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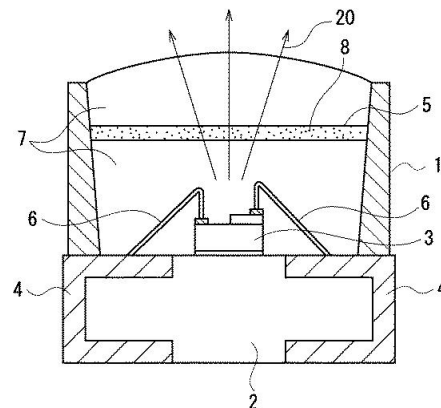
(54) [Title of the Invention] Light-Emitting Device

(57) [Abstract]

[Problem] To provide a light-emitting device capable of high-luminance emission with extremely low variation in emitted light.

[Solution] The light-emitting device comprises a light-emitting element 3 and a phosphor region in which phosphor particles 8, which absorb light emitted from the light-emitting element 3 and emit light of a different wavelength, are dispersed in a binder. The phosphor region is composed of a phosphor layer 5 in which the volume ratio of the phosphor particles 8 per unit volume is 10% or more.

[Selected Drawing] FIG. 1



[Claims]

[Claim 1]

A light-emitting device comprising a light-emitting element and a phosphor region formed by dispersing at least one type of phosphor particle, which absorbs light from the light-emitting element and emits light of a different wavelength, in a binder, and disposing the phosphor region in the light path of light from the light-emitting element, the light-emitting device characterized in that the phosphor region is composed of a phosphor layer in which the volume ratio of phosphor particles per unit volume is 10% or more.

[Claim 2]

The light-emitting device according to claim 1, wherein the volume ratio of phosphor particles is 19% or more.

[Claim 3]

The light-emitting device according to claim 1, wherein the volume ratio of phosphor particles is 40% or more.

[Claim 4]

The light-emitting device according to any of claims 1 to 3, wherein the shape of the aforementioned phosphor particles is polyhedral or spherical, and the average particle diameter is 0.1 μm to 15 μm .

[Claim 5]

The light-emitting device according to any of claims 1 to 4, further comprising a light guide member that receives light from the light-emitting element and emits planar light, wherein the phosphor layer is disposed in the light path of light emitted from the light-emitting element and the planar light emitted from the light guide member.

[Claim 6]

The light-emitting device according to any of claims 1 to 5, wherein the light-emitting element contains a nitride semiconductor that emits blue light, the phosphor layer emits yellow-green to orange light, and a mixture of the blue light and the yellow-green to orange light emits white light.

[Claim 7]

The light-emitting device according to any of claims 1 to 5, wherein the light-emitting element contains a nitride semiconductor that emits blue light, the phosphor layer emits green light and red light, and the blue light, green light, and the red light are mixed to emit white light.

[Claim 8]

The light-emitting device according to any of claims 1 to 5, wherein the light-emitting element is an element that emits ultraviolet light, and the phosphor layer has three types of phosphor layers that absorb at least some of the ultraviolet light and emit blue, green, and red light.

[Claim 9]

The light-emitting device according to any of claims 1 to 5, wherein the light-emitting element is an element that emits ultraviolet light, and the phosphor layer contains three types of phosphor particles that absorb at least some of the ultraviolet light and emit blue light, green light, and red light.

[Detailed Description of the Invention]

[Technical Field]

[0001]

The present invention relates to a light-emitting device used in an LED display, backlight light source, traffic signal, and indicator lights, and in particular to a wavelength conversion light-emitting device capable of converting the light emitted from a light-emitting element to a desired color hue, saturation, and brightness, and of realizing uniform light emission without deterioration in transparency, reduction in luminance, or color unevenness.

[Background Art]

[0002]

A color-conversion type light-emitting device comprising a light-emitting element (blue semiconductor light-emitting element) utilizing a nitride semiconductor that emits blue light (for example, $\text{Ga}_x\text{Al}_{1-x}\text{N}$, where $0 < x < 1$) and a phosphor that absorbs some of the blue light and emits yellow light, thereby obtaining white light, and a white light-emitting device comprising a light-emitting element that emits ultraviolet light and a phosphor that absorbs the ultraviolet light and emits blue, green, and red light are both known in the art.

