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**Govyadinov et al.**

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(54) **MICROFLUIDIC MIXING DEVICE**

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,858,185 B1 \* 2/2005 Kopf-Sill ..... B01L 3/5027 422/504  
7,763,453 B2 7/2010 Clemmens et al.  
(Continued)

FOREIGN PATENT DOCUMENTS

CN 102145265 A 8/2011  
WO WO-2009118689 A 10/2009  
(Continued)

OTHER PUBLICATIONS

Mansur, E. A. et al.; A State-of-the-art Review of Mixing in Microfluidic Mixers, Aug. 4, 2008; The State Key Laboratory of Chemical Engineering.

(Continued)

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(57) **ABSTRACT**

A microfluidic mixing device comprises a main channel and a number of secondary channels extending from a portion of the main channel and entering another portion of the main channel. A number of actuators are located in the secondary channels to pump fluids through the secondary channels. A microfluidic mixing system comprises a microfluidic mixing device. The microfluidic mixing device comprises a main fluid mixing channel, a number of main channel actuators to pump fluid through the main fluid mixing channel, a number of secondary channels fluidly coupled to the main fluid mixing channel, and a number of secondary channel actuators to pump fluids through the secondary channels. The microfluidic mixing device also comprises a fluid source, and a control device to provide fluids from the fluid source to the microfluidic mixing device and activate the main channel actuators and secondary channel actuators.

**20 Claims, 15 Drawing Sheets**

