Identification of nickel emission lines using Nd:YAG laser-induced breakdown spectroscopy

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Abstract. Identification of nickel element (Ni) is necessary in various fields including agriculture, mining, and industries. In this study, rapid identification of nickel metal was made by using laser-induced plasma spectroscopy method. Experimentally, a pulse laser beam (Nd:YAG laser, 1064 nm) was focused on a sample target to initiate a plasma. The plasma emission was detected by optical multichannel analyzer system to obtain the emission spectrum from the sample target. The target used was pure nickel metal plate and Indonesian currency coin containing Ni. The results show that the Ni lines can clearly be detected from the Ni plate at the wavelengths of neutral Nickel (Ni I) at wavelength of 300.363, 305.432, 310.188, 313.411, 341.348, 345.289, 351.977, 356.637, 351.977, 356.637, 361.939, and 778.894 nm for neutral Ni lines and at the wavelength of 337.897 nm for ionic Ni line. It was also demonstrated that the Ni emission lines at the same wavelength in the Ni metal plate was also detected from the other sample of currency coin containing Ni. This certified that the present can be used to identify Ni emission in metal sample containing Ni.

1. Introduction

Heavy metals naturally contain in the Earth’s crust and spread to the environment by many sources of activity such as mining, agriculture, and industrial activities [1]. Identification of metal was very important in many sectors to find out many elements that are contained in the samples. Nickel metal (Ni) is the most element in the earth (24th most abundant) that can be found in all environmental media including soil, air, water, and sediment. Detection of nickel element as an impurity can be applied in environmental pollution like soils and air, which are contaminated by heavy metals from industrial area. Soils that contains nickel can induce serious health problems such as respiratory cancer, etc. [2,3]. For medical application, identification of nickel has been made because nickel has a serious effect in human urinary infection that increases the PH of urine [3]. Furthermore, identification of nickel was also carried out on food sample using liquid-liquid microextraction combined with electro-thermal atomic absorption spectrometry method, because nickel that contain in the food sample can cause allergic contact dermatitis [4].

One of good analytical method that can be used to identify nickel is laser-induced breakdown spectroscopy (LIBS). This is simple spectroscopic method to identify atoms in material. In LIBS, a
pulaseNd:YAG laser is usually used as an energy source to induce a plasma on material target at atmospheric pressure. Compared with other techniques, LIBS have a simple and flexible sample preparation, also can be employed for rapid and direct analysis [5]. Furthermore, LIBS can also reduce false composite between samples and references from different sources [6]. This technique also can be used for analysis of soft sample such as soil sample and powder sample [7].

The other methods used to identify elements in metal are X-Ray Fluorescence (XRF) [8], micro XRF [9], Gamma Ray Transmission (GRT) [8], atomic absorption spectroscopy, inductively coupled plasma mass spectrometry [7]. However, those methods have a complicated sample preparation, where the density and thickness of the sample should be known, and analysis to identify elements in metal samples are quiet long [7,9]. For micro XRF method, the combination of data for the samples must be avoided [9], and if concentration of the elements is low, the obtained images will be bad because of the relatively high background intensity [10].

In this study, Identification of nickel emission from the pure Ni metal target was made by using laser-induced breakdown spectroscopy. Furthermore, the spectroscopic characterization of nickel was also discussed. Identification of Ni element was also carried out from the Indonesian currency coin containing Ni at quiet high concentration.

2. Experimental Setup

Basic experimental set-up used in this work is shown in Fig. 1. In this experiment, 2 material targets were used as samples, namely pure nickel metal plate (Hikari, HC0326, Ni contents of 99.99 %) and Indonesian currency coin containing Ni element. The sample A pulse neodymium yttrium aluminum garnet (Nd:YAG laser, 1064 nm, 7 ns, 40 mJ) was used as an energy source. Experimentally, a pulse laser was directed and focused on a sample target to produce a plasma. The plasma emission was detected by using Optical Multi channel Analyzer (OMA system, Lambda Vision, SA-100W-HPCB1024/C) via optical fiber. The experiment was conducted at low pressure of air surrounding gas (2.67 kPa). The emission spectra obtained in this study was confirmed with the data reference of NIST [11].

![Figure 1. Experimental setup used in this work](image)

3. Result And Discussion

The mechanism of laser generation is as follows: a pulse Nd:YAG laser hits a nickel surface and heats up the sample. The sample is then melted and a small mass of sample is ablated. The ablated material moves with very high speed and induces a shock wave plasma just above the sample surface. The ablated material is dissociated and excited in the plasma region. The shock wave plasma consists of 2 regions, which are called primary plasma and secondary plasma. The primary plasma contains high-dense electrons and therefore high-ionization process takes place in the plasma region. Continuum emission was also gained due to the Bremsstrahlung effect and free-bond recombination process. In
the secondary plasma, excited atomic emission was produced as shown in the photograph of the plasma emission (Fig. 2). Blue-color emission represents zinc emission lines at the wavelength of around 400 nm. This region most often emits discreet emission including neutral and ionic atomic lines.

![Figure 2. Photograph of plasma obtained from the pure nickel metal](image.png)

Figure 2. Photograph of plasma obtained from the pure nickel metal

Figure 3(a) shows emission spectrum of nickel (Ni) taken from the Nickel sheet (Hikari. HC0326, Cu contents of 99.99 %). As shown in the figure, emission lines of neutral nickel (Ni I) can clearly be seen at the wavelength of 300.363, 305.432, 310.188, 313.411, 341.348, 345.289, 351.977, 356.637, 351.977, 356.637, 361.939, and 778.894 nm. Further, emission line of ionic nickel (Ni II) clearly appears at the wavelength of 337.897 nm. This result certified that the present method can be employed to detect a nickel element in the metal target containing high-concentration nickel.

![Figure 3. Emission spectra obtained from (a) the pure nickel metal, and (b) the Indonesian currency coin](image.png)

Figure 3. Emission spectra obtained from (a) the pure nickel metal, and (b) the Indonesian currency coin.
To confirm that the present method can be used to identify element in the metal target containing nickel, a detection of Ni element was made from the Indonesian currency coin. Figure 3(b) shows emission spectrum obtained from the Indonesian currency coin. Nickel emission lines strongly appear at the same wavelength as in the case of nickel metal plate. Furthermore, Neutral iron line (Fe) at 507.405 also occurs clearly as shown in the figure. This is because Indonesian currency coin is made of nickel and iron elements. This result confirmed that the nickel element can clearly be detected by using the present LIBS method.

4. Conclusion
Identification of nickel element in pure nickel metal plate and Indonesian currency coin containing nickel has been demonstrated by using pulse Nd:YAG LIBS. The experiment was carried out at 1 atmospheric pressure air environment. Neutral and ionic emission lines of Ni from both sample targets can clearly be identified at the wavelength of 300.363, 305.432, 310.188, 313.411, 341.348, 345.289, 351.977, 356.637, 351.977, 356.637, 361.939, and 778.894 nm. Furthermore, Fe emission line was also detected from the Indonesian currency coin. This result confirmed that the Indonesian currency coin contains nickel and iron elements.

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