[0003]

Such light-emitting devices emit white light by mixing blue light emitted from a light-emitting element composed of a semiconductor nitride electrically connected to a lead electrode and yellow light emitted from a phosphor substance such as YAG:Ce dispersed in a binder such as a transparent resin encapsulating the light-emitting element, and projecting the mixed light through a convex lens.

[0004]

Such light-emitting devices can also emit light of various colors, such as bluish white and yellowish white, depending on the type and amount of phosphor material used. In addition, white light with improved color rendering can be obtained by adding a phosphor material that emits red light.

[0005]

[Patent Document 1] JP H09-26511 A

[Patent Document 2] JP 2002-304129 A

[Patent Document 3] JP 2002-50800 A

[Disclosure of the Invention]

[Problem to Be Solved by the Invention]

[0006]

In such light-emitting devices, phosphor particles dispersed in the binder may cause unwanted light reflection and scattering, which reduces luminance. In response, the light-emitting device described in Patent Document 3 prevents a decrease in brightness by reducing the amount of phosphor dispersed in the light-transmitting resin.

[0007]

However, reducing the amount of phosphor in order to increase luminance means sacrificing the freedom to adjust the emission color by increasing the amount of phosphor particles, so this is not a fundamental solution.

[0008]

It is an object of the present invention to solve this problem and provide a light-emitting device with no variation in light emission by converting light from the light-emitting element into white light via a phosphor layer filled with high-density phosphor particles.

[Means for Solving the Problem]

[0009]

The present invention is a light-emitting device comprising a light-emitting element and a phosphor region formed by dispersing at least one type of phosphor particle, which absorbs light from the light-emitting element and emits light of a different wavelength, in a binder, and disposing the phosphor region in the light path of light from the light-emitting element, the light-emitting device characterized in that the phosphor region is composed of a phosphor layer in which the volume ratio of phosphor particles per unit volume (the "filling density" below) is 10% or more, preferably 19% or more, and more preferably 40% or more.

[0010]

The shape of the phosphor particles is preferably polyhedral or spherical. This improves the fluidity of the binders composed of, for example, an epoxy, acrylic, polycarbonate, or silicone binder in which the phosphors are dispersed, thereby improving workability and enabling a higher filling density of phosphor particles, which in turn allows for the formation of thinner phosphor layers. The average particle size of the phosphor is preferably in the range of 0.1 μm to 15 μm . This is because the luminous intensity of the phosphor particles themselves tends to decrease when the average particle size is smaller than 0.1 μm , and the luminous efficiency decreases when it exceeds 15 μm .

[0011]

The present invention may also emit white light by combining a light-emitting element composed of a nitride semiconductor that emits blue light and a phosphor layer composed of phosphor particles that emit yellow-green to orange light, and mixing the blue light and the yellow-green to orange light together. In addition, the present invention may emit white light by using a phosphor layer composed of phosphor particles that emit light in the green range and the red range instead of a phosphor layer composed of phosphor particles that emit light in the yellow-green to orange range, and mixing blue light with the green light and the red light. These simple configurations are able to realize a white light-emitting element with high luminance and high color rendering.

[0012]

The concept of increasing the filling density of phosphor particles, which is a feature of the present invention, may also be applied to light-emitting devices that use a light-emitting element that emits ultraviolet light and combines this with phosphor particles that absorb at least some of the ultraviolet light and emit blue-colored light, green-colored light, and red-colored light (B, G, and R light) to obtain white light by mixing these colors together. In this case, the three types of phosphor particles may be uniformly dispersed in a single layer, or laminated in three layers, namely, a blue phosphor layer, a green phosphor layer, and a red phosphor layer.

[Effect of the Invention]

[0013]

The present invention is a light-emitting device comprising a light-emitting element and a phosphor region formed by dispersing at least one type of phosphor particle, which absorbs light from the light-emitting element and emits light of a different wavelength, in a binder, and disposing the phosphor region in the light path of light from the light-emitting element, the light-emitting device characterized in that the phosphor region is composed of a phosphor layer in which the volume ratio of phosphor

particles per unit volume is 10% or more. This configuration makes it possible to provide a light-emitting device with high luminance and no variation in light emission using a small quantity of phosphor particles.

