



US007968219B1

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

(10) **Patent No.:** **US 7,968,219 B1**
(45) **Date of Patent:** **Jun. 28, 2011**

(54) **MAGNETICALLY SOFT, HIGH SATURATION
MAGNETIZATION LAMINATE OF
IRON-COBALT-NITROGEN AND
IRON-NICKEL FOR PERPENDICULAR
MEDIA UNDERLAYERS**

(75) Inventors: **Hai Jiang**, Fremont, CA (US); **Kyusik Sin**, Pleasanton, CA (US); **Yingjian Chen**, Fremont, CA (US)

(73) Assignee: **Western Digital (Fremont), LLC**, Fremont, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 62 days.

(21) Appl. No.: **12/033,991**

(22) Filed: **Feb. 20, 2008**

Related U.S. Application Data

(60) Division of application No. 10/854,119, filed on May 25, 2004, now Pat. No. 7,354,664, which is a continuation-in-part of application No. 10/137,030, filed on May 1, 2002, now Pat. No. 6,778,358.

(51) **Int. Cl.**
G11B 5/66 (2006.01)

(52) **U.S. Cl.** **428/829; 428/821; 428/827**

(58) **Field of Classification Search** None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,589,042	A	5/1986	Anderson et al.
5,006,395	A	4/1991	Hori et al.
5,264,981	A	* 11/1993	Campbell et al. 360/125.45
5,408,377	A	4/1995	Gurney et al.
5,465,185	A	11/1995	Heim et al.
5,606,478	A	2/1997	Chen et al.

5,713,197	A	2/1998	Ogawa et al.
5,766,743	A	6/1998	Fujikata et al.
5,874,010	A	2/1999	Tao et al.
6,118,628	A	9/2000	Sano et al.
6,259,583	B1	7/2001	Fontana, Jr. et al.
6,335,103	B1	1/2002	Suzuki et al.
6,338,899	B1	1/2002	Fukuzawa et al.
6,353,511	B1	3/2002	Shi et al.
6,449,122	B1	9/2002	Yazawa et al.
6,490,131	B2	12/2002	Sano et al.
6,538,845	B1	3/2003	Watanabe et al.
6,541,065	B1	4/2003	Sasaki et al.
6,641,935	B1	11/2003	Li et al.
6,645,647	B1	11/2003	Litvinov et al.

(Continued)

OTHER PUBLICATIONS

Soft High Saturation Magnetization (Fe0.7Co0.3)1-xNx Thin Films for Inductive Write Heads, Sun et al, IEEE Transactions on Magnet-ics, vol. 36, No. 5 Sep. 2000.*

(Continued)

