論 文 内 容 の 要 旨

The subject of this work is a development of method for on-site identification of elemental composition of deep-sea water. In the present study, a systematic analysis of the microplasma discharge in sea water and optical emission spectra of the plasma is presented in order to develop compact device for on-site measurements. Recently marine resources are taking a lot of attention owing to their growing role in sustainable development. Growing interest to exploration of marine resources, and numerous studies on ecology and biochemistry are requiring high precision analysis of sea water. Development of the compact analytical tool could be essential for noted above studies and could make measurements faster and cheaper.

In the first part of the thesis, microplasma discharge in sea water was investigated using a needle-to-plane electrode system with various types of needle electrodes types and insulation. A needle-to-plane electrode system was placed with a gap of 10-50 μm in the artificial sea water. A pulse current source, consisting of a MOSFET switch, a capacitance and inductance was used. The sea water between the electrodes performed as resistance for the current source circuit. The circuit parameters were optimized to decrease the breakdown voltage and the spark duration to suppress erosion of the electrodes. Using a microgap configuration, microarc discharges were reproducibly ignited in the highly conductive seawater at low breakdown voltages. The ignition of spark discharges required not only a critical voltage sufficient for breakdown, but also a critical energy for preheating of the sea water, sufficient for bubble formation. In order to significantly decrease the current dispersing into the surrounding water, the needle electrode was insulated, enabling more accurate investigation of the preheating and bubble formation processes before the microplasma discharge. For the first time, it was confirmed that the microplasma discharge was ignited after formation of the bubble of size sufficient to cover entire discharge gap between the electrodes. Influence of the needle electrode insulation on microplasma parameters was investigated. Mathematical model was developed for more detailed analysis of the discharge process. The modelling showed good agreement with experimental results and confirmed that the needle electrode could be reused to generate reproducible microarc discharges even after erosion caused by the arc. Moreover, it was confirmed that shape of the needle electrodes tip shape does not affect measured optical emission spectra; however, in the case of damaged needle electrode for measuring reproducible spectra precise focusing and arrangement of the lens was required. Possibility of use of damaged needle electrodes could be essential for development of measurement tools for on-site analysis of deep-sea water.

In the second part of the thesis, possibility of use of atomic emission spectroscopy of micro arc discharges operated in sea water for on-site elemental composition analysis has been studied. We analyzed the discharge process and optical emission spectra from micro arc discharges in three types of liquid, namely artificial sea water composed of 10 main components, reference solutions each containing a single component and naturally sampled deep sea water. Micro-arc discharges were operated under a low breakdown voltages using a needle-to-plate electrode system immersed into each liquid in a quartz cuvette. In the spectra, the emission peaks for the main components of sea water and contaminants from the electrodes were detected. Owing to the complex composition of sea water, spectra from discharges in different liquids (reference solutions, ultrapure water) were compared for assigning the emission peaks. The proposed method showed good potential for detection of Fe and other metals in sea water. Using the present setup, it was possible to detect Fe impurities at a concentration of 300 ppm. The possibility of using atomic emission spectroscopy of micro arc discharges in sea water for on-site elemental composition analysis has been demonstrated. To study the effect of materials of the electrodes on the optical emission spectra and plasma parameters, three types of needle electrodes were used. Effect of the experimental conditions on measured optical emission spectra was studied, and applicability of proposed method for on-site composition analysis was confirmed.