[Best Mode For Carrying Out the Invention]

[0014]

Through trial and error by conducting various experiments, the present inventors discovered that the main cause of variations in light emission and decreases in the luminance of color-converting light-emitting devices is related to the dispersion and disposal of the phosphor particles. The present invention is a product of this discovery.

[0015]

Color-conversion light-emitting devices of the prior art were designed based on the understanding that the filling density of phosphor particles should be as low as possible. Some light-emitting devices are known in the art in which phosphor particles are concentrated around the light-emitting element, but even in such cases, the filling density of the phosphor particles was at most about 5%. In the following explanation, "filling density" refers to the volume ratio of phosphor particles per unit volume of the phosphor region formed by dispersing phosphor particles in a binder.

[0016]

The inventors of the present invention have overturned the conventional wisdom that phosphor particles should fill the region in the light path from the light-emitting element at a density that is as low as possible in this type of light-emitting device, and have newly discovered that by filling the light path with a high density of phosphor particles, it is possible to obtain high luminance light emission without variation. This is thought to be due to the fact that this configuration effectively suppresses light scattering and reflection from the light-emitting element while efficiently and uniformly exciting the phosphor particles in the phosphor layer.

[0017]

The first embodiment of the present invention will now be described with reference to the drawings. FIG. 1 is a schematic cross-sectional view showing a light-emitting diode constituting the light-emitting device in the present embodiment.

[0018]

As shown in FIG. 1, a recessed portion is formed in a package 1 provided on a substrate 2, and a light-emitting element 3 is arranged on the bottom surface of this recessed portion. The light-emitting element 3 and two lead electrodes 4, 4 on the substrate 2 side are electrically connected via a pair of wires 6, 6 exposed from the bottom surface of the recessed portion. The light-emitting element 3 is formed by bonding a gallium nitride semiconductor to a sapphire substrate via a buffer layer. An epoxy resin is used to fill the recessed portion and seal the light-emitting element 3 disposed in this manner, forming a sealed portion 7. A phosphor layer 5, in which phosphor particles 8 are densely packed, is formed in the light path 20 of the light from light-emitting element 3. The phosphor layer 5 can be formed at any position in the light path 20, but in the present embodiment, it is formed in the sealed portion 7. The phosphor layer 5 may also be formed substantially parallel to the upper surface of the substrate 2. However, the phosphor layer may be curved such that the distance that light from the light-emitting element 3 travels through the phosphor layer is substantially equal across the entire light-emitting surface. The present embodiment of the present invention will now be described in greater detail.

[0019]

(Light-Emitting Element)

In the present invention, the light-emitting element 3 is capable of emitting light including a wavelength that excites the phosphor material (phosphor particles) 8, and there are no other restrictions in particular. However, semiconductor light-emitting devices, particularly gallium nitride semiconductors or gallium nitride-indium semiconductors capable of emitting short wavelengths that efficiently excite phosphor particles 8, are especially preferred as they are easy to mass produce and apply to various applications.

[0020]

In the light-emitting device of the present invention, white light emission can be achieved using various methods. For example, the emission wavelength of the light-emitting element 3 is set to 400 nm or more and 530 nm or less, preferably 420 nm or more and 490 nm or less, and a phosphor layer 5 is formed using phosphor particles 8 that emit light of a yellow color complementary to these wavelengths, such as YAG-based phosphor particles activated with Ce. By combining such a YAG-based phosphor with a nitrogen-containing Ca-Si-Al-O-N-based phosphor activated with Eu and/or Cr, it is possible to form a light-emitting diode with extremely high color rendering properties using a light-emitting element 3 that emits blue light.

[0021]

As another example, by setting the emission wavelength of the light-emitting element 3 to be shorter than 400 nm in the ultraviolet region and forming a phosphor layer 5 using phosphor particles 8 that absorb some of the ultraviolet light emitted from light-emitting element 3 and emit B, G, and R light, a color conversion type light-emitting device with higher color rendering properties can be obtained.