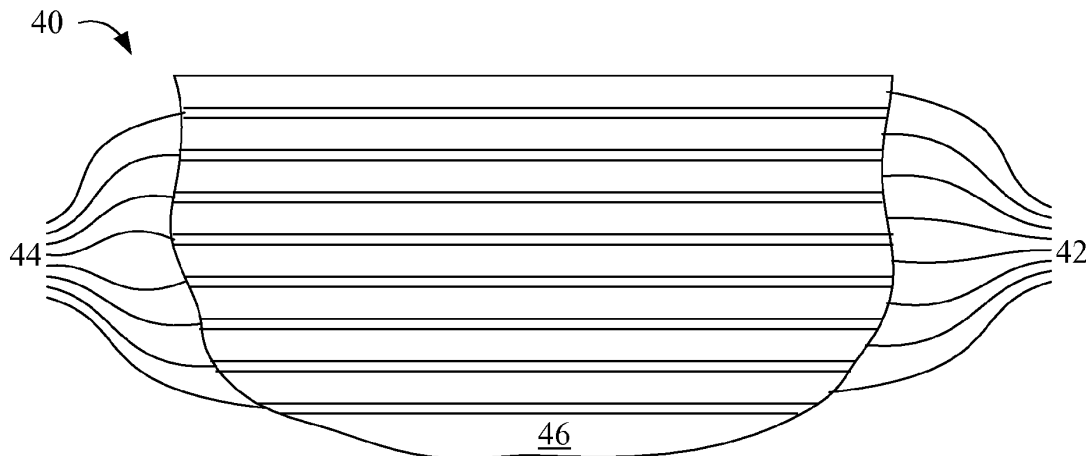
Primary Examiner — Mark Ruthkosky

Assistant Examiner — Gary Harris

(57) **ABSTRACT**

A magnetic disk includes a substrate, a soft magnetic under-layer disposed over the substrate, and a media layer disposed over the underlayer. The underlayer includes a first plurality of layers each containing NiFe having an atomic concentration of iron that is at least about thirty percent. The underlayer further includes a second plurality of layers that is interleaved with the first plurality of layers. The second plurality of layers each contain FeCoN having an atomic concentration of iron that is greater than an atomic concentration of cobalt, and having an atomic concentration of nitrogen that is less than the atomic concentration of cobalt. The atomic concentration of nitrogen is less than eight percent. The media layer contains a magnetically hard material having an easy axis of magnetization oriented substantially perpendicular to both the media layer and the underlayer.

6 Claims, 4 Drawing Sheets



U.S. PATENT DOCUMENTS

6,646,827 B1 11/2003 Khizroev et al.
 6,667,118 B1 12/2003 Chang et al.
 6,667,850 B2 * 12/2003 Khan et al. 360/125.5
 6,680,831 B2 1/2004 Hiramoto et al.
 6,713,197 B2 3/2004 Nakamura et al.
 6,714,380 B2 3/2004 Kawasaki et al.
 6,764,778 B2 7/2004 Saito et al.
 6,773,556 B1 8/2004 Brockie et al.
 6,777,066 B1 8/2004 Chang et al.
 6,778,358 B1 8/2004 Jiang et al.
 6,805,966 B1 10/2004 Formato et al.
 6,815,082 B2 11/2004 Girt
 6,835,475 B2 12/2004 Carey et al.
 6,844,724 B1 1/2005 Peng et al.
 6,890,667 B1 5/2005 Lairson et al.
 6,943,041 B2 9/2005 Sugita et al.
 6,970,324 B2 11/2005 Ikeda et al.
 7,008,702 B2 3/2006 Fukuzawa et al.
 7,097,924 B2 8/2006 Haginoya et al.
 7,177,117 B1 2/2007 Jiang et al.
 7,354,664 B1 4/2008 Jiang et al.
 2001/0008712 A1 7/2001 Yazawa et al.
 2002/0008936 A1 1/2002 Kawasaki et al.
 2002/0058161 A1 5/2002 Yamamoto et al.
 2002/0109947 A1 * 8/2002 Khizroev et al. 360/319
 2003/0022023 A1 * 1/2003 Carey et al. 428/694 MM
 2003/0197988 A1 10/2003 Hasegawa et al.
 2005/0011590 A1 1/2005 Kawasaki et al.

OTHER PUBLICATIONS

B. Viala, et al., "Microstructure and Magnetism in FeTaN Films Deposited in the Nanocrystalline State", *Journal of Applied Physics*, 80(7), Oct. 1996, pp. 3941-3956.
 N.X. Sun, et al., "Microstructure and Soft Magnetic Properties of High Saturation Magnetization Fe-Co-N alloy Thin Films", *Materials Research Society Symposium*, vol. 614, Apr. 2000, pp. F9.2.1-F9.2.12.
 S. Nakagawa, et al., "Improvement of soft magnetism of Fe₉₀Co₁₀ sputtered films by addition of N and Ta", *Journal of Applied Physics*, 79(8), Apr. 1996, pp. 5156-5158.

