dielectric properties. Aurum can be used for low silicon applications when fast spinning is desired. Aurum is supplied for most turbine caps and spinner parts on probes designed for fluorine studies and other applications where carbon is not a problem. Turbine caps may be used from -30°C to 80°C repeatedly. (In non-spinning parts of the spinner assembly, the upper temperature limit is 240°C.)

Torlon*: Torlon is used for fastest spinning of DI3 turbines. This green thermoplastic polyamide-imide, has exceptional chemical resistance. Although Aurum is usually our standard, Torlon can be used as a substitute as the NMR characteristics are similar. Torlon is not recommended for proton studies or for some carbon studies. Caps may be used from -30°C to 80°C repeatedly. *The caps may be used once to higher temperatures but they will be too loose after that.* (In non-spinning parts of the spinner assembly, the upper temperature limit is 260°C.)

Vespel: This brown plastic is used for some extended temperature caps and for non-spinning spinner assembly parts that will reach temperatures over 200°C. Vespel is not recommended for proton studies or for some carbon studies.

O-Ring Caps

For wet samples, air sensitive samples, and variable temperatures

O-ring Caps: Turbines and plug caps with dual Viton o-ring seals are available for Macor, silicon nitride, and zirconia rotors. Macor rotors, (available only for standard and high speed probes) are recommended for wet samples, air sensitive samples, and temperatures from -60°C to 250°C. A single (rear) cap with o-rings is used with a Macor rotor. However, if faster spinning is critical, VT and air-sensitive experiments can be done in silicon nitride or zirconia rotors using o-ring-sealed cap pairs. O-ring turbine caps are normally inserted and removed by hand. Turbines with threaded holes can be ordered with a threaded insertion tool for use when loading samples in a glove box (and to remove standard speed plug caps.) Caps can be ordered with axial out-gassing holes for higher temperature work or to remove air bubbles.
Although the supersonic o-ring caps can be used for air sensitive samples in XC5 and XC7 probes, XC sealing cells are usually preferred.

- **Kel-F O-ring Caps:** ..... Temperature range with o-rings: -45°C to 80°C.
- **Aurum or Torlon O-ring Caps:** ..... Temperature range with o-rings: -45°C to 120°C.

Extended Temperature Caps

- **DI, XC4 and XC5 probes (and most supersonic) use Glass-fiber-reinforced Torlon (GFT) – glued in**.
  GFT – if glued in: ..... Temperature range: -170°C to 250°C

Except for DI3, Aurum is usually provided but Torlon may be supplied, depending on availability.

Doty MAS Spinning Speeds

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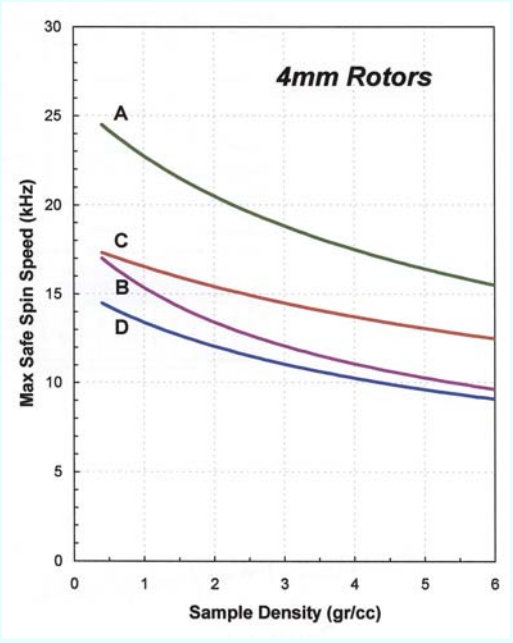
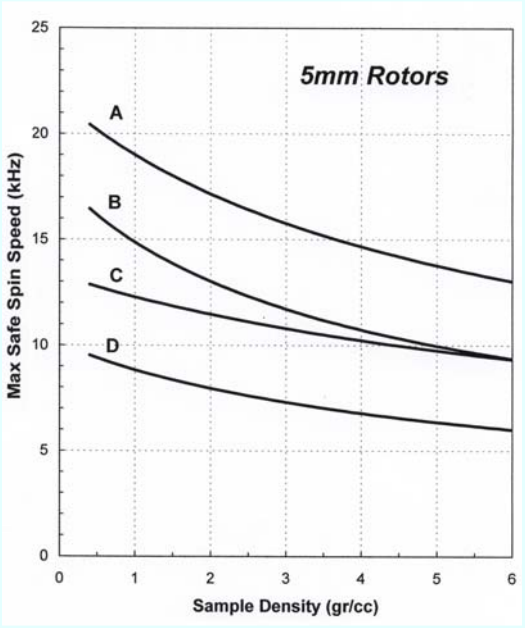
For the lastest updates on this page, see our website www.dotynmr.com

