[0016] According to another aspect of the present invention, a thin film photovoltaic device with back contacts is disclosed. The thin film photovoltaic device comprises; a first electrode disposed in a first layer; a semiconductor disposed in a second layer on the first electrode; an insulator disposed in a third layer on the semiconductor and having an interrupted pattern; a second electrode disposed in a fourth layer and only on the insulator; and an absorber entirely filling a fifth layer and disposed on the second electrode and filling the interrupted patterns of the insulator and the second electrode.

[0017] According to yet another aspect, a thin film photovoltaic device with back contacts is disclosed. The thin film photovoltaic device comprises; a first contact; a first semiconductor disposed on the first contact; a second semiconductor disposed on the first semiconductor; an interrupted second contact disposed on the second semiconductor; and an absorber disposed on the second contact and filling the interrupts in the second contact.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. **1** schematically shows a cross-sectional view of an aspect of a photovoltaic device of the present disclosure with back contacts;

[0019] FIGS. **2***a* and **2***b* show cross-sectional and plan views of a photovoltaic device of the present disclosure having three different semiconducting materials, each disposed in different layers with a layer comprised of a patterned contact between two such layers;

[0020] FIGS. **3***a* and **3***b* show cross-sectional and plan views of a photovoltaic device of the present disclosure having a patterned contact and a patterned insulator;

[0021] FIGS. **4***a* and **4***b* show cross-sectional and plan views of a photovoltaic device of the present disclosure having a patterned contact, an insulator, and an absorber extending into a semiconductor comprising layer;

[0022] FIGS. **5***a* and **5***b* show cross-sectional and plan views of a photovoltaic device of the present disclosure having a patterned contact and three different semiconducting materials, each disposed in a different layer, the patterned contact having a different geometry than that of the photovoltaic device shown in FIG. **2**;

[0023] FIGS. **6***a* and **6***b* show cross-sectional and plan views of a photovoltaic device of the present disclosure having a superstrate geometry;

[0024] FIGS. **7***a* and **7***b* show cross-sectional and plan views of a photovoltaic device of the present disclosure having a patterned contact and a patterned insulator;

[0025] FIG. **8** shows a cross-sectional scanning electron microscope image of a photovoltaic device of the present disclosure;

[0026] FIG. **9** shows a cross-sectional scanning electron microscope image of another aspect of the photovoltaic device of the present disclosure; and

[0027] FIG. **10** is a graphical illustration of the External Quantum Efficiency (EQE) as a function of the energy of the incoming light (eV) for an aspect of the present disclosure.

DETAILED DESCRIPTION

[0028] The following detailed description is of the currently contemplated modes of carrying out, or aspects of, the invention. The description is not to be taken in a limiting sense, but is made merely for the purpose of illustrating the general principles of the invention, since the scope of the invention is best defined by the appended claims. Various inventive features are described below that may each be used independently of one another or in combination with other features.

[0029] Aspects of the present disclosure may be of a first, second, or third generation device. For example, the photovoltaic device disclosed herein may be a third generation device and may include three-dimensional (3D) micro- or nano-scale structures (e.g., nano-wires and nano-rods in polymers), which may improve its efficiency. A third generation device may have a lower manufacturing cost than first and second generation devices and/or higher efficiency.

[0030] Aspects of the present disclosure may provide back-contact geometries for thin film devices with a micrometer-scale thickness and a contact (electrode) pitch that may be at or below a few micrometers. The pitch is defined as the imposed periodicity or typical pattern dimensions of the upper electrode.

[0031] In at least one aspect of the present disclosure, a photovoltaic device having two back contacts is provided wherein each back contact is disposed in a separate plane. In accordance with at least one aspect of the present disclosure, a three dimensionally structured thin film photovoltaic device is provided with back contacts in different layers. The back contacts may comprise two electrodes that are in different layers of the photovoltaic device wherein the layers having a contact are spaced apart with an insulating material or semiconducting material. The two electrodes may be configured to serve as back contacts for carrier extraction, when the device is in use. Optionally, the device may comprise an insulating substrate, or alternatively, one of the back contacts may be configured to dispose the other layers of the photovoltaic device and the device may be void of a substrate.

[0032] In at least one aspect of the present disclosure, a photovoltaic device comprises at least two electrodes with an insulating material therebetween. For example, a first electrode may be disposed in a first layer, an insulator may be disposed in a second layer, and a second electrode may be disposed in a third layer.

[0033] Aspects of the present disclosure may also comprise one or more thin film layers of one or more semiconducting materials or semiconductors. For example, the layer or layers between the first and second electrode may comprise one or more semiconducting material(s). The semiconducting materials may comprise n-type and/or p-type materials. Aspects of the presently disclosed device may further comprise one or more thin film layers of one or more absorbers. For example, an absorber may be disposed on the second electrode and the absorber may comprise a semiconducting material. In at least one aspect of the photovoltaic device disclosed herein, the semiconductor disposed on the first electrode comprises a first semiconductor and the absorber comprises a second semiconductor. The first semiconductor may comprise an n-type material and the second semiconductor may comprise a p-type material. Alternatively, the first semiconductor may comprise a p-type material and the second semiconductor may comprise a n-type material.

[0034] The present disclosure may provide a three-dimensional thin film photovoltaic device with back contacts that may be used for carrier collection when the device is illuminated. The back contacts may be disposed in different layers and may have an insulating material, or insulator, therebetween. Aspects, features and benefits may now become clear