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(54) **APPARATUS AND METHOD FOR  
 MICROWAVE PROCESSING OF LIQUIDS**

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 219/751; 422/21

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(56) **References Cited**

**U.S. PATENT DOCUMENTS**

3,611,135	10/1971	Margerum .	
4,144,468	3/1979	Mourier .	
4,196,332	4/1980	MacKay et al. .	
4,340,796	7/1982	Yamaguchi et al. .	
4,415,789	11/1983	Nobue et al. .	
4,504,718	3/1985	Okatsuka et al. .	
4,593,167	6/1986	Nilssen .	
4,777,336	10/1988	Asmussen .	
4,825,028	4/1989	Smith .	
4,843,202	6/1989	Smith et al. .	
4,866,344	9/1989	Ross et al. .	
4,889,966	* 12/1989	Meredith	219/745
4,937,418	* 6/1990	Boulard	219/751

(List continued on next page.)

**FOREIGN PATENT DOCUMENTS**

1-274380 \* 11/1989 (JP) ..... 219/745

**OTHER PUBLICATIONS**

A. K. Bose et al "Microwave-Induced Rapid Reactions for  
 Preparative Organic Chemistry," Proc. 29th Microwave  
 Power Symp., pp. 35-38 Int'l Microwave Power Inst., Jul.  
 25-27, 1994, Chicago IL.

H. D. Kimrey et al, "Microwave Sintering of Zirconia-  
 Toughened Alumina Composites," Mat. Res. Soc. Symp.  
 Proc., vol. 189, pp. 243-55, 1991.

Terry N . Tiegs et al. "Comparison of Properties of Sintered  
 and Sintered Reaction-Bonded Silicon Nitride Fabricated  
 by Microwave & Conventional Heating," Mat. Res. Soc.  
 Symp. Proc., vol. 347, pp. 501-6, 1994.

R. A. Abramovitch, "Applications of Microwave Energy in  
 Organic Chemistry. A Review," Org. Prep. Proceed. Int. , 23,  
 pp. 683-711, 1991.

R. J. Lauf et al, "2 to 18 GHz Broadband Microwave  
 Heating Systems," Microwave Journal, Nov. 1993.

B. MacKay et al, "Frequency Agile Sources for Microwave  
 Ovens," Journal of Microwave Power, 14 (1), 1979.

C. E. Holcombe et al "Importance of 'Casketing' for Micro-  
 wave Sintering of Materials," Journal of Materials Science  
 Letters 9 425-428, 1990.

C. E. Holcombe et al "Microwave Sintering of Titanium  
 Diboride," Journal of Materials Science 26, 3730-3738,  
 1991.

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(57) **ABSTRACT**

A microwave heating apparatus designed to allow concen-  
 tration of microwave power to a liquid sample to be  
 processed, by use of a field-perturbing tool disposed within  
 or proximate to the volume of liquid. Uniformity of pro-  
 cessing is achieved by circulating the liquid past the tool  
 during processing. The apparatus and method is particularly  
 useful when used to excite a nonlinear process whereby  
 greater overall process efficiency may be achieved.

**42 Claims, 6 Drawing Sheets**

