Dielectric properties of RE$_2$W$_2$O$_9$ (RE = Pr, Sm-Gd)

P. Urbanowicz$^1$, E. Tomaszewicz$^2$, B. Sawicki$^1$, T. Groń$^1$, Z. Kukula$^1$ and M. Piątkowska$^2$

$^1$University of Silesia, Institute of Physics, ul. Uniwersytecka 4, 40-007 Katowice, Poland
$^2$West Pomeranian University of Technology, Department of Inorganic and Analytical Chemistry, Al. Piastów 42, 71-065 Szczecin, Poland

Tungstates, molybdates and molybdato-tungstates doped with rare-earth ions are promising materials to use as phosphors in LEDs and as ultra-short solid state lasers [1,2]. The compounds under study crystallize in the monoclinic type structure with the space group $P2_1/c$ [2]. Magnetic susceptibility measurements showed a paramagnetic state of magnetic moments above 4.2 K for RE$_2$W$_2$O$_9$ compounds (RE = Pr, Nd and Gd), and a weak response to the magnetic field and the temperature for Sm$_2$W$_2$O$_9$ and Eu$_2$W$_3$O$_9$ tungstates. Only for Gd$_2$W$_2$O$_9$ the magnetization is a universal function of $\mu_0H/T$, characteristic for the superparamagnetism [3].

The electrical conductivity $\sigma(T)$ and the $I$-$V$ characteristics of the tungstates under study have been measured with the aid of the DC method using a KEITHLEY 6517B Electrometer/High Resistance Meter. The thermoelectric power $S(T)$ was measured in the temperature range of 300-600 K with the aid of a Seebeck Effect Measurement System (MMR Technologies, Inc., USA). Dielectric measurements were carried out using pellets, polished and sputtered with (~80 nm) Ag electrodes in a frequency range from $5 \times 10^2$ to $5 \times 10^6$ Hz on a Novocontrol Alpha Impedance analyzer. For the electrical measurements, the powder samples were compacted in a disc form (10 mm in diameter and 1–2 mm thick) using a pressure of 1.5 GPa and then they were sintered during 2 h at 1073 K.

The $\sigma(T)$ and $S(T)$ measurements showed the insulating properties and a weak conduction of $n$-type for Sm$_2$W$_2$O$_9$ and Eu$_2$W$_2$O$_9$ as well as $p$-type one for Pr$_2$W$_2$O$_9$ and Gd$_2$W$_2$O$_9$. The $I$-$V$ characteristics of RE$_2$W$_2$O$_9$ tungstates (RE = Pr, Sm-Gd), measured at 300 and 400 K, showed symmetrical and linear behavior as well as almost a permanent conductance which is slightly higher at higher temperature. Relative dielectric permittivity ($\varepsilon_r$), real ($\varepsilon'$) and imaginary ($\varepsilon''$) components of permittivity as well as loss tangent (tan$\delta$) do not depend on the temperature for all tungstates under study. $\varepsilon_r$ and $\varepsilon'$ increase from 8 via 12 and 17 to 32 in the sequence of the RE element: Gd, Eu, Pr and Sm, respectively. Loss tangent is close to zero for all samples. $\varepsilon_r$, $\varepsilon'$ and $\varepsilon''$ show a maximum at the frequency $f = 2 \times 10^6$ Hz, characteristic of dipole polarization. These results are interpreted in the context of the shallow trap levels [4] and Maxwell-Wagner model [5]. Thus, in the examined ceramics may form the boundary phases and insulating areas "immersed" in almost not-conducting solid material. It can finally lead to the accumulation of induced charge or to the blocking of the current cross-section by the boundary phases under the influence of the applied electric external field [6]. Most of the (charged) traps do reside in the grain boundaries with the depletion layers reaching into the adjacent grains.