



US009411208B2

(12) **United States Patent**  
**Yamazaki**

(10) **Patent No.:** **US 9,411,208 B2**  
(45) **Date of Patent:** **Aug. 9, 2016**

- (54) **DISPLAY DEVICE**
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- (\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.
- (21) Appl. No.: **14/740,599**
- (22) Filed: **Jun. 16, 2015**
- (65) **Prior Publication Data**  
US 2015/0309347 A1 Oct. 29, 2015

USPC ..... 257/43, 347  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

5,731,856 A 3/1998 Kim et al.  
5,744,864 A 4/1998 Cillessen et al.

(Continued)

**FOREIGN PATENT DOCUMENTS**

CN 001527649 A 9/2004  
EP 1737044 A 12/2006

(Continued)

**OTHER PUBLICATIONS**

Asakuma.N et al., "Crystallization and Reduction of Sol-Gel-Derived Zinc Oxide Films by Irradiation With Ultraviolet Lamp", Journal of Sol-Gel Science and Technology, 2003, vol. 26, pp. 181-184.

(Continued)

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(57) **ABSTRACT**

One object is to provide a transistor including an oxide semiconductor film which is used for the pixel portion of a display device and has high reliability. A display device has a first gate electrode; a first gate insulating film over the first gate electrode; an oxide semiconductor film over the first gate insulating film; a source electrode and a drain electrode over the oxide semiconductor film; a second gate insulating film over the source electrode, the drain electrode and the oxide semiconductor film; a second gate electrode over the second gate insulating film; an organic resin film having flatness over the second gate insulating film; a pixel electrode over the organic resin film having flatness, wherein the concentration of hydrogen atoms contained in the oxide semiconductor film and measured by secondary ion mass spectrometry is less than  $1 \times 10^{16} \text{ cm}^{-3}$ .

**20 Claims, 26 Drawing Sheets**

- Related U.S. Application Data**
- (63) Continuation of application No. 14/154,534, filed on Jan. 14, 2014, now Pat. No. 9,070,596, which is a continuation of application No. 13/594,934, filed on Aug. 27, 2012, now Pat. No. 8,637,863, which is a continuation of application No. 12/959,989, filed on Dec. 3, 2010, now Pat. No. 8,269,218.
- (30) **Foreign Application Priority Data**  
Dec. 4, 2009 (JP) ..... 2009-276454
- (51) **Int. Cl.**  
**H01L 29/12** (2006.01)  
**H01L 27/12** (2006.01)  
(Continued)
- (52) **U.S. Cl.**  
CPC ..... **G02F 1/1368** (2013.01); **G02F 1/1337** (2013.01); **H01L 27/1225** (2013.01); **H01L 29/7869** (2013.01); **H01L 29/78606** (2013.01); **H01L 29/78648** (2013.01)
- (58) **Field of Classification Search**  
CPC ..... H01L 27/1225; H01L 29/78606; H01L 29/7869