C.L. Platt, et al., "Magnetic and Structural Properties of FeCoB Thin Films", *IEEE Transactions on Magnetics*, vol. 37, No. 4, Jul. 2001, pp. 2302-2304.
 E.J. Yun, et al., "Magnetic Properties of RF Diode Sputtered CoFe_{100-x} Alloy Thin Films", *IEEE Transactions on Magnetics*, vol. 32, No. 5, Sep. 1996, pp. 4535-4537.
 N.X. Sun, et al., "Soft High Saturation Magnetization (Fe_{0.7}Co_{0.3})_{1-x}N_x Thin Films for Inductive Write Heads", *IEEE Transactions on Magnetics*, vol. 36, No. 5, Sep. 2000, pp. 2506-2508.
 T. Nozawa, et al., "Magnetic Properties of FeCoV Film Sandwiched by Thin Soft-Magnetic Films", *IEEE Transactions on Magnetics*, vol. 37, No. 4, Jul. 2001, pp. 3033-3038.
 X. Liu, et al., "High Moment FeCoNi Alloy Thin Films Fabricated by Pulsed-Current Electrodeposition", *IEEE Transactions on Magnetics*, vol. 37, No. 4, Jul. 2001, pp. 1764-1766.
 S. Wang et al., Improved high moment FeAlN/SiO₂ Laminated Materials for Thin Film Recording Heads, *IEEE Transactions on Magnetics*, vol. 27, Nov. 1991, pp. 4879-4881.
 B.D. Cullity, "Introduction to Magnetic Materials", Addison-Wesley, 1972, pp. 148.
 Higano et al., "Magnetic Properties of Re-TM-N System", vol. . . . Mag-23, No. 5, Sep. 1987.
 T. Ichihara et al., "Improvement of the Magnetic Characteristic of Multilayered Ni-Fe thin Films by Supplying External In-Plane Field during Sputtering", *IEEE Transactions on Magnetics*, vol. 32, No. 5, Sep. 1996, pp. 4582-4584.
 S. Nakagawa et al., "Soft Magnetic and Crystallographic Properties of Ni_{sub.81}Fe_{sub.19}/Co_{sub.67}Cr_{sub.33} Multilayers as Backlayers in Perpendicular Recording", *IEEE Transactions on Magnetics*, vol. 30, No. 4, 1994, pp. 4020-4022.
 N.R. Darragh et al., "Observation of Underlayer Domain Noise in Perpendicular Recording Disks", *IEEE Transactions on Magnetics*, vol. 29, No. 6, Nov. 1993, pp. 3742-3744.
 Parkin et al., "Oscillations in Exchange Coupling and Magnetoresistance in Metallic Superlattice Structures: Co/Ru, Co/Cr and Fe/Cr", *Phys. Rev. Lett.*, vol. 64, 1990, pp. 2034.

