In the recent years white light emitting diodes LED (WLED) lamps as solid-state light sources for the next generation of lighting have been displacing traditional light sources due to their advantages and unique properties, including high luminous efficiency, low electric consumption and energy saving, high brightness, long lifetime, small volume, environmental friendliness and price competitiveness against fluorescent lamps. The rate of the displacement for various applications such as backlighting for displays, automotive and general lighting depends on developing more powerful near UV and blue chips, more efficient PC and new conversion schemes of chip radiation to white light. It is assumed that for mass-producible 60W LED bulbs, the average luminous efficiency will increase from 76 lm/W in 2014 to ~110 lm/W in 2021 by taking into account a practical efficacy limit of 200 lm/W whereas the luminous efficiency of incandescent and fluorescent lamps is 15 and 75 lm/W, respectively. Replacing light bulbs and fluorescent tubes with WLED will lead to a drastic electricity reduction by taking into account that 20-30% of the electricity consumed in industrial economies is used for lighting.

At present a WLED source manufactured based on the blue LED chip and a yellow emitting YAG:Ce powder phosphor converter (PC) dispersed in plastic encapsulate resin like epoxy and silicone is a canonical device (Fig.1a). While a large number of different phosphors have been developed to date, YAG:Ce is still the most popular phosphors for manufacturing WLED.

In the last decade the so-called Chip-Level-Conversion (CLC) design became accepted predominantly for the production of high power WLEDs (Fig.1b). The YAG:Ce and other high-temperature stable garnet crystals is a promising candidates for a planar phosphor in WLEDs. The yellow emission band of the Ce^{3+} doped garnets is complementary to the blue light emitted by an InGaN LED, thus making white light when the crystal thickness is around 0.4–0.6 mm. The emission color of such WLED can be changed by controlling the crystal thickness and Ce concentration. The highest reported value of the luminous efficacy of such device is around of 110 lm/W, which is comparable to that of commercial WLEDs.

For future developed CLC design for high-power WLEDs, we propose to use a new class of phosphors based on the single crystalline films of Ce^{3+} doped $(Lu,Gd,Tb,Y)_3Al_5O_{12}$ and $(Ca,Y)_3(Mg,Sc)_2Si_3O_{12}$ mixed garnets. Matrixes of these rare-earth based garnets can possess some important advantages compared to the conventional YAG:Ce phosphor due to additional channels for the excitation energy transfer from host to Ce^{3+} activator as well as the conditions for the creation of multicolor emission under excitation by near UV or blue LED chips.

Other pioneering works were performed in our project. Aside from the film phosphors, as a further development of the CLC concept, the use of two- and three- layered composite film-crystal epitaxial structures as colour converter for WLED is also considered in our project. White light under blue LED excitation was obtained by providing one- or two-layered $(Lu,Gd,Tb,Y)_3Al_5O_{12}$:Ce or $(Ca,Y)_3(Mg,Sc)_2Si_3O_{12}$:Ce garnet film phosphors epitaxially deposited onto Ce^{3+} doped YAG:Ce, LuAG:Ce and GAGG:Ce substrates to induce green, yellow and red emission in respective proportion suitable for creation of WLED with “colour on demand” white emission. To our knowledge, this is the first effort to create a multi-layered converter for WLED by epitaxy of one or two- single crystalline film converters onto YAG:Ce, LuAG:Ce and GAGG:Ce crystal-substrate converters.

To our knowledge, the development of PC based on the film and film-crystals epitaxial structures of Ce^{3+} doped $Lu,Gd,Tb,Y)_3Al_5O_{12}$:Ce or $(Ca,Y)_3(Mg,Sc)_2Si_3O_{12}$:Ce mixed garnets hasn’t been realized so far. We plan to perform this work at the Chair for Optoelectronic Materials of the Institute of Physics Kazimierz Wielki University in Bydgoszcz taking into account that our group has dominant experience in the world in the development of garnet phosphors and possesses different technological equipments for the preparation of mixed garnets in the various crystalline forms.

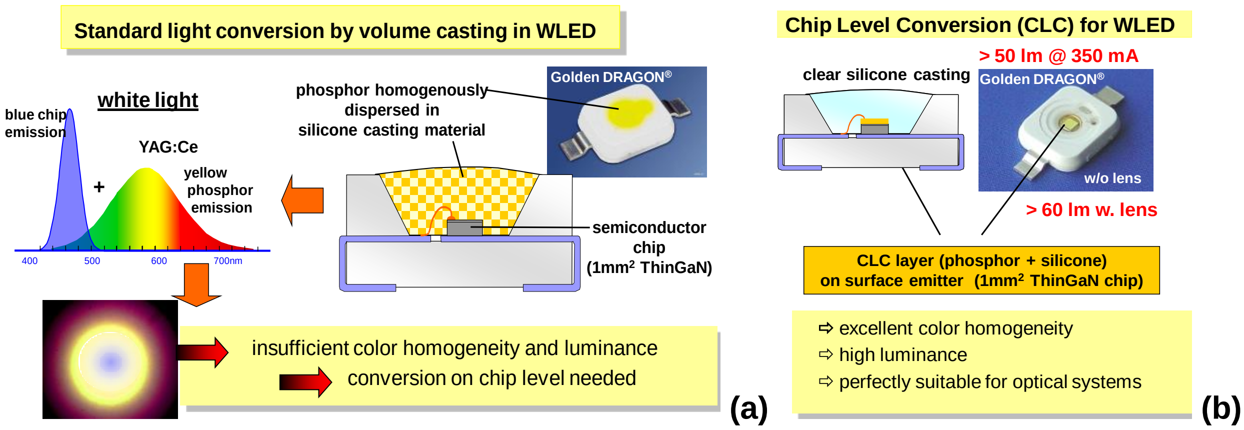

Fig.1 Typical Volume-Casting-Conversion design (a) and Chip-Level-Conversion (CLC) design (b) in WLED (https://www.osram.com/os/).