Single crystalline ceria samples with the composition Ce$_{0.9}$Gd$_{0.1}$O$_{2-\delta}$ were pre-polarized with ±5 V for up to 300 s using a Pt coated AFM tip as working electrode. The direct contact zone had a diameter of <50 nm. Subsequently, the effect of the polarization on the surface potential of the samples was investigated by mapping the introduced defect gradient and its decay with time using Kelvin probe force microscopy. The generated surface potential gradients were found to have a diameter of up to 1 μm, which is explained by the local ionization of defect associates by the applied high electric field. Measurements were performed at room temperature and 50°C. The polarization behavior of the Ce$_{0.9}$Gd$_{0.1}$O$_{2-\delta}$ single crystals was compared to cyclovoltammetry and polarization-relaxation experiments at $T \leq 350°C$ and in dry air or nitrogen which were performed using a specially suited AFM (Controlled Atmosphere High Temperature Scanning Probe Microscope CAHT-SPM by Semilab).