* cited by examiner

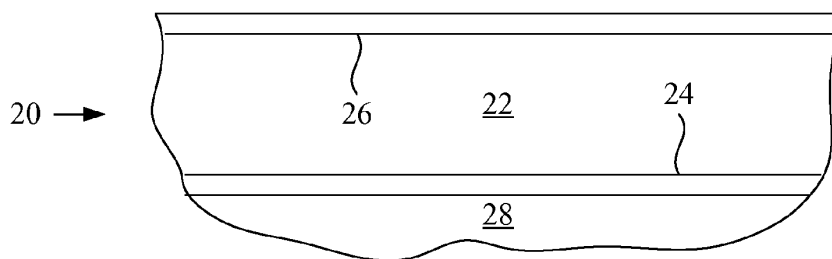


FIG. 1

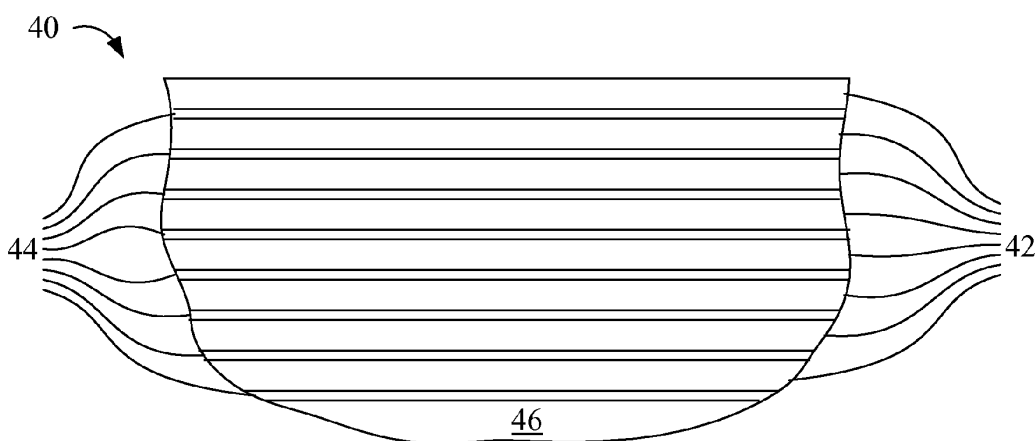


FIG. 2

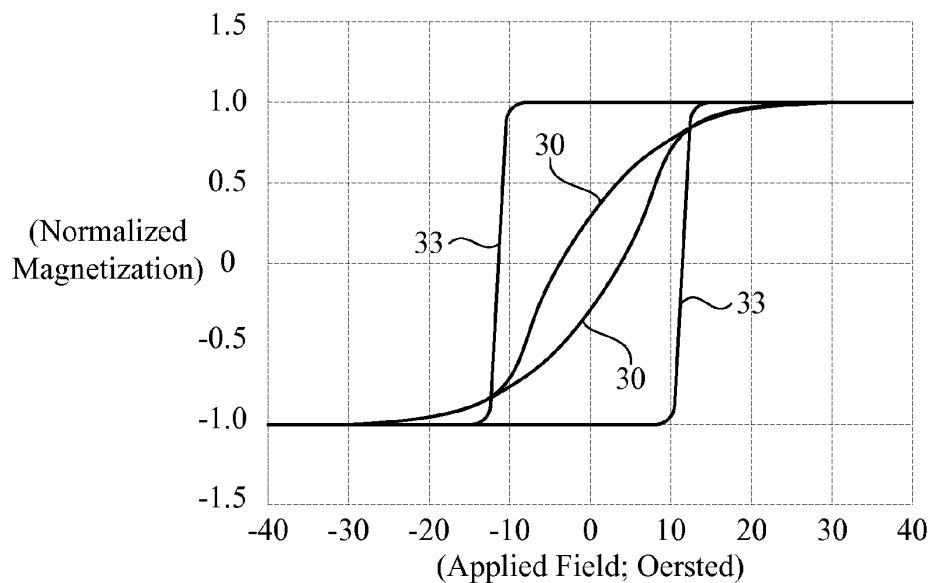


FIG. 3