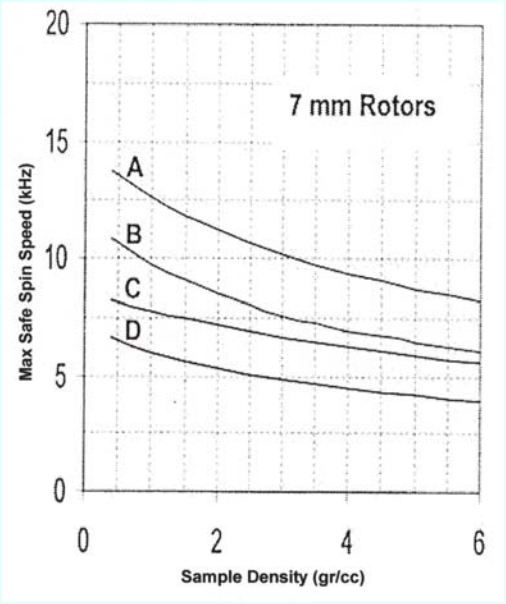
Maximum **PROBE** Speeds (kHz)	
DI 4	**18**
XC4	**24**
XC5	**18**
5 SS	**18**
5 HS	**14**
5 Std	**9**

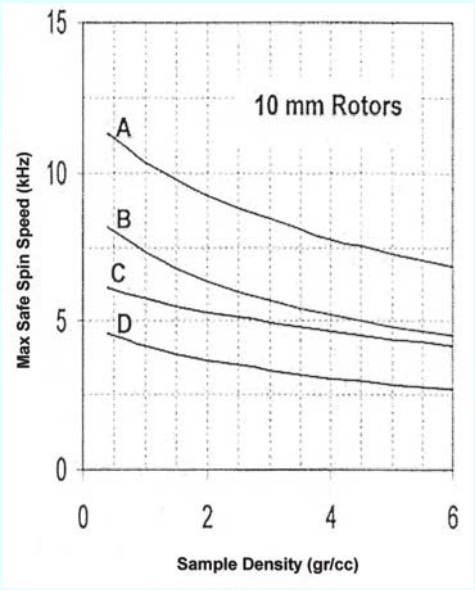




A - *Si_3N_4 Thick Wall* | **B -** *Si_3N_4 Thin Wall* | **C -** *Zr Thick Wall* | **D -** *Zr Thin Wall*

Maximum **PROBE** Speeds (kHz)	
XC7	**12**
7 SS	**12**
7 HS	**9**
7 Std	**6**
XC10	**8.5**
10 SS	**8.5**





MAS Turbine Cap Spinning Speeds

Maximum Spinning Speeds (kHz) For Caps at Room Temperature

Cap Style	4 mm	5-mm XC or SuperSonic	5-mm Standard & High-Speed	7-mm XC or SuperSonic	7-mm Standard & High-Speed	10-mm XC or SuperSonic
Kel-F	**11**	**10**	**9**	**7**	**6**	**5**
Caps with o-rings	**----------**	**10**	**9**	**7**	**6**	**5**
Vespel w/screw	**----------**	**----------**	**9**	**12**	**11**	**8**
Vespel	**21**	**16**	**14**	**12**	**11**	**8**
Aurum	**----------**	**----------**	**14**	**14**	**12**	**10**
Torlon or GFT	**24**	**20**	**14**	**14**	**12**	**10**

Note: This chart represents only material characteristics for caps. Check the Probe Specifications. The spinning speed is often more limited by the probe or the rotor material.