[0022]

In order to provide such a phosphor layer 5 on the sealed portion 7 of the light-emitting element 3, phosphor particles 8 may be dispersed in a binder before injecting a predetermined amount of this binder mixture onto the light-emitting element 3. In addition, the sealing agent for a light-emitting element 3 that emits ultraviolet light is preferably a resin or glass that is relatively resistant to ultraviolet light, taking into consideration deterioration caused by ultraviolet light.

[0023]

(Phosphor Particles)

The phosphor particles 8 used in the light-emitting device of the present invention can be any phosphor particles capable of being excited by at least some of the light from the light-emitting element 3 and emitting light of the desired wavelength. For example, the phosphor particles 8 in a light-emitting device that emits white light when used with a blue light-emitting element 3 can contain a YAG-based phosphor activated with cerium as mentioned above. This phosphor material has excellent durability due to its garnet structure, and its excitation spectrum peak can be designed to be around 450 nm.

[0024]

In addition, the B, G, and R emitting phosphor particles 8 used in combination with an ultraviolet light-emitting device, although not extensively listed here, may contain any phosphor material common in the art with excitation wavelengths in the near-ultraviolet region, such as $(\text{Ba}, \text{Ca}, \text{Mg})_{10}(\text{PO}_4)_6\text{Cl}_2:\text{Eu}$ and other halophosphates, $(\text{Ba}, \text{Ca})_3\text{MgSi}_2\text{O}_8:\text{Eu}$ and other silicates, $\text{BaMgAl}_{10}\text{O}_{17}:\text{Eu}$, $\text{BaAl}_{12}\text{O}_{19}:\text{Eu}$, $\text{SrAl}_2\text{O}_4:\text{Eu}$, $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}$ and other aluminates, and $\text{Y}_2\text{O}_3\text{S}:\text{Eu}$, $\text{La}_2\text{O}_3\text{S}:\text{Eu}$ and other sulfides.

[0025]

In the present invention, the phosphor layer 5 is formed so that the filling density of the phosphor particles 8 is 10% or more, preferably 19% or more, and more preferably 40% or more. Because a relatively high filling density must be realized when mixed with a binder composed of an epoxy resin, the phosphor particles 8 preferably have a narrow particle size distribution and a spherical or polyhedral shape. In addition, the average particle size of the phosphor particles 8 is preferably in the range of 0.1 μm to 15 μm . An appropriate amount of secondary phosphor particles 8, which are smaller in diameter

than the primary phosphor particles 8, are preferably added to the primary phosphor particles 8, so that the overall structure approaches the densest packing structure.

[0026]

More specifically, when primary phosphor particles 8 have the average particle radius R and a spherical shape, the size (r) of particles that fit into the gaps between three primary phosphor particles 8 is $0.15R$, and the size of the particles filling the gaps between four primary phosphor particles 8 is $0.22R$. Therefore, by bringing secondary phosphor particles 8, which have a size in the range $0.15R \leq r \leq 0.22R$, with each of the primary phosphor particles 8, a state extremely close to the densest packing state can be achieved. This allows for further control of light concealment, scattering, and reflection, and for the creation of high-luminance light-emitting devices. In addition, by setting the size of the phosphor particles 8 within the range described above, the light absorption rate can be increased and the conversion efficiency improved (by improving transmittance). Furthermore, the light-emitting wavelength range can be increased.

[0027]

The phosphor layer 5 may be formed by mixing different types of phosphor particles 8 throughout the phosphor layer 5, or by laminating multiple phosphor layers, each containing a single type of phosphor particle 8.

[0028]

In the present invention, the thickness of the phosphor layer 5 may be determined in accordance with the wavelength and intensity of light from the light-emitting element 3, the hue, saturation, and brightness of the desired light, and the average particle size and luminance of the phosphor. However, a thinner layer is more preferable. The parameters are selected so that the particle size is preferably $50\text{ }\mu\text{m}$ or less, and more preferably $10\text{ }\mu\text{m}$ or less.

[0029]

The following is a description of examples of the present invention. The present invention is not limited to the examples shown below.

[0030]

(Example 1)

A surface-mounted light-emitting device like the one shown in FIG. 1 is formed. The light-emitting element 3 is a nitride semiconductor light-emitting element having an $\text{In}_{0.2}\text{Ga}_{0.8}\text{N}$ semiconductor with a monochromatic emission peak in the visible light range of 475 nm as the light-emitting layer, which is disposed in package 1.

