US009979259B2

(12) **United States Patent**
Puskarich et al.

(10) **Patent No.: US 9,979,259 B2**
(45) **Date of Patent: May 22, 2018**

(54) **ELECTROMAGNETIC LEVITATOR**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)

(72) Inventors: **Paul Puskarich**, Palo Alto, CA (US); **Clark D. Della Silva**, San Francisco, CA (US); **Charles A. Schwalbach**, Menlo Park, CA (US); **David Samuel Kumka**, San Francisco, CA (US); **Andy Weidner**, San Francisco, CA (US); **Paulina Mustafa**, San Francisco, CA (US); **Jean-Marc Gery**, Los Angeles, CA (US)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 269 days.

(21) Appl. No.: **14/837,924**

(22) Filed: **Aug. 27, 2015**

(65) **Prior Publication Data**

US 2017/0063194 A1 Mar. 2, 2017

(51) **Int. Cl.**

H02K 7/09	(2006.01)
H02K 11/215	(2016.01)
F16C 32/04	(2006.01)

(52) **U.S. Cl.**

CPC ***H02K 7/09*** (2013.01); ***F16C 32/0444*** (2013.01); ***F16C 32/0446*** (2013.01); ***F16C 32/0453*** (2013.01); ***F16C 32/0457*** (2013.01); ***H02K 11/215*** (2016.01)

(58) **Field of Classification Search**

CPC H02K 7/09
USPC ..... 310/68 B
See application file for complete search history.

(56) **References Cited**

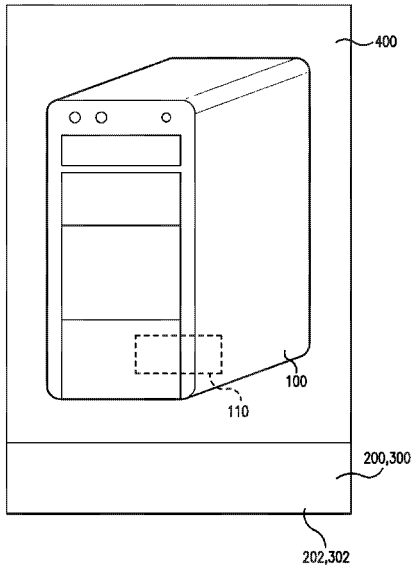
U.S. PATENT DOCUMENTS

4,585,282	A *	4/1986	Bosley	F16C 32/0451 104/284
5,168,183	A *	12/1992	Whitehead	F16C 32/044 104/284
5,332,987	A *	7/1994	Hennessy	H02N 15/00 310/90.5
7,185,590	B2 *	3/2007	Fu	H02N 1/08 104/281
7,348,691	B2 *	3/2008	Davis	A63H 33/26 104/284
8,647,166	B2 *	2/2014	Orozco	A63H 23/14 335/219
9,245,679	B1 *	1/2016	Termain	A47G 23/0241
2007/0170798	A1 *	7/2007	Gohin	H02N 15/00 310/90.5
2008/0026669	A1 *	1/2008	Rehkemper	A63H 3/28 446/301
2012/0062061	A1 *	3/2012	Belisle	B64C 39/001 310/90.5
2013/0309935	A1 *	11/2013	Olson	A63H 3/20 446/330

(Continued)

Primary Examiner — Forrest M Phillips
(74) *Attorney, Agent, or Firm* — Sterne, Kessler, Goldstein & Fox P.L.L.C.

(57) **ABSTRACT**

A levitator is disclosed. The levitator may include a repulsion wire coil having a vertical coil axis, a position control wire coil having a vertical coil axis, a rotation control wire coil having a horizontal coil axis, and a controller coupled to each of the repulsion wire coil, position wire coil, and rotation wire coil, where the controller is configured to independently control currents provided to each of the repulsion wire coil, position wire coil, and rotation wire coil to levitate an item.

51 Claims, 13 Drawing Sheets