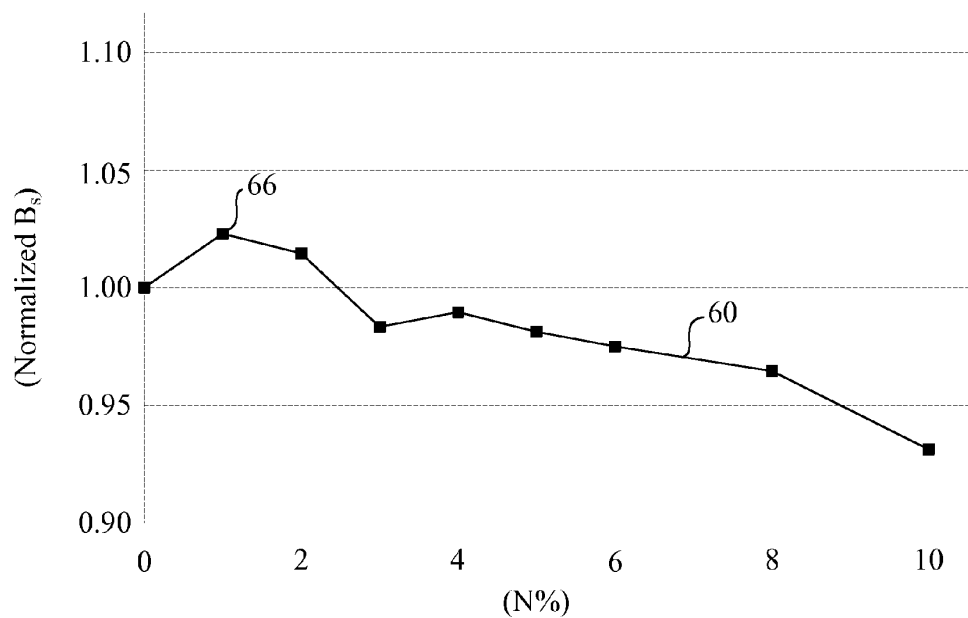


FIG. 4

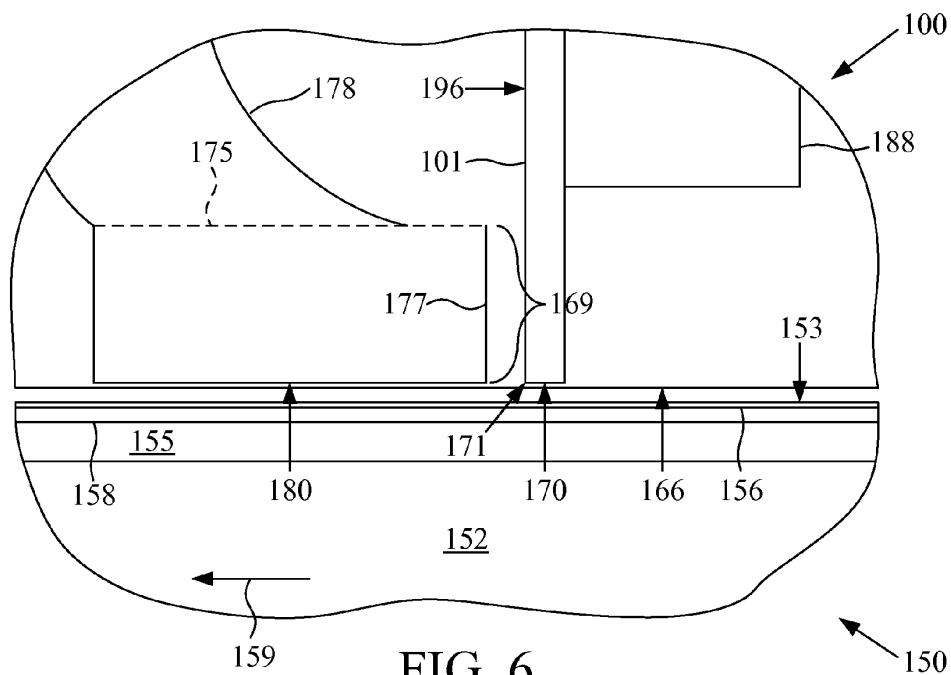
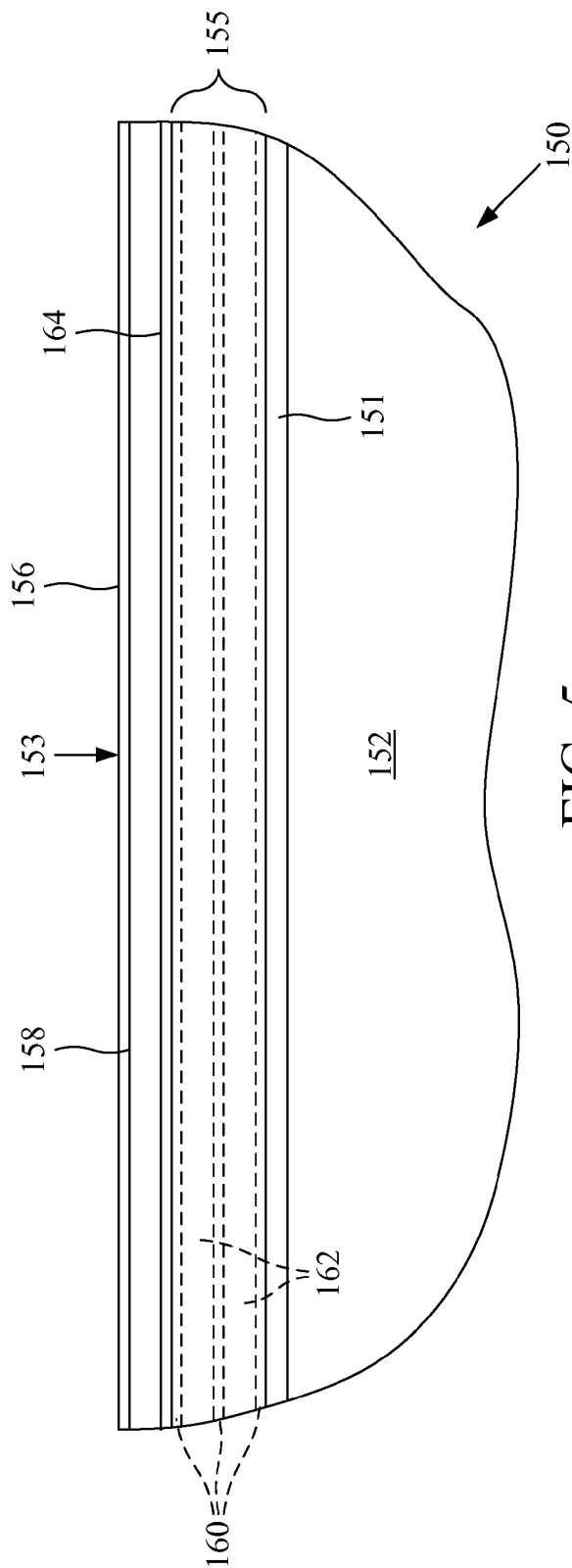


FIG. 6



Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.