[0031]

Meanwhile, phosphor particles 8 (YAG:Ce) with an average particle size of approximately $2\text{ }\mu\text{m}$ and a roughly spherical shape are mixed into a liquid epoxy resin binder to reach a filling density of approximately 40%, and the mixture is thoroughly stirred using three rollers.

[0032]

First, a sealing agent composed of an epoxy resin, etc., is injected into the package 1 to form a first sealed portion 7. Then, a predetermined amount of the binder containing the phosphor particles 8 is injected onto the upper portion of the first sealed portion 7 to form a phosphor layer 5. At this time, the sealed portion 7 has cured somewhat so that the phosphor particles 8 do not enter the interior of the sealed portion 7. Then, the epoxy resin is injected onto the phosphor layer 5 to form a second sealed portion 7. Note that if the refractive indices of the binders in the sealed portion 7 and the phosphor layer 5 are different, light loss will occur, so the same epoxy resin is used. In this way, a color conversion type

light-emitting device is obtained by adjusting the thickness of the phosphor layer 5 to output white light exhibiting the desired chromaticity of 0.31 (simply "white light" below).

[0033]

(Example 2)

A color-conversion type light-emitting device that emits "white light" was obtained in the same manner as Example 1 except that a phosphor layer 5 was formed using phosphor particles 8 with a filling density of approximately 19%.

[0034]

(Comparative Example 1)

A color-conversion type light-emitting device that emits "white light" was obtained in the same manner as Example 1 except that a phosphor layer 5 was formed using phosphor particles 8 with a filling density of approximately 6%.

[0035]

(Comparative Example 2)

A color-conversion type light-emitting device that emits "white light" was obtained in the same manner as Example 1 except that a phosphor layer 5 was formed using phosphor particles 8 with a filling density of approximately 1.6%.

[0036]

For each of Examples 1 and 2 and Comparative Examples 1 and 2, (a) the luminance of the "white light" emitted, (b) the thickness of the phosphor layer, and (c) the amount of phosphor used were determined. The results are summarized in Table 1. Note that (c) the amount of phosphor is expressed as the ratio ($V1/V2$) of the total volume ($V2$) of phosphor in the phosphor layer of Comparative Example 2 to the total volume ($V1$) of phosphor in the phosphor layers of Examples 1 and 2 and Comparative Examples 1 and 2. In the case of Comparative Example 2, this ratio is 1.0.

[0037]

[Table 1]

	Filling Density	(a) Luminance of Emitted "White Light"	(b) Thickness of Phosphor Layer	(c) Amount of Phosphor Used (Volume Ratio vs. Comparative Example 2)
Example 1	40%	220	6 μm	0.38
Example 2	19%	215	14 μm	0.41
Comparative Example 1	6%	210	50 μm	0.47
Comparative Example 2	1.6%	200	400 μm	1.0

[0038]

Table 1 shows that increasing the filling density of the phosphor reduces the amount of phosphor required and produces high-intensity "white light."

[0039]

Next, the second embodiment of the present invention will be described with reference to Figure 2. FIG. 2 is a schematic perspective view of the light-emitting device (backlight) in the present embodiment.

[0040]

The light-emitting device (backlight) 10 comprises an LED (light-emitting diode) 11, a light guide sheet (light guide member) 12, a reflector sheet 13, a diffuser sheet 14, and a prism sheet 15. The LED 11 comprises the same components as the light-emitting diode in the first embodiment shown in FIG. 1, except for the phosphor layer 5, and is disposed opposite the side surface of the light guide sheet 12. Reflector sheet 13 is disposed on the rear surface of the light guide sheet 12, and the diffuser sheet 14 and the prism sheet 15 are laminated on the surface of light guide sheet 12. The light emitted from the LED 11 enters light guide sheet 12, where some of it is reflected by the reflector sheet 13 and emitted from the surface of light guide sheet 12, passing through the diffuser sheet 14 and the prism sheet 15. This causes planar emission from the surface of the light guide sheet 12 (the surface of the prism sheet 15).

[0041]

In the present embodiment, the phosphor layer 5, which is densely packed with phosphor particles 8, is disposed between the light guide sheet 12 and the diffuser sheet 14, rather than inside the LED (light emitting diode) 11. The phosphor layer 5 is in the form of a thin layer or sheet and is adhered to the surface of the light guide sheet 12. The phosphor layer 5 may also be formed integrally with the light guide sheet 12. In addition, the phosphor layer 5 can be positioned at any location in the light path 20 from the LED 11, for example, between the LED 11 and the light guide sheet 12, or between the diffuser sheet 14 and the prism sheet 15.

[0042]

In addition to a backlight, the present invention can be applied to other lighting devices such as headlights for vehicles. In this case, the phosphor layer may be disposed at any position in the light path, including not only the interior of the LED but also the exterior of the LED (for example, on the inner surface of a lens or a cover for covering the exterior of the LED).

[0043]

In other words, the present invention is not limited to the embodiments described above and modifications thereof, and various modifications may be made depending on the design, etc., as long as they do not depart from the technical concept of the present invention.

[Brief Description of the Drawings]

[0044]

[FIG. 1]

FIG. 1 is a schematic cross-sectional view showing a light-emitting diode constituting the light-emitting device in the first embodiment.

[FIG. 2]

FIG. 2 is a schematic perspective view showing the light-emitting device in the second embodiment.

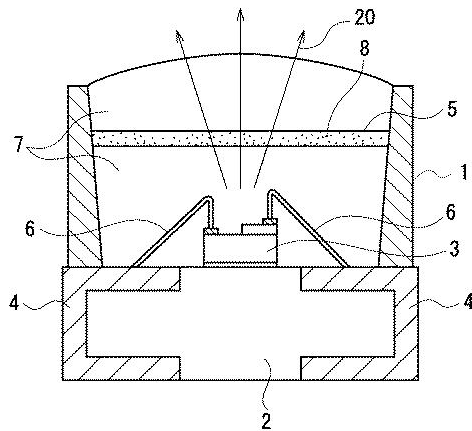
[Reference Numbers]

[0045]

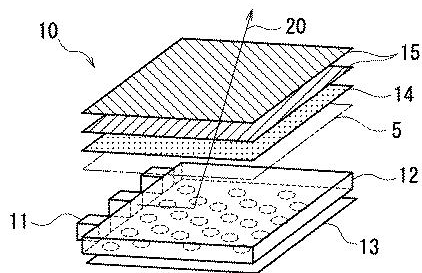
- 1 ... Package
- 2 ... Substrate
- 3 ... Light-emitting element
- 4 ... Lead electrode
- 5 ... Phosphor layer

- 6 ... Wire
- 7 ... Sealed portion
- 8 ... Phosphor particles
- 10 ... Light-emitting device (backlight)
- 11 ... LED (light-emitting diode)
- 12 ... Light guide sheet (light-guiding member)
- 13 ... Reflector sheet
- 14 ... Diffuser sheet
- 15 ... Prism sheet
- 20 ... Light path

[FIG. 1]



[FIG. 2]



Continued From Front Page

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**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD**

Affidavit of Frank McGee

I, Frank McGee, hereby declare as follows:

I am a citizen of the United States of America and I am over 18 years of age. I have personal knowledge of the matters stated in this affidavit, all of which are true and correct.

I am a Translator for Sun IP.

I submit this declaration to certify the accuracy of the translation I performed relating to JP2005332963A (hereinafter "-963").

I am qualified to translate Japanese technical documents into English, including translating Japanese patent documents into English. My qualifications include an MA in East Asian Languages from the University of Chicago and 30 years of experience as a full-time Japanese-to-English IP translator.

Attached as **EX1019** is a true and accurate copy of -963.

Attached as **Exhibit 1004** is a true and accurate copy of an English translation of -963, which I prepared based on **EX1019** and my personal knowledge of the Japanese and English languages.

I understand that by submitting this declaration I may be called to testify about the facts contained in this affidavit and/or my translation of -963, and I agree to make myself available to testify at a reasonable location and time.

I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

A handwritten signature in blue ink, appearing to read 'Frank McGee', with a long horizontal flourish extending to the right.

Date: August 20, 2025

By: